Physiological response of nursery-grown landscape trees to fertigation

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Objectives

To evaluate the impact of various fertilizer regimes on growth and physiology of nursery crops

To determine the impact of irrigation and fertilization on productivity and quality of field-grown woody ornamentals

To develop nutrient diagnostic methods to provide decision support for nutrient management

To develop a research platform which can leverage support for additional research trials (e.g., new plant material trials, herbicide screening, pesticide trials)

Summary

Height and diameter growth of landscape trees in the shade tree nursery trial at SWMREC varied by species and fertigation treatments (SWMREC annual report 2003). During the summer of 2004 we investigated the physiological bases for species and fertigation treatment effects on growth of the landscape trees at SWMREC. The nursery trial was installed in 2001 as a split-plot design with fertigation treatments (control, irrigation only, fertilizer only, irrigation + fertilizer) as the main plot and tree species as the subplot (Fig. 1). Irrigated plots received 0.75” to 1.5” of water per week though a drip irrigation system depending upon PET and rainfall. Fertilizer was applied at the rate of 150 lbs/ac per year as ammonium nitrate through the drip system. Tree growth (height and stem diameter at 12”) was measured every year (Fig.2). In the summer of 2004 we measured light saturated photosynthetic rate (Amax) with a portable photosynthesis system (Li-6400, Li-Cor, Inc.) on three dates (Fig. 3). Variable chlorophyll fluorescence (Fv/Fm) was determined using a portable flourometer (Plant Efficiency Analyzer, Hansatech, Ltd., Norfolk, England). Relative leaf chlorophyll content was determined using a portable chlorophyll meter (Minolta SPAD-502, Spectrum Technologies, Plainfield, Il).

Results

Tree growth

Four years after nursery establishment, tree height, diameter, and volume index varied ($P<0.0001$) among species (Table 1). Honeylocust, scarlet oak, pin oak, and bur oak grew over 3' in height during 2004 (Fig. 4). In contrast, growth of goldenchain, Norway maple and redbud was relatively slow during the throughout the study. Diameter increment in 2004 was 0.4 inch or greater for all species except goldenchain, Norway maple, and sugar maple. For both height and diameter growth, response to fertigation was due to irrigation rather than fertilization. Averaged across species, irrigation increased ($P<0.01$) height by 9" and increased ($P<0.01$) diameter by approximately 1/4". The interaction of irrigation x fertilizer was significant ($P<0.05$) for diameter, which was related to a slight decrease in caliper for trees that were fertilized but not irrigated. This result is somewhat counter-intuitive but may be due to a build up of fertilizer salt near the fertigation drip-tube emitters.

Physiological responses

Variation in key physiological parameters was similar to variation in growth. Except for foliar N concentration, species had a larger effect on physiological responses than fertigation treatments (Table 2). Fertilization increased foliar N concentration for all species except honeylocust and mulberry. In general, foliar N was relatively high, averaging 2.8% on the unfertilized plots and 3.1% on the fertilized plots. Fertilization increased ($P<0.05$) leaf chlorophyll concentration as indicated by SPAD meter measurements. Variable chlorophyll florescence increased ($P<0.05$) under irrigation but was not affected

by fertilization. Species variation in Fv/Fm was related (R^2=0.84, P<0.0001) to specific leaf area (Fig. 5). This suggests that species with thinner leaves (high specific leaf area) have a lower photosynthetic efficiency than thicker leaves, possibly due to reduced mesophyll surface area within the leaf.

Species varied widely (P< 0.0001) in their maximum rate of photosynthesis (Amax). Species variation in Amax was largely explained by species differences in leaf conductance (Table 3). The ratio of Amax to leaf conductance (water use efficiency) varied among species but to a much smaller extent than either Amax or leaf conductance. Species variation in Amax appears to contribute to differences in productivity among species (Fig. 6). Species with high rates of gas exchange, such as the oaks, were more productive than species with lower rates of gas exchange such as the maples.

In summary, productivity response to fertilization was small, suggesting nutrition was adequate for growth without N additions. Responses to irrigation were statistically significant but growth increase was modest. Species was the largest factor determining tree productivity, apparently due to variation in photosynthetic rate. We are also investigating variation in tree leaf area and production efficiency (growth per unit leaf area) based on litterfall collections in the winter of 2004-05.

Table 1. Analysis of variance of 4th year growth response of 13 species of landscape trees grown under a 2 x 2 combination of irrigation and fertilization at SWMREC

Source	df	Height		Diameter		Volume[1]	
Block	9	0.82		2.12		1.31	
Irrigation (I)	1	11.76	**	13.03	**	15.77	**
Fertilization (F)	1	0.04		0.01		0.74	
I x F	1	3.64		5.16	*	7.96	**
Error A	27						
Species (S)	12	92.87	***	73.31	***	65.53	***
S x I	12	0.81		1.24		1.47	
S x F	12	0.78		0.82		0.95	
S x I x F	12	0.59		1.40		1.38	
Error B	345						

Note: * Effect significant at P = 0.05
** Effect significant at P = 0.01
*** Effect significant at P= 0.001
[1] Volume index = dia^2 x height

Table 2. Analysis of variance for maximum photosynthetic rate, SPAD chlorophyll index, variable chlorophyll fluorescence and foliar nitrogen of 13 species of landscape trees grown under a 2 x 2 combination of irrigation and fertilization at SWMREC, Summer 2004.

Source	df	Amax		SPAD		Fv/Fm		Foliar N	
Block	5	3.19		1.82		9.98		1.10	
Irrigation (I)	1	0.23		2.15		6.32	*	10.37	**
Fertilization (F)	1	0.76		5.78	*	2.42		91.62	***
I x F	1	3.47		1.93		0.98		0.64	
Error A	15								
Species (S)	10	73.5	***	17.61	***	5.45	***	71.77	***
S x I	10	2.89	**	0.62		1.26		1.18	
S x F	10	1.35		0.95		1.21		2.79	*
S x I x F	10	0.96		1.14		1.23		1.68	
Error B	200								

Table 3. Mean maximum photosynthetic rate, leaf conductance and water use efficiency of landscape trees grown under a 2 x 2 combination of irrigation and fertilization at SWMREC, Summer 2004.

	Amax		Conductance		Water use efficiency	
Bur oak	19.2	a	0.31	a	3.08	ab
Swamp white oak	18.9	a	0.28	ab	3.15	bc
Mulberry	18.2	ab	0.33	a	3.11	bc
Pin oak	16.5	bc	0.24	bc	3.28	ab
Scarlet oak	14.9	c	0.19	cd	3.43	ab
Redbud	11.9	d	0.14	d	3.63	a
Red maple	11.5	d	0.13	de	3.41	ab
Goldenchain	11.4	d	0.17	d	3.05	bc
Norway maple	10.0	d	0.15	d	2.75	c
Sugar maple	7.5	e	0.08	e	3.41	ab

Figure 1. Landscape nursery trial establishment. Spring 2001.

Figure 2. Tree height and caliper measurements. Summer 2002.

Figure 3. Gas exchange measurements with a Li-6400 portable photosynthesis system.

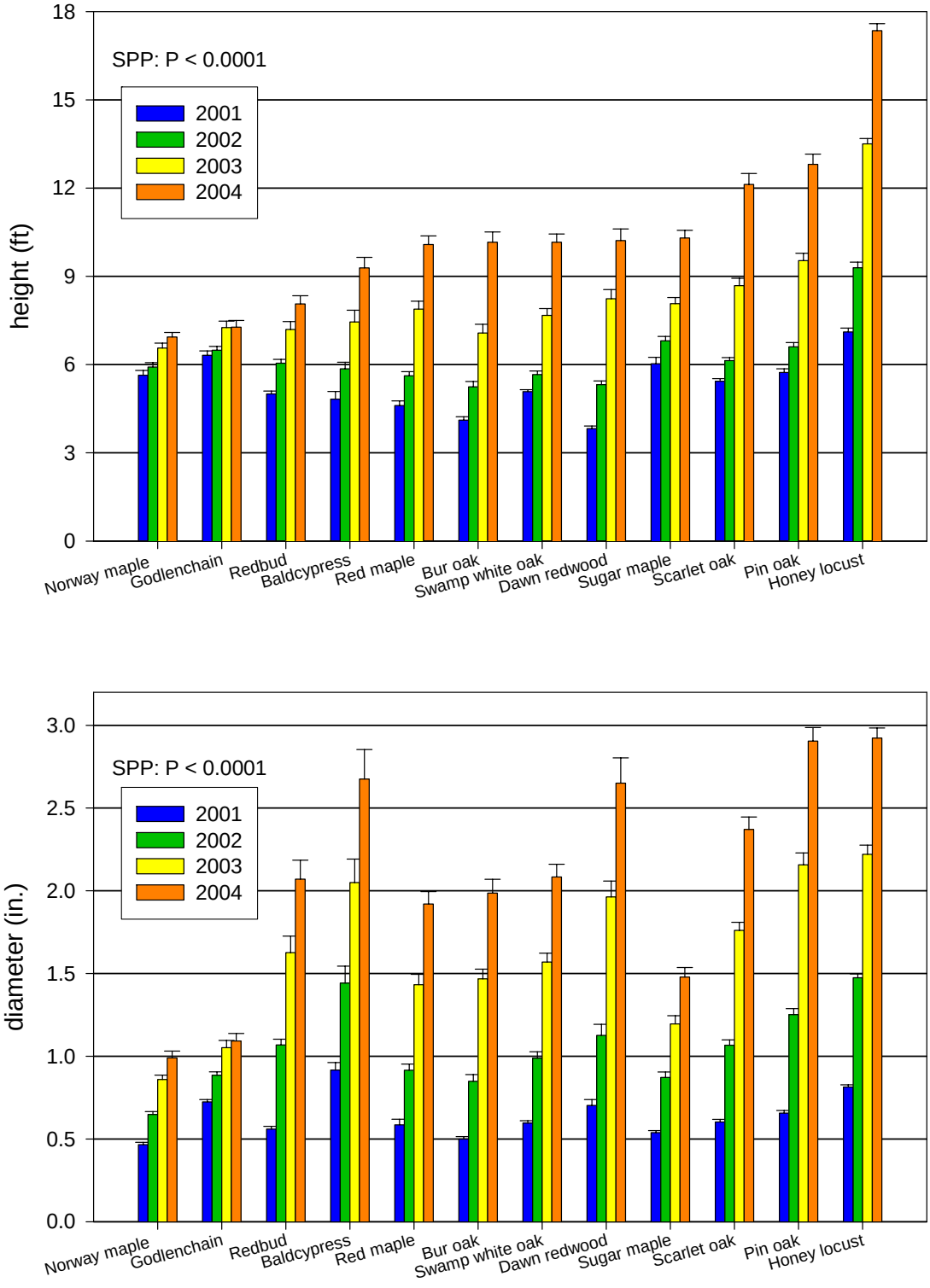

Figure 4. Height and diameter growth response of various landscape tree species after 4 years at SWMREC. Note: Means averaged across fertigation treatments.

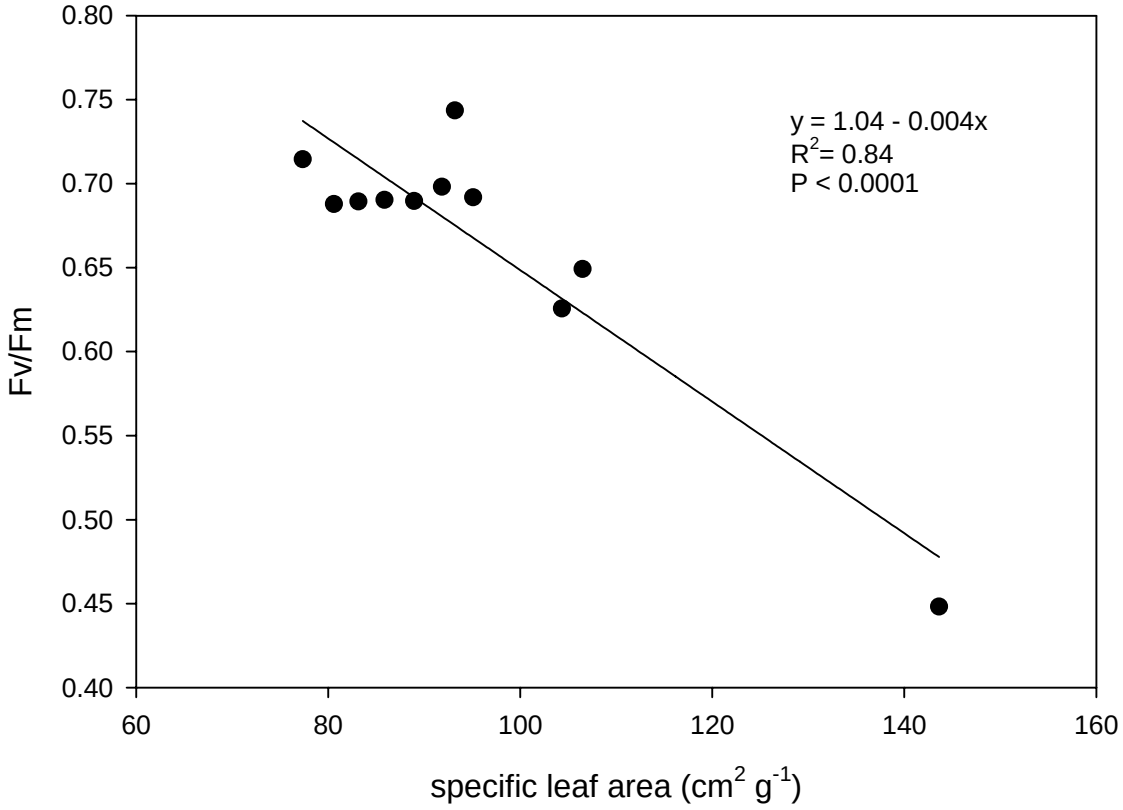

Figure 5. Relation of variable chlorophyll fluorescence and specific leaf area of landscape trees at SWMREC.

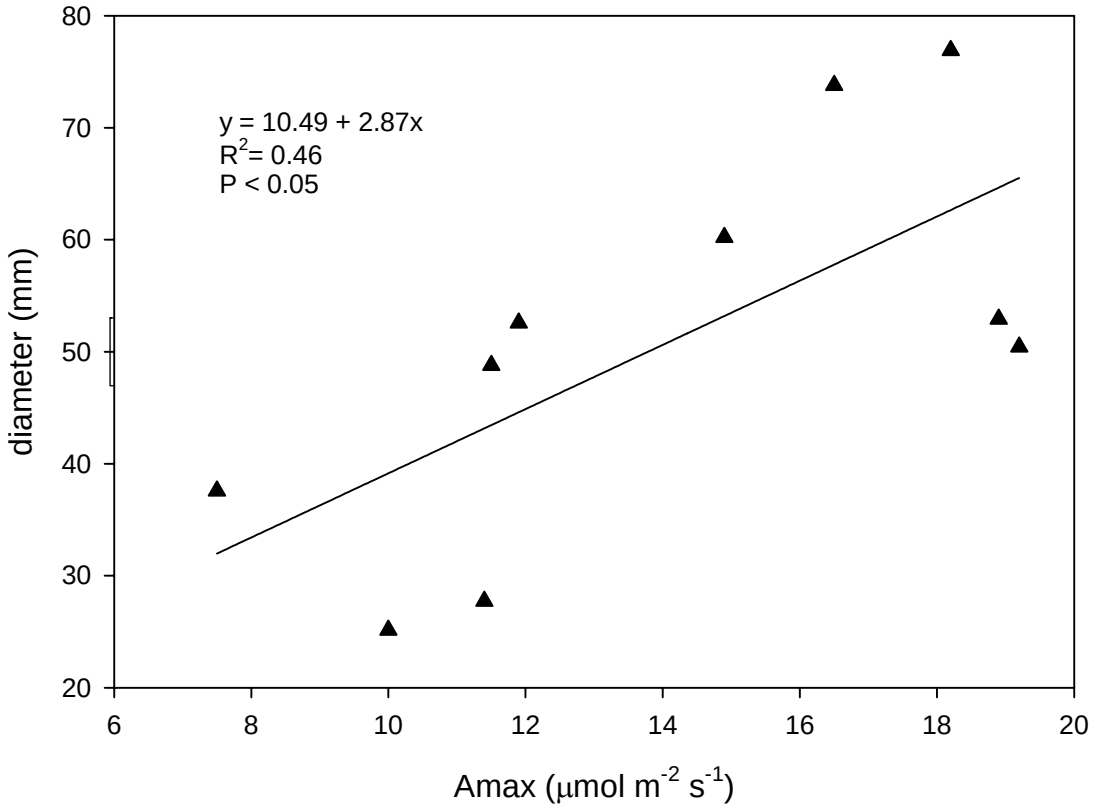

Figure 6. Relation of stem diameter growth and maximum photosynthetic rate of landscape trees at SWMREC.

Figure 7. Netting landscape nursery trees to collect litterfall to estimate foliar biomass and whole-tree leaf area. SWMREC 2004.