PLANTING SURVIVAL OF SELECTED STREET TREE TAXA

by Randall H. Miller and Robert W. Miller[1]

Abstract. Planting survival rates were determined for commonly planted street trees in Wisconsin. Removal records provide evidence of a four year establishment period. With a few exceptions, survival was found to be generally independent of species/cultivar selections in the cities of Milwaukee and Stevens Point, but significant differences were found in the city of Waukesha. Recommendations are made regarding species/cultivar use.

Many cities have suffered heavy losses of street trees due to Dutch elm disease *(Ceratocystis ulmi)* and other maladies. In response, aggressive planting campaigns have been initiated in many of these cities to repopulate streets with trees. Unfortunately, little objective information has been published that can be applied to taxa selection for these programs. For this reason, Gerhold (8) cited the urgent need for testing cultivars in urban environments.

A study was conducted by Schuman (17) in five Wisconsin cities which evaluated the adaptability of street trees based on their overall condition using condition class from the Council of Tree and Landscape Appraisers tree valuation system (3). Schuman (17) concluded that four species: green ash *(Fraxinus pennsylvanica)*, honeylocust *(Gleditsia triacanthos* var. inermis), littleleaf linden *(Tilia cordata), and Norway maple (Acer platanoides)* were in the best overall condition along Wisconsin streets.

The current study followed Schuman (17) with an examination of existing plantings to determine the planting survival rates of commonly planted taxa in Wisconsin. Several studies on survival have been previously published by Nowak and others (14), Foster and Blaine (7), Dawson and Khawajha (4), and Berring and others (2). These studies provide useful information, but more is required to develop taxa selection guidelines. This study was designed to use survival data for widely planted taxa to serve as a basis for selection.

Methods

Milwaukee, Stevens Point, and Waukesha, Wisconsin were selected as study sites. These cities were selected because they represent two hardiness zones (zones 4 and 5), and have good inventory and planting records.

Sample description. Cultivars of Norway maple, green ash, honeylocust, and littleleaf linden were sampled as they accounted for about 84% of the planting from 1980 to 1982 in Milwaukee and Waukesha, and 65% of the planting in Stevens Point from 1975 to 1986 (12). In addition, callery pear *(Pyrus calleryana)* and English oak *(Quercus robur)* were studied in Waukesha and Milwaukee, and 'Autumn Purple' white ash *(Fraxinus americana* 'Autumn Purple') and Crimean linden *(Tilia* x *euchlora)* were evaluated in Milwaukee. In Stevens Point, 'Centurian' flowering crab *(Malus* spp. 'Centurian') and 'Shubert' chokecherry *(Prunus virginiana* 'Shubert') were included in the study (Table 1).

Planting records were randomly sampled to obtain a set of 50 individuals of target taxa planted in each city. In cases where less than 50 trees of a particular taxon were planted, all individuals were evaluated.

Milwaukee planted trees 5 to 7.5 cm (2 to 3 inch) in diameter. Fall planting was balled and burlapped while spring planting was 50% bare root and 50% balled and burlapped. The sample totaled 1003 trees, with eight cultivars of Norway maple comprising 42.8% of the sample. The Waukesha sample totaled 677 trees, planted as 4.5 to 5.0 cm (1.75 to 2.0 inch) bare root stock, 43.4% of which were Norway maples represented by six cultivars. There were not enough trees planted in Stevens Point between 1980 and 1982 to provide a sufficient sample for most cultivars; therefore, sample dates were expanded back to 1975. Stevens Point planted 5.0 to 6.5 cm (2 to 2.5 inch) balled and burlapped stock. The sample totaled 368 trees, 27% of which were Norway maple and 23% green ash. The following data were taken in the summer of

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1986 for each tree sampled: location, date planted, date removed (if available), condition class and diameter at breast height (dbh).

Results

Planting establishment. Removal records were not available for Stevens Point and were incomplete in Milwaukee and Waukesha. In Milwaukee, removal records existed for 181 trees accounting for 43.8% of known mortality. In Waukesha, removal records were available for 94 of the 165 (57.0%) removals. Incomplete removal records were attributed to adjacent property owners removing dead trees, unreported vehicular damage, theft, and lost records. Removals for the study years 1980, 1981, and 1982 were combined and plotted through a four year period for Milwaukee and Waukesha. About half of the trees lost in the four year period (46.8% in Milwaukee and 52.9% in Waukesha) were removed by the end of the first year, and an additional 25% were removed by the time the trees were two years old (Figure 1).

Removals of trees planted in 1981 and 1982 could be traced for five and six years respectively (Figures 2 and 3). In each case removals for Milwaukee and Waukesha followed much the same pattern as Figure 1, stabilizing when the planting was four years old (Figures 2 and 3). Stevens Point has no removal records, but significance could not be found between the survival rates of four year old trees and trees up to eleven years old, indicating the population had stabilized at or before four years.

Evidence of a four year establishment period is consistent with conjecture by Miller (13) suggesting that a five year period be allowed before planting success can be realistically evaluated. Watson and others (18) found that a period of four or more years of stress followed transplanting of 5 to 10 cm diameter trees. They concluded that this is a function of the time needed to replace root loss due to transplanting. Other factors contributing to the loss of small trees in this period include vandalism and unintended injuries, such as mower damage.

Milwaukee. The overall survival of the Milwaukee sample was 58.8% (Table 2). This was significantly lower than the 76.5% survival of Waukesha (P = 0.01) and the 74.9% survival of Stevens Point (P = 0.01 [Table 2]). However, the city of Milwaukee received federal redevelopment grants to plant trees in old neighborhoods during the target years of the study (15). There were 311 trees sampled from redevelopment areas of Milwaukee (Table 2) and these trees had a 51.8% survival rate, which was significantly lower than the 62.0% survival of the remaining Milwaukee trees (P = 0.01). Since survival in the redevelopment area was signficantly lower, the two areas were treated as distinct populations.

Significant probabilities (P = 0.05) and probabilities that approached significance (P = 0.10) resulting from chi-square comparisons of non-redevelopment and redevelopment area taxa were used to compare planting survival. With a few ex-

Table 1. Species/cultivars sampled in Milwaukee, Waukesha, and Stevens Point, Wisconsin.

Species/cultivar (Common name)	City* Milwaukee	Waukesha	Stevens Point
Fraxinus pennsylvanica (Green ash)			
'Marshall's Seedless'	50	49	50
'Summit'	50	50	35
Gleditsia triacanthos (Honeylocust)			
'Imperial'	50	0	0
'Shademaster'	50	49	0
'Skyline'	49	50	32
Tilia cordata (Littleleaf linden)			
'Chancellor'	50	0	0
'Greenspire'	50	50	50
Acer plataniodes (Norway maple)			
	50	0	0
'Cleveland'	50	49	0
'Columnar'	50	46	0
'Emerald Queen'	50	50	50
'Faassens'	50	0	0
'Royal Red'	30	0	0
'Schwedler'	50	49	51
'Summershade'	50	0	0
'Superform'	50	50	0
'Jade Glen'	0	50	0
Pyrus calleryana (Callery pear)			
'Bradford'	29	43	0
'Redspire'	47	43	0
Quercus robor (English oak)	49	49	
Fraxinus americana (White ash)			
'Autumn Purple'	50	0	0
Tilia x *euchlora* (Crimean linden)			
	50	0	0
Malus spp. (Flowering crabapple)			
'Centurian'	0	0	50
Prunus virginiana (Chokecherry)			
'Shubert'	0	0	50

*Number of individuals sampled in each city

ceptions, survival in the non-redevelopment area of Milwaukee was independent of taxa. Crimean linden (81.0% survival), 'Summershade' Norway maple (80.4%), and 'Marshall's Seedless' green ash (74.4%) were the only taxa that recorded survival significantly greater than two or more other taxa. Similarly, only four cultivars recorded survival significantly lower than one or more other taxa: 'Autmun Purple' white ash (10.0% survival), 'Bradford' callery pear (47.1%), 'Faassens' Norway maple (50.0%) and 'Royal Red' Norway maple (52.0%).

Significance between the survival rates of the assorted taxa is sporadic in the redevelopment area, primarily due to the uneven sample sizes and associated problems in analysis. 'Autumn Purple' white ash (0% survival) had significantly lower survival than five taxa. Crimean linden (24.1%) was significantly lower than seven taxa, and 'Cleveland' Norway maple survival (89.9%) was significantly greater than four taxa.

Planting season (fall verses spring) had no effect on survival in Milwaukee.

Stevens Point. The Stevens Point sample survival rate was 74.1%. There were no significant differences between survival of taxa. Planting season (spring versus fall) had no effect on survival in Stevens Point.

Waukesha. The overall survival rate in Waukesha was 75.6%. Fall planting had 81.4% survival in Waukesha which was significantly higher than the 73.2% survival of spring planting ($P = 0.02$ [Table 3]).

'Summit' green ash had 96% survival which was significantly better than eight taxa. 'Marshall's Seedless' green ash with 85.7% survival out performed five taxa. The two honeylocust cultivars, 'Shademaster' (93.9% survival) and 'Skyline' (93.0% survival) each performed significantly better than six taxa. The 89.8% survival of 'Schwedler' Norway maple was significantly better than five taxa. 'Superform' Norway maple recorded 46.0% survival which was significantly inferior to nine taxa. 'Bradford' callery pear registered 62.8% survival which was lower than six taxa. 'Redspire' callery pear recorded 53.3% survival which was significantly inferior to five taxa. 'Greenspire' littleleaf linden, with a survival rate of 58.0%, was significantly lower than seven taxa.

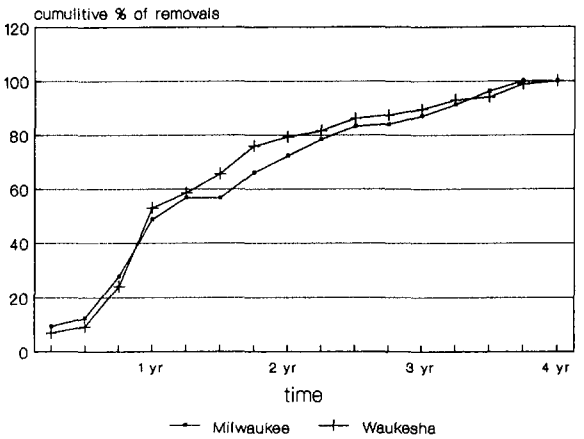

Figure 1. Cumulative percent total mortality over a four year period of all trees removed from the 1980, 1981, and 1982 plantings in Milwaukee and Waukesha.

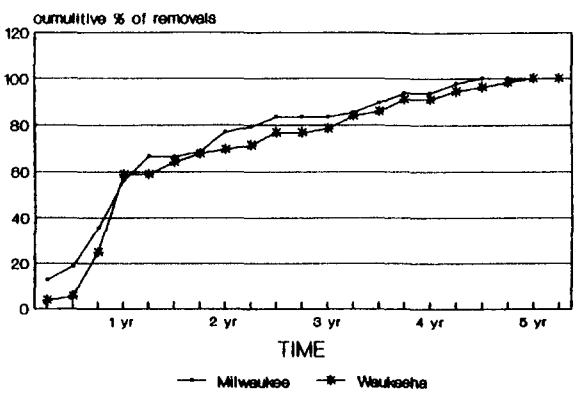

Figure 2. Cumulative percent total mortality over a five year period of all trees removed from the 1981 plantings in Milwaukee and Waukesha.

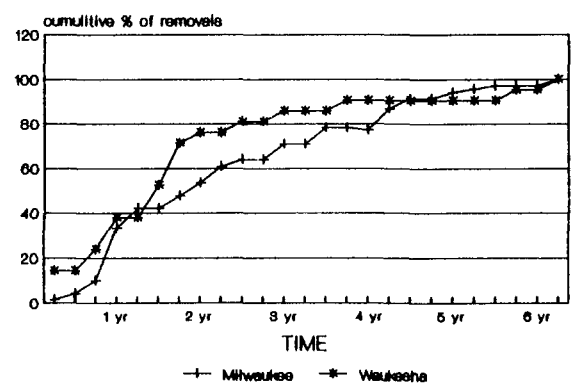

Figure 3. Cumulative percent total mortality over a six year period of all trees removed from the 1980 plantings in Milwaukee and Waukesha.

Discussion

Survival. Overall survival for the three cities was Milwaukee (redevelopment area), 51.8%; Milwaukee (non-redevelopment area), 62.0%; Waukesha, 76.5%; and Stevens Point, 74.9%. Survival in Milwaukee was lower than expected in the sample years due to an attempt to lift trees in the municipal nursery in the fall, heeling them over winter, and planting them in the spring (15). Current survival in Milwaukee 15 months (two growing seasons) after planting is 83% (15). When this figure is plotted on the cumulative percent survival graph (Figure 1), survival in Milwaukee at the end of the four year establishment period is projected at 75%.

Milwaukee Redevelopment Area. A substantial part of the mortality in the redevelopment area of Milwaukee can be attributed to vandalism (15). Field observation of existing plantings indicated two types of vandalism; snapped tree trunks, and wounds that were carved or gouged on trees. Many blocks were observed where 100% of the trees had been vandalized.

The effect of vandalism can be illustrated by comparing the 24.1% survival of Crimean linden in the redevelopment area verses its 81.0% survival in the non-redevelopment area. Twenty-two of the crimean lindens were sampled from one of the most heavily vandalized areas in Milwaukee (12). Nineteen of these Crimean lindens have been removed, accounting for 79.2% of the mortality of this species for the entire city.

Milwaukee Non-redevelopment Area. With a few exceptions, survival in the non-redevelopment area of Milwaukee was independent of taxa. If 'Autumn Purple' white ash is excluded from consideration, only 10% of the taxa studied were significantly different from more than one other taxa.

Stevens Point. No significant differences were found between taxa in the city of Stevens Point.

Waukesha. There was greater difference between taxa survival in Waukesha than in either Milwaukee or Stevens Point. None of the city's sixteen work units (selections of the city established as management areas) had survival significantly different from other work units. Moreover, vandalism was not apparent through field observation. The evidence indicates that significant differences in street tree survival is dependent on taxa in Waukesha. In addition, fall planting had significantly higher survival rates than spring planting.

Individual Taxa Survival

Norway maple. There was a great deal of variability in planting survival of different Norway maple cultivars. In Milwaukee non-redevelopment areas, Norway maple survival ranged from 80.4% for 'Summershade' to 50% for 'Faassens'. Similarly, the range in Waukesha extended from 87.8% for 'Schwedler' to 46.0% for 'Superform'. In general, the survival of Norway maple did not distinguish itself as superior to other species studied.

There is evidence of heavy reliance on Norway maple as an elm replacement species in many cities (12, 16). However, results from this study do not provide justification for this dependence; rather they corroborate the opinion of Dirr (5) who considers Norway maple an over-used and over-

Table 2. Chi-square statistics of street tree planting survival comparing Milwaukee with Stevens Point, and Milwaukee with Waukesha, and Milwaukee redevelopment areas with Milwaukee non-redevelopment areas.

Cities Compared	*% Survival*	*Observed survival*	*Expected survival*	*N*	*P*	X^2
Milwaukee	58.8	590	638	1003		
vs.					0.01	29.25
Stevens Point	74.9	275	232	368		
Milwaukee	58.8	590	657.9	1003		
vs.					0.01	49.83
Waukesha	76.5	512	444.1	677		
Milwaukee non-redevelopment	62.0	429	407.1	692		
vs.					0.01	9.26
Milwaukee redevelopment	51.8	161	182.9	311		

rated species.

'Cleveland' did not have superior survival in either Milwaukee or Waukesha. In each case, the survival of 'Cleveland' did not differ significantly from over three quarters of the other taxa in the study.

'Columnar' out performed 'Autumn Purple' white ash in Milwaukee non-redevelopment areas and two taxa in Waukesha. 'Columnar' accounted for about 15% of all trees planted in Milwaukee and Waukesha between 1980 and 1982 (12). Its heavy use is primarily in narrow tree borders and where space restricts acceptable crown width. These site factors likely influence survival.

The survival performance of 'Schwedler' and 'Emerald Queen' was average in Stevens Point and Milwaukee. There was no significance in Stevens Point comparisons, and it did not differ significantly from 20 of the Milwaukee non-redevelopment taxa. However, its survival was significantly better than four taxa in Waukesha.

'Summershade' was limited to the Milwaukee portion of the study. It's survival was significantly greater than six other taxa, including four Norway maple cultivars.

The survival of 'Superform' in Milwaukee and Waukesha was quite different. The survival in non-redevelopment areas of Milwaukee was not significantly lower than any taxon studied. However, in Waukesha it was significantly worse than nine taxa. The conflicting data would call for further investigation on the performance of this cultivar before any conclusions can be drawn regarding its survival.

'Autumn Purple' white ash. 'Autumn Purple' white ash was limited to the Milwaukee portion of the study where it almost completely failed. This cultivar has been plagued by mortality linked to basal cracks associated with the graft union. There has been recent speculation that this mortality may be ash decline syndrome (9). Subsequent early spring plantings of "Autmun Purple" white ash in Milwaukee using balled and burlapped stock have met with success, so this cultivar should not be ruled out as a potential street tree (15).

Green ash. Green ash is well adapted to survive street planting. Marshall's Seedless' was superior to one taxon in non-development areas of Milwaukee, and five taxa in Waukesha. No taxon showed significantly better survival than "Marshall's Seedless' in Stevens Point. 'Summit' out performed one taxon in the non-redevelopment area of Milwaukee, approached superiority to eight taxa in Waukesha. In terms of consistently high survival rates, 'Summit' turned in the best survival performance of any taxon in the study.

Honeylocust. Honeylocust displayed the best survival of any study species. 'Shademaster' had excellent survival performance in Waukesha (the best survival of any taxon in the city) and reliable performance throughout the study. 'Skyline' provided dependable survival performance throughout the study, as no taxon was significantly superior to it.

'Centurian' flowering crab and 'Shubert' chokecherry. 'Centurian' flowering crab and 'Shubert' chokecherry were limited to the Stevens Point portion of the study and were not found to exhibit survival different from any other taxon in the city.

Callery Pear. Callery pear did not distinguish itself by its planting survival. However, it was not widely planted in Milwaukee and Waukesha during the target years of the study making it necessary to sample nearly all individuals planted. As a result, the sample for callery pear was concentrated on a few blocks in both Milwaukee and Waukesha. Unfortunately, this may have biased the data as individual blocks can have singular impacts on survival (12). Therefore, caution should be exercised in drawing conclusions from this study regarding callery pear survival performance.

English oak. English oak did not have significantly lower survival than any taxa in the redevelopment area of Milwuakee. However, in Waukesha, it was significantly lower than five taxa studied. This disparity may be due in part to a slight moderation of climate that Milwaukee experiences from Lake Michigan. Southern Wisconsin is at the northern limit for this species, making it susceptible to winter injury. Further scrutiny of English oak survival is recommended.

Table 3. Chi-square statistics comparing Waukesha spring verses fall planting survival.

Season	*Observed survival*	*Expected survival*	*N*	*P*	X^2
spring	216	227.5	295	0.002	5.35
fall	219	207.5	269		

Littleleaf linden. "Greenspire' was the only littleleaf linden cultivar common to all three study cities. Its survival was not significantly different from any taxon in Stevens Point, but in Waukesha it was significantly lower than seven taxa. During the study period, 'Greenspire' suffered mortality due to an unidentified canker associated with bare root planting stock. Waukesha has since planted 'Greenspire' balled and burlapped and the survival rate is now believed to be 75% (11).

Crimean linden. Crimean linden was superior to two non-redevelopment cultivars in Milwaukee. Over half the samples was located in the redevelopment area and these trees were heavily vandalized. The evidence in the study suggests Crimean linden is a promising species.

Management Implications

Barker (1) encourages diversity and has proposed a five percent species use limit. However, the need for diversity must be juxtaposed with the limited number of species available, the need for esthetic and architectural unity, and the suitability of particular taxa to specific sites. Considering these factors, a five percent use limit may be too low. We suggest Barker's (1) use categories be expanded to accomodate a ten percent species use limit. The species in the current study would fall into the following categories for the study cities:

1. Liberal Use—not to exceed 10%:
   a. Norway maple—good survival in all three study cities. This recommendation is made with reservation because use already exceeds 10%.
   b. green ash—Well adapted to survive street planting in all three cities.
   c. honeylocust—best overall survival of all study species.
   d. littleleaf linden—good survival in Milwaukee nonredevelopment areas and favorable reviews by Dirr (5), Flint (6), Wyman (20) and Walheim (19) and Schuman (17).
   e. Crimean linden—good survival in Milwaukee nonredevelopment areas and favorable reviews by Dirr (5), Schuman (17) and Wyman (20).
2. Limited use—not to exceed 5%:
   a. 'Centurian' flowering crab—good survival in Stevens Point but it should be limited to wide tree lawns because of its spreading crown (20).
   b. 'Shubert' chokecherry—good survival in Stevens Point, but subject to suckering which causes maintenance problems.
3. Candidate use—not to exceed 2%:
   a. English oak—moderate to below average survival, of questionable hardiness in Wisconsin thus requiring future scrutiny.
   b. callery pear—good reviews by Dirr (5), Flint (6) and Walheim (19) but requires future scrutiny.
   c. 'Autumn Purple' white ash—nearly complete failure in Milwaukee, but recent plantings show promise.

A ten percent use limit has several advantages. Enough species are likely available in most regions for its implementation. The five species recommended for liberal use by this study could make up as much as 50% of a planting program, with the remaining portion being drawn from other use categories and species not evaluated by this study. Ten percent use would also protect 90% of the population from a catastrophic taxon specific event.

Conclusion

Overall survival for the three cities in the sample years was Milwaukee (redevelopment area), 51.8%; Milwaukee (non-redevelopment area), 62.0%; Waukesha, 76.5%; and Stevens Point, 74.9%. Current survival in Milwaukee is 75% based on the cumulative percent survival graph (Figure 1).

Removal records for Milwaukee and Waukesha provide evidence of a four year establishment period for street trees. Stevens Point data corroborated this finding.

Survival was generally independent of taxa in Stevens Point and Milwaukee. Norway maple, green ash, honeylocust, littleleaf linden and Crimean linden exhibited average to excellent survival. English oak, 'Autumn Purple' white ash and callery pear require future scrutiny. 'Centurian' flowering crab and 'Shubert' chokecherry had good survival in Stevens Point.

In Waukesha, survival was more dependent on taxa. Cultivars of honeylocust and green ash did particularly well. English oak and littleleaf linden performed poorly by comparison. The survival of Norway maple varied from poor to excellent depending on cultivar.

Many factors were not addressed that could conceivably affect survival differences between

taxa. Soil was not analyzed, nor was planting technique relative to fall versus spring planting. The origin of planting stock was not examined. It is also likely that selection of specific cultivars for specific site conditions also affects survival, such as planting 'Columnar' Norway maple in narrow tree borders.

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Résumé. Des taux de survivance à la plantation étaient déterminés pour les arbres de rues couramment plantés au Wisconsin. Les données extraites fournissent la preuve certaine d'une périod d'établissement de quatre ans. Sauf quelques exceptions, la survivance était jugée être généralement indépendante de la sélection des cultivars d'espèces au sein des villes de Milwaukee et de Stevens Point, mais des différences significatives étaient observées dans la ville de Waukesha. Les recommandations sont faites en regard des espèces et cultivars employés.

Zusammenfassung: Die überlebungsrate für normalgepflanzten Straßenbäumen in Wisconsin wurde festgestellt. Die Baumentfernungs-unterlagen liefern Beweise von einer vierjährigen Festsetzungs- periode. Mit einigen Ausnahmen, wurde es in Milwaukee und Stevens Point festgestellt, daß das überleben unabhängig vom Baumarten-auswahl ist, aber in der Stadt Waukesha gab es wesentliche Unterschiede. Empfehlungen mit Bezug auf Spezie- und Artbenutzung sind geliefert.