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Nitrogen fertilization during planting and establishment of the urban forest: A collection of five studies

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Abstract

Today's urban forest increasingly consists of planted trees, especially as native forest fragments yield to urban sprawl. These trees are usually larger (over 2-m tall) than typical reforestation trees and grow very little for the first few years after planting. Stressful urban sites exacerbate this effect and many practitioners hope to shorten the time required to reach environmentally functional size by fertilizing at planting. This is a controversial practice since nitrogen (N) application creates the potential for water quality impairment and effectiveness is uncertain. It is not clear how nitrogen application affects large trees with radically altered root:shoot ratios or how nursery production methods and restrictive sites affect response. In a series of five separate studies, we tested several N rates on ten shade tree species (both field- and container-grown) and transplanted to a range of urban sites, from a relatively undisturbed forest fragment to a highly compacted cutover soil with an absent A horizon. Trunk diameter increase, as an integrative metric of tree biomass accumulation, was followed for up to 4 years on each experiment. Overall, we saw little effect from fertilizing at planting at any rate we tested, regardless of location. Three studies that included leaf analysis with a SPAD-502 chlorophyll meter indicated that neither SPAD meter values or N concentration within leaves was increased by fertilizing at planting, suggesting that the newly planted shade trees took up very little of the applied N. Overall, SPAD-502 readings correlated well with actual leaf N concentration ($r = 0.692$). This group of studies indicates that fertilization at planting does not increase post-transplant growth, even in stressful urban sites and it is therefore not effective at shortening the establishment period of transplanted shade trees.

Keywords: Nursery production method; Site preparation; Soil compaction; Transplanting; Urban soil

Introduction

Shade tree fertilization has been studied for many years (see Struve, 2002, for a general review), although reports on fertilization of newly planted trees are few, especially on trees transplanted in the urban soils typical of many of today's landscapes (Craul, 1985). Although plant growth is very dependent on rhizosphere N (Mengel and Kirkby, 2001), it is not clear how plant response to N differs between newly transplanted and fully established trees. Normally, the functional equilibrium between roots and shoots can largely be explained by the production (i.e. through photosynthesis) and partitioning of carbon associated with the uptake and use of N (Argren and Ingestad, 1987). However, the root

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systems of large field-grown trees are often drastically reduced when transplanting (Gilman, 1988). The much altered root:shoot relationship and the resulting compromised ability to take up N likely interact to affect post-transplant growth. Although the response of container- and field-grown trees to N fertilizer at planting is poorly understood, many practitioners attempt to restore pre-transplant growth rates to newly transplanted trees through fertilization at planting.

Eleven species of bare-root trees showed no growth response to N during establishment, although leaves of fertilized trees were visibly darker green in the second year (Shoup et al., 1981). Silver maple (*Acer saccharinum* L.), a highly vigorous species, grew more rapidly with increased N when planted in a clay loam soil, but had no response when planted on a site with nutrient-deficient silt loam soil (Schulte and Whitcomb, 1975). After these mixed results, Whitcomb recommended fertilizing lightly at planting (Whitcomb, 1984). Neely (1980) found that established trees in fertile soil received only a small benefit from fertilization. In a recent study on two urban sites in Milan, Italy, fertilization increased photosynthesis rate of Japanese pagoda tree (*Styphnolobium japonicum* Schott) and sweetgum (*Liquidambar styraciflua* L.), but not European ash (*Fraxinus excelsior* L.) during the first year (Ferrini and Baietto, 2006). In subsequent years, this effect disappeared or was reversed and in no case was growth affected by fertilizer. In another recent study, there were no effects of fertilizing balled-and-burlapped (B&B) red maple (*Acer rubrum* L.) or linden (*Tilia cordata* Mill.) at recommended rates when transplanting into infertile, but uncompacted soil (Day and Harris, 2007). Unnecessary fertilizer is obviously not cost effective and raises concerns of degrading water resources through runoff or nitrogen leaching. It is apparent from the mixed results discussed above that fertilization research to date does not provide the definitive answers needed to make fertilization recommendations for newly transplanted urban trees. Few studies have included the less-than-ideal soils found in urban areas where rapid establishment could potentially provide significant financial and environmental benefits because of increased canopy cover and reduced tree replacement costs.

This group of studies seeks to determine if fertilization practices have potential to speed establishment rates in a broad cross-section of soil conditions typical of developed land. The five studies presented here all share the same objective: Can fertilizer be effectively used to improve the nutrient status of trees during the establishment period and thereby hasten their entry into the environmentally productive phase of their life? These studies include 10 deciduous shade tree species and 276 individual trees that were either field (transplanted B&B or bare root) or container grown (two container sizes) to full "landscape size" and transplanted into a variety of site conditions, including poor sites, typical of urban landscapes. This variety of planting sites, tree species, and production methods presents a broad look at the effect of fertilization at planting on the growth of shade trees.

Methods

Overview

All experiments were conducted at or near Virginia Tech's main campus in Blacksburg, VA, USA. The experimental design was completely random for all five experiments, and each species was analyzed separately. Trunk diameter was chosen as the most critical metric of establishment (Gilman and Beeson, 1996; Struve et al., 2000) and growth because it strongly correlates with total tree biomass (Avery and Burkhart, 2002). Trunk diameter increase was recorded annually for up to 4 years after transplanting. Soil characteristics were analyzed by Virginia Tech soil analysis laboratories within the Crop and Soil Environmental Sciences Department and can be found in Table 1. Total soil N and C were quantified using a Vario Max CNS elemental analyzer (Elementar Instrument, Mt. Laurel, NJ, USA). Experimental data were analyzed with multivariate repeated measures protocol and regression analysis within the GLM and REG procedures of SAS (vers. 9.1, SAS Institute, Cary, NC, USA) for Experiments 1 through 4 and for Experiment 5, respectively. Yearly tree size per treatment is presented for Experiments 1 through 4 (Figs. 1–4), and final post-transplant growth per treatment is presented for Experiment 5 (Fig. 5). *P*-values for treatment effects (Exp. 1–4) and parameter estimates from regression analysis (Exp. 5) are presented in Table 2. Experiments 1 and 5 were in soils that were undisturbed enough to be classified as a normal soil taxonomic series (described below), but Experiments 2, 3, and 4 were conducted in highly disturbed or "urban" soils (Craul, 1985) in which a normal soil series no longer accurately reflected its characteristics. Each experiment is individually described below.

Experiment 1: 55-L container-grown trees in average soil conditions (1-CON-AVG)

6 replications × 4 fertilization rates × 4 species = 96 trees

Container-grown (55-L) swamp white oak (*Quercus bicolor* Wild.), shingle oak (*Quercus imbricaria* Michx.), pear (*Pyrus calleryana* Decne. "Cleveland Select"), and Freeman maple (*Acer × freemanii* Autumn Blaze®) trees were obtained from Dewis Nursery (Bedford, VA, USA) and planted approximately 4 m apart in rows at Virginia