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Factors influencing urban tree planting program growth and survival in Florida, United States

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ABSTRACT

High levels of mortality after installation can limit the long-term benefits associated with urban tree planting initiatives. Past planting projects funded by the Florida Forest Service were revisited two to five years after installation to document tree survival and growth and assess program success. Additionally, various site (e.g., soil compaction, installed irrigation) and tree-related (e.g., species, nursery production method, initial size at planting) factors were noted to assess their impact on tree growth. Results show that the overall establishment rate for the 26 sites ($n = 2354$ trees) was high, with 93.6% of trees alive at the time of final inspection. On-site irrigation played a significant role in tree survival and growth, especially for *Magnolia grandiflora* (97.7% survival on irrigated sites; 73.8% survival on non-irrigated sites). Findings from this work validate the effectiveness of current program policies which include maintenance of tree quality within the first year after planting, and offer further insights regarding the impacts of season of planting and initial size of nursery stock on plant growth and development.
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Introduction

Municipalities, non-profit groups, and state government agencies devote significant resources toward tree-planting initiatives intended to maximize and sustain the ecological services and health benefits associated with urban forests (Kendall and McPherson, 2012; Pincetl et al., 2013). In recent years, the scale and notoriety of these initiatives have increased, with numerous million-tree planting programs underway in major North American cities like Miami, Los Angeles, Denver, and New York (City and County of Denver, 2006; City of Los Angeles, 2006; Miami-Dade County, 2011; PlaNYC, 2013). While the number of trees planted can be an important factor in gauging the potential impact of these efforts (and is the primary metric tracked by each program), tree establishment in the landscape and longevity must ultimately be considered when assessing long-term program success.

Many of the benefits offered by urban trees increase as trees grow in size (Leibowitz, 2012; Maco and McPherson, 2003). Insufficient post-planting care (Beatty and Heckman, 1981; Gilman et al., 1998; Harris and Gilman, 1993), poor-quality nursery stock (McKay, 1996; Struve, 2009), limiting site conditions (Beatty and Heckman, 1981; Lemaire and Rossignol, 1999), and vandalism (Nowak et al., 1990; Jones et al., 1996; Impens, 1999; Nowak et al., 2004) can all contribute to the death of recently transplanted urban trees before they are able to make meaningful environmental and economic contributions to a community. In extreme cases of immediate or nearly complete post-transplant loss (Yang and McBride, 2003; Sklar and Ames, 1985; see Table 1), planting initiatives represent a wasted investment of human and financial capital, including materials and labor. Beyond economics, trees that die after transplanting do an ecological disservice considering the material inputs, energy inputs, and environmental impacts associated with tree production, transplanting, maintenance, removal, and disposal (Nowak et al., 2002; Kendall and McPherson, 2012; Ingram, 2012, 2013).

Urban tree mortality is generally greatest among the youngest trees, especially in the first two to three years following transplanting (Miller and Miller, 1991; Richards, 1979; Roman et al., 2013). In the past three decades, numerous researchers from North America and Europe have assessed post-transplanting establishment rates and growth during this tenuous period of an urban tree's life (Table 1). Many earlier works focused solely on gauging the level of planting survival in urban replanting efforts. However, more recent research has attempted to determine the biological,

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Table 1
Early (<10 years since planting) urban tree survival rates for past cited planting program studies.

Source	Location	Species	% survival (*n*)	Yrs since planting	Notes
Impens and Delcarte (1979)	Brussels, Belgium	Numerous	88.7 (2905)	1	Average survival and number planted for 4 assessment periods
Sklar and Ames (1985)	Oakland, CA, United States	Numerous	0.5 (2000)	<10	Federal inner-city planting program
			60–70 (1500)	<10	Community-based inner-city planting program; includes replacements
Gilbertson and Bradshaw (1990)	Liverpool, United Kingdom	Numerous	77.3(401)	3	
Nowak et al. (1990)	Oakland/Berkley, CA, United States	*Robinia pseudoacacia*	65.4 (254)	2	
		Magnolia grandiflora	63.8 (199)	2	
		Platanus × acerifolia	81.5 (27)	2	
Miller and Miller (1991)	Wisconsin, United States	Numerous	67.5 (2048)	4	Average survival across 10 species and 3 cities
Gerhold et al. (1994)	Pennsylvania and Maryland, United States	*Malus* spp.	94–100 (unknown)	3	Range of survival for 10 cultivars planted in 12 communities
Yang and McBride (2003)	Beijing, China	*Sophora japonica*	83.1 (450)	<1 (11 wks)	Large trees planted bare root with the majority of main structural roots/scaffold branches removed
		Fraxinus chinensis	62.7 (300)		
Thompson et al. (2004)	Iowa, United States	Numerous	91 (932)	4	Average for 21 cities/towns
Lu et al. (2010)	New York, NY, United States	Numerous	91.3 (45,094)	2	
Jack-Scott (2011)	Philadelphia, PA, United States	Numerous	95 (590)	1–5	Bare root stock; excludes missing/removed trees
			96 (573)	1–5	Balled-and-burlapped stock; excludes missing/removed trees
Roman and Scatena (2011)	Philadelphia, PA, United States	*Acer campestre*	78.8 (151)	2–10	
Jack-Scott et al. (2013)	New Haven, Connecticut, United States	Numerous	73.8 (1393)	4–16	
Roman et al. (2013)	Oakland, CA, United States	Numerous	80.3 (unknown)	1–4	

and in some cases, social factors contributing to young tree survival and mortality (Lu et al., 2010). In identifying the conditions associated with elevated planting mortality, urban forest managers can potentially eliminate or at least partially mitigate those conditions consistently linked to low rates of survival and establishment.

In this study, past planting projects funded by the Florida Forest Services from 2004 to 2008 were revisited to assess installed urban trees and identify conditions that contributed to enhanced or reduced survival and growth rates. This time frame includes data from a period of more intensive post-hurricane recovery planting following the 2004 and 2005 hurricane seasons (where seven named storms impacted parts of Florida). This work provides information about species tolerance to specific urban conditions in Florida, as well as key information regarding the appropriateness of stock type, tree size, and other factors under these conditions.

Materials and methods

Project selection

Records from the Florida Forest Service (FFS; formerly Florida Division of Forestry) headquarters in Tallahassee, FL (United States) were accessed in March 2010 to evaluate the success of past state urban forestry tree planting grants. Records were available for approximately 150 grants funded from 2004 to 2008. Only projects with an available project manager or contact person and mapped locations were included in the study data set. The trees in this study were installed in public spaces by volunteers, contractors, and staff through numerous organizations under a variety of urban conditions, nursery production systems, and hardiness zones. Prior to assessment, projects were stratified by geographic region (North/Temperate, Central/Transition, South/Sub-tropical; Fig. 1) site type, and presence or absence of irrigation. When available, at least three different projects were randomly chosen from the resulting groupings for on-site data collection. *Quercus virginiana* was the most commonly planted tree during the time period assessed and thus makes up the largest component of the study sample ($n = 1197$).

Trees were planted between March 2005 and March 2009. Each site was inspected by FFS personnel in the weeks following planting, and then again one year later, to ensure all trees were present, alive, met the Florida #1 grade (i.e., single trunk, full crown, minor/no trunk injuries, and only easily-corrected structural defects present) in accordance with Florida Grades and

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