Field Production

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Growth and physiology of field-grown *Acer pseudoplatanus* L. trees as influenced by irrigation and fertilization

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Index Words: Chlorophyll fluorescence, leaf gas exchange, field production, sycamore maple

Significance to Industry: Irrigation and fertilization are commonly used practices in nurseries to obtain trees of adequate size and quality for sale in a short time. This study focused on the effects of slow-release fertilizers and drip irrigation on the physiology and growth of a widely used field-grown shade tree species. Results confirmed that fertilization is a useful mean to improve growth, but may cause stress to the trees if provided without adequate irrigation. On the other hand, irrigation had only limited effect on growth but greatly increased leaf gas exchange and carbon assimilation. To maximize stand productivity, irrigation should be coupled with fertilization.

Nature of Work: Nutrient and water managements are key factors for determining the quality and the growth rate of plants in the nursery. The importance of these practices has been reported by many studies: irrigation is widely recognized as a fundamental mean to improve growth both in the nursery and after planting in the landscape (6), and previous research highlighted that irrigation increases growth, leaf gas exchange and radiation use efficiency (1, 15). Other authors look to irrigation in the nursery with scepticism, and found that induction of moderate stress during the nursery period may increase drought tolerance after planting in the landscape (2). Anyways, if drought in the nursery penalizes carbon assimilation, the consequent reduction of growth and reserves stored within the plant may lead to reduced plant quality and marketability (16).

Fertilization increases growth, leaf area index (LAI), carbon assimilation, foliar nitrogen and allows nutrient loading during the nursery period (9, 3, 11). Nutrient and carbohydrate loading in the nursery may be a good strategy to improve post-transplant performances, since fertilization at transplant is not always effective to aid establishment in the landscape (4). On the other hand, nurseries are under increasing pressure to reduce chemical input and nutrient runoff. This means that a rational and sustainable use of water and fertilizers has to be achieved. To reach this target, nutrients have to be supplied only if they can effectively contribute to increase plant growth and gas exchange. For example, some authors (7) found that P fertilization increased drought tolerance of *Eucaliptus grandis* in black soils, whereas in sandy soils both N and P fertilization decreased gas exchange under drought conditions. Moreover, it has been reported that fertilization may reduce tolerance to drought stress by stimulating shoot growth to a greater degree than root growth, thus increasing tree water demand and simultaneously reducing tree ability to acquire water during drought (8). In general, fertilization may result ineffective if trees are subjected to other limiting stresses (i.e. drought) (12). The aim of this work was to investigate the effect of irrigation and fertilization on growth and leaf gas exchange of sycamore maple trees grown in the field.

In spring 2005, 60 uniform 10-12 cm (4-5 in.) circumference *Acer pseudoplatanus* trees were planted in the field. The experiment was located in the orchard of Fondazione Minoprio, in Vertemate con Minoprio (Como, Italy; 45°44' N, 9°04' E). The experimental design was a 2x2 factorial, consisting of two irrigation and two fertilization treatments repeated three times. Fifteen trees were irrigated (I), 15 were fertilized (F), 15 were both irrigated and fertilized (F+I). The remaining 15 trees were selected as controls and were neither watered nor fertilized. Fertilization of F and F+I trees was done at planting by incorporating in the planting hole 0.5 kg (1.1 lb) of a 8-9 month controlled-release fertilizer, Ficote® (15-8-12). In spring 2006 F and F+I plants were re-fertilized with 0.5 kg (1.1 lb) per plant of Nitrophoska® Gold, used as topdressing placed near the stem. Irrigation was provided by drip irrigation only to I and F+I trees, which were irrigated once per week from early-July until the end of August in 2005, and from mid-May until the end of July in 2006. In-row weed control was performed with an herbicide, while turf was left between the rows and periodically mowed.

Measured parameters were shoot elongation, stem diameter at breast height and plant height (measured in winter 2005 and 2006). Leaf gas exchange was measured 10 times in 2005 and 4 times in 2006 with a portable infrared gas analyser (CIRAS-2, PP Systems, Hertfordshire, UK). Measured variables were instant net photosynthetic rate (A; μmol m^{-2} s^{-1}) and transpiration rate (E; mmol m^{-2} s^{-1}). Water use efficiency (WUE; μmol CO_2 / mmol H_20) was calculated as A to E ratio. Measurements were taken between 8.00 and 12.00 h. Fifteen fully expanded leaves (3 leaves per 5 plants) per irrigation and fertilization treatment were used for gas exchange. For each measurement, leaves from the outer part of the crown at different heights were sampled. Chlorophyll fluorescence was measured twice with a portable analyzer (Handy Pea, PP Systems, Hertfordshire, UK) during summer 2005. Chlorophyll fluorescence is a good indicator of drought stress in plants (10). All data were subjected to two-way ANOVA and Duncan's multiple range test was used to separate means of the main effects (fertilization and irrigation). Differences were considered significant for $P \leq 0,05$. Statistical analysis was made with SPSS statistical package for Windows (SPSS Inc., Chicago, IL).

Results and Discussion: In 2005 shoot elongation was increased in both irrigated and fertilized trees (Table 1). The effect of fertilization was more evident (lower P-value) and went on also in 2006, while irrigation alone failed to increase shoot elongation in the second year of the experiment. Stem diameter was increased by irrigation both in 2005 and 2006, while fertilization increased secondary growth only in 2006. Plant height was unaffected by the treatments. There was a clear interaction between irrigation and fertilization: plants that were both irrigated and fertilized developed thicker stems and longer shoots than control plants or plants that were only irrigated or fertilized (Table 1). This was also confirmed by a greater weight of the pruned material of the F+I treatment, if compared to the other thesis. In plants that were both irrigated and fertilized, the fresh weight of the pruned material was respectively 47%, 41% and 35% higher than in plants which were either irrigated or fertilized and than in control plants. This parameter is highly representative because it is a good indicator of vegetative growth. Irrigation significantly increased leaf gas exchange: well-watered plants had greater carbon assimilation and transpired more water than non-watered trees both in 2005 and 2006 (Table 2). The adoption of a water-conservative strategy limiting transpiration by increased stomatal resistance is common in drought-stressed plants. The lower stomatal conductance reduces net photosynthesis, as well as transpiration, and this may lead to lower carbohydrates to support future growth. Irrigation decreased water-use efficiency and the decline of WUE is typical of plants with a favourable water status (14). Fertilization, whether or not coupled with irrigation, significantly reduced carbon assimilation in the first year after transplant (2005). In 2005, fertilized, non-irrigated plants showed lower carbon assimilation and transpiration if compared to irrigated plants and control plants (Table 2). This made us hypothesize that, as reported by some authors (8), nutrient supply can decrease plant tolerance to drought. In 2006, carbon assimilation was no more affected by fertilization, which only decreased transpiration either in presence or absence of irrigation.

Chlorophyll fluorescence was influenced by irrigation and fertilization treatments on 28th June, while no significant differences were found on 14th July (Table3). Percival *et al.* (10) proposed that, in the absence of stress, the ratio between variable fluorescence and maximum fluorescence (Fv/Fm) should remain above 0,75. On 28th June, the irrigated plants were not stressed, while some stress occurred in non-irrigated maples. Fertilization also decreased fluorescence on 28th June, and fertilized plants were more stressed than those which did not receive nutrient supply. A significant interaction between factors showed that fertilization, if provided without irrigation, leads to a greater stress in the period after planting (Table 3). On the other hand, if coupled with irrigation, fertilization may help producing fast-growing, unstressed trees.

In conclusion, our results show that fertilization increased shoot growth of sycamore maple. However, if fertilization is applied in the absence of irrigation, it may lead to stomatal closure, reduced carbon assimilation and gas exchange and may increase tree predisposition to water stress. Thus, in fertilized, non-irrigated tree stands, nutrient availability may increase shoot growth at the expense of root growth and storage of reserves, at this may lead to transplant failing, especially in the first year (13, 5, 8). Irrigation had a slight effect on shoot growth, but increased stem diameter, gas exchange and chlorophyll activity. As reported by other authors (1, 3, 15), our results confirm that, in order to maximize tree stand productivity, irrigation should be coupled with fertilization.

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Table 1. Shoot elongation, stem diameter at breast height, plant height and weight of pruned biomass after pruning trees to uniform size in sycamore maples grown with different irrigation and fertilization treatments.

	Shoot elongation (cm)		Stem diameter (mm)		Plant height (cm)		Weight of pruned material (g)
Treatment	2005	2006	2005	2006	2005	2006	2006
				Irrigation			
Irrigated	13.7 a[z]	55.9	38.2 a	46.7 a	394.8	441.5	947.6
Non-irrigated	11.5 b	54.2	36.4 b	42.7 b	393.5	435.8	739.7
P-value	*0.039*	*0.454*	*0.019*	*0.019*	*0.803*	*0.430*	*0.055*
				Fertilization			
Fertilized	14.0 a	62.1 a	37.4	48.3 a	395.3	445.7	913.2
Non-fertilized	11.2 b	47.9 b	37.0	45.8 b	393.0	431.7	739.7
P-value	*0.010*	*0.000*	*0.732*	*0.047*	*0.622*	*0.055*	*0.167*
				Irrigation x Fertilization			
Fertilized, non-irrigated	12.7 ab	58.4 b	35.3 b	45.1 b	391.7	438.3	637.7 b
Irrigated, non-fertilized	12.2 b	45.9 c	36.9 b	45.5 b	390.7	430.0	706.7 b
Fertilized and irrigated	15.3 a	65.8 a	39.5 a	51.5 a	399.0	453.0	1188.6 a
Control	10.3 b	50.0 c	37.4 ab	46.1 b	395.3	433.3	772.7 b
P-value	*0.013*	*0.009*	*0.004*	*0.006*	*0.263*	*0.212*	*0.016*

[z] Means within the same column with different letters are significantly different, Duncan's multiple range test ($P \leq 0.05$).

Table 2. Carbon assimilation, transpiration and water use efficiency in sycamore maple grown with different irrigation and fertilization treatments.

	Carbon assimilation (μmol $m^{-2}s^{-1}$)		Transpiration (mmol $m^{-2}s^{-1}$)		Water Use Efficiency	
Treatment	2005	2006	2005	2006	2005	2006
			Irrigation			
Irrigated	6.47 a[z]	8.30 a	3.80 a	2.51 a	1.70 b	3.31 b
Non-irrigated	5.56 b	6.73 b	2.74 b	1.83 b	2.10 a	3.68 a
P-value	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.038*
			Fertilization			
Fertilized	5.78 b	7.23	3.22	2.04 b	1.80	3.54
Non-fertilized	6.24 a	7.81	3.31	2.30 a	1.89	3.40
P-value	*0.029*	*0.070*	*0.325*	*0.002*	*0.149*	*0.397*
			Irrigation x Fertilization			
Fertilized, non-irrigated	5.03 b	6.50	2.52 c	1.70 c	2.00	3.82
Irrigated, non-fertilized	6.40 a	8.71	3.68 a	2.67 a	1.74	3.26
Fertilized and irrigated	6.54 a	7.89	3.92 a	2.35 b	1.67	3.36
Control	6.08 a	6.90	2.96 b	1.93 c	2.05	3.58
P-value	*0.001*	*0.432*	*0.001*	*0.000*	*0.916*	*0.128*

[z] Means within the same column with different letters are significantly different, Duncan's multiple range test ($P \leq 0.05$).

Table 3. Chlorophyll fluorescence in sycamore maple grown with different irrigation and fertilization treatments.

Treatment	*28-June-2005*	*14-July-2005*
	Irrigation	
Irrigated	0.78 a[z]	0.77
Non-irrigated	0.65 b	0.75
P-value	*0.004*	*0.429*
	Fertilization	
Fertilized	0.67 b	0.76
Non-fertilized	0.77 a	0.76
P-value	*0.016*	*0.855*
	Irrigation x Fertilization	
Fertilized, non-irrigated	0.54 b	0.72
Irrigated, non-fertilized	0.77 a	0.75
Fertilized and irrigated	0.78 a	0.79
Control	0.76 a	0.77
P-value	*0.007*	*0.168*

[z] Means within the same column with different letters are significantly different, Duncan's multiple range test (*P≤0.05*).

Growth and gas exchange responses of two field-grown maple tree species to three reference evapotranspiration based irrigation regimes

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Index words: *Acer x freemanii* 'Autumn Blaze', *A. truncatum*, Reference Evapotranspiration, Irrigation

Significance to Industry: For many nurseries, water conservation is a top priority. However, while reducing the amount of water used in nursery production is crucial, little data exists which quantifies the amount of water needed to produce field-grown trees, or methodology to estimate tree water requirements. This research suggests calculating irrigation levels based upon estimated tree root area and reference evapotranspiration may provide sufficient water for growth, yet avoid over irrigating and wasting resources. In addition, this research indicates irrigation volume will influence gas exchange and growth of field-grown maple tree species, but proper irrigation volume can conserve water and produce satisfactory growth.

Nature of Work: Drought and depleted water tables have increased the number of ordinances (often without regard to plant water requirements) in many municipalities and irrigation districts. These ordinances often limit the amount of water nurseries can use to irrigate trees (1). Even though research on water conservation in nurseries is currently ongoing (3), little research has been conducted to inform growers, municipalities, and irrigation districts the amount of water required to produce field-grown (FG) tree species (2). To help determine the influence of limited irrigation on FG tree species, this research investigated gas exchange and growth of two FG maple tree species subjected to three reference evapotranspiration based irrigation regimes in a semi-arid climate.

Research was conducted at a field nursery in Lubbock, TX. Selected species were: Autumn blaze (*Acer x freemanii* 'Autumn Blaze') and Shantung (*A. trunctaum*) maple. During Spring 2002, nine containerized (3 gal) trees of each species were planted in a randomized block design. Irrigation regimes were based upon estimated soil surface area above the tree's root system (in^2) and local reference evapotranspiration (ETo (in)). During the dormant period after each growing season root area was estimated by removing soil from several trees. Climatic data was collected from an on site weather station. Irrigation regimes were: 100, 60, and 30% of ETo (high, medium, and low, respectively). Trees were irrigated through a drip irrigation system. Each tree had 3, 2, or 1 emitters (1 gal hr^{-1}) placed at the base of the tree and trees were irrigated an equal amount of time twice each week. If precipitation occurred, precipitation accumulation was subtracted from ETo. Trees were not fertilized or pruned during the experiment. During the 2002 growing season, all trees were irrigated at 100% ETo. Irrigation treatments began Spring 2003 and continued through the 2005 growing season. On several occasions each growing season gas exchange data (pre-dawn leaf water potential and mid-day stomatal conductance) were collected. Growth data (trunk caliper increase, shoot elongation, and total leaf area) were collected at the end of each growing season. Data were subjected to ANOVA appropriate for a randomized block design. If treatment differences were found, means were separated by Fisher's LSD. Due to page limitations and similarity of data between growing seasons, 2004 data will be presented.

Results and Discussion: Climatic data from the growing season (1 April through 30 September) indicate precipitation total was 7.9 inches and total ETo was 46.5 inches. For each irrigation treatment, total irrigation volume applied to each tree ranged from to 138 gallons (low irrigation regime) to 462 gallons (high irrigation regime) (data not shown).

Pre-dawn leaf water potential and mid-day stomatal conductance measurements during the growing season were variable (data not shown). For Shantung maple, pre-dawn leaf water potential and stomatal conductance measurements varied between irrigation regimes. However, trees receiving the greatest amount of irrigation generally where under less stress (less negative pre-dawn leaf water potential and greater stomatal conductance means) when compared to trees receiving less irrigation. For Autumn blaze maple, pre-dawn leaf water potential and stomatal conductance means also varied between irrigation. However, on several occasions trees receiving low and medium irrigation had greater stomatal conductance and lower pre-dawn leaf water potential than trees receiving the high irrigation treatment.

Data indicate irrigation treatment also influenced growth of each species. When compared to the low and medium irrigation treatments, shoot growth and leaf area of Shantung maple trees receiving the high irrigation treatment had greater growth (Fig. 1). However, there was no difference for caliper increase between irrigation treatments. Similar growth trends were not found for Autumn blaze maple. For each growth parameter, Autumn blaze maple trees receiving the medium irrigation treatment had similar or greater growth when compared to trees receiving the high irrigation treatment and generally greater growth than trees receiving the low irrigation treatment (Fig. 2).

This research indicates irrigation volume can influence gas exchange and growth of these FG, maple varieties. It is interesting to note that the greatest gas exchange and growth was not necessarily associated with trees receiving the greatest amount of irrigation volume. In addition, despite limited irrigation all trees survived and were of similar aesthetic quality. Therefore, it appears for some tree species irrigation volume may be reduced and produce similar growth when compared to trees receiving greater irrigation volume. In addition, it appears the influence of irrigation volume on growth of these FG trees is plant structure and species specific. Data also suggests irrigation of FG trees based upon soil surface root area and local ETo measurements may be a means to conserve irrigation water and produce FG trees with acceptable growth. However, continued research on the influence of reduced irrigation on FG tree species is needed.

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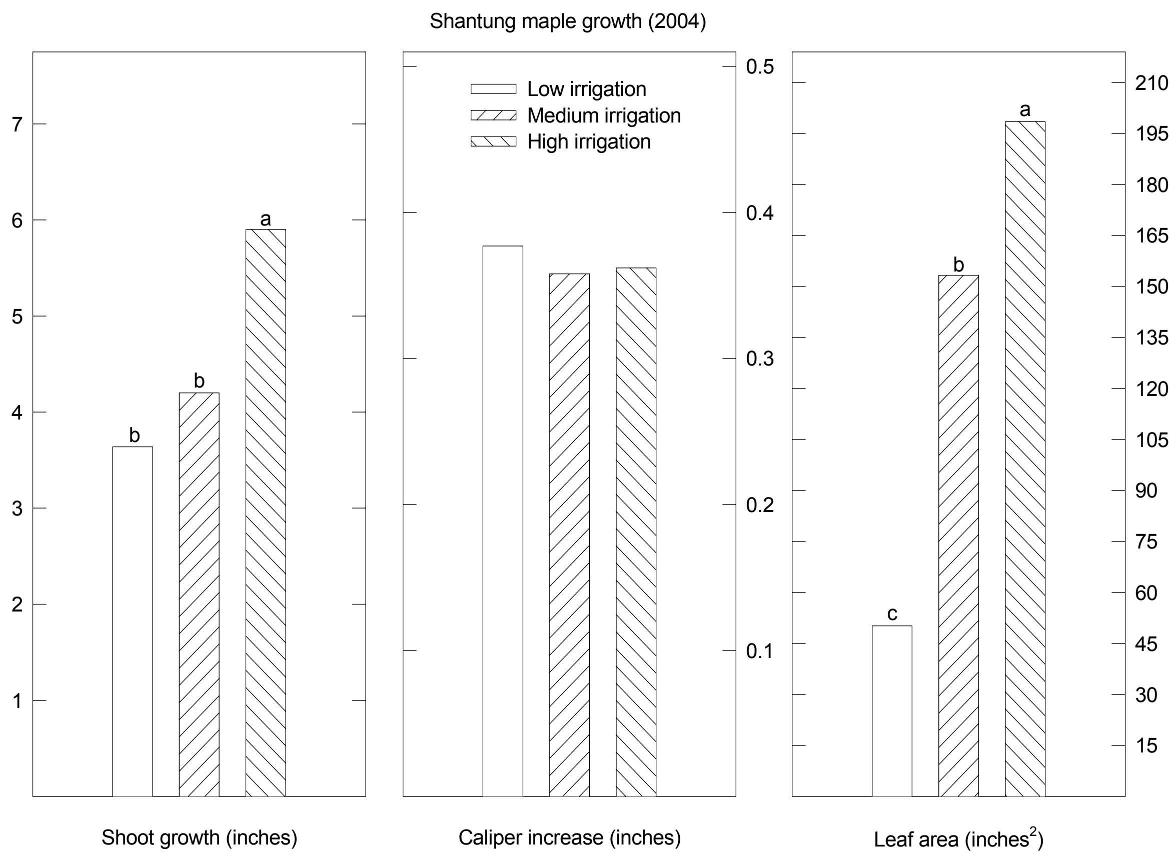

Figure 1. Shoot growth, caliper increase and total leaf area for field-grown Shantung maple trees subjected to three irrigations regimes (100, 66, and 33% reference ET (high, medium, and low, respectively). Different letters indicate significant effects of irrigation regime ($P \leq 0.05$).

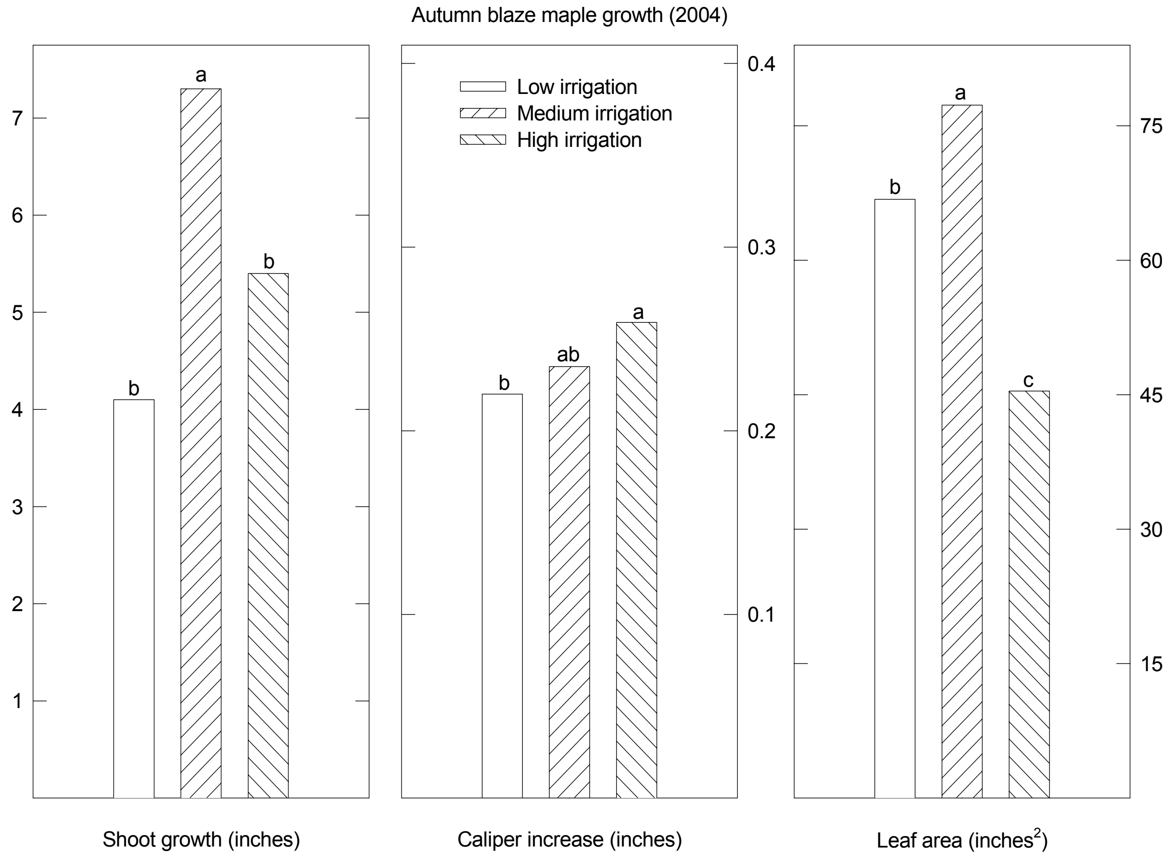

Figure 2. Shoot growth, caliper increase and total leaf area for field-grown Autumn blaze maple trees subjected to three irrigations regimes (100, 66, and 33% reference ET (high, medium, and low, respectively). Different letters indicate significant effects of irrigation regime ($P \leq 0.05$).

Investigating water requirements of select, field-grown tree species in a semi-arid climate

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Index words: *Acer buergeranum*, *A. campestre*, *Quercus muehlenbergii*, *Q. robur* x *Q. bicolor* 'Asjes', reference evapotranspiration, irrigation

Significance to Industry: For many nurseries, water conservation is a top priority. However, while reducing the amount of water used in nursery production is crucial, little data exists which quantifies the amount of water needed to produce field-grown trees, or methodology to estimate tree water requirements. This research suggests calculating irrigation levels based upon estimated tree root area and reference evapotranspiration may provide sufficient water for growth, yet avoid over irrigating and wasting resources. In addition, this research indicates irrigation volume will influence field-grown maple tree species, but proper irrigation volume can conserve water and produce satisfactory growth.

Nature of Work: Recent droughts and depleted water tables across many regions have elevated the necessity to irrigate field-grown (FG) nursery trees. At the same time, ordinances restricting nursery irrigation volume have been implemented, often without regard to plant water requirements. These ordinances often limit the amount of water nurseries can use to irrigate trees (1). Even though research on water conservation in nurseries is currently ongoing (3), little research has been conducted to inform growers, municipalities, and irrigation districts the amount of water required to produce FG tree species (2). To help determine the influence of limited irrigation on FG tree species, this research investigated growth of two FG maple and two FG oak tree species subjected to three reference evapotranspiration based irrigation regimes in a semi-arid climate.

Research was conducted at a field nursery in Lubbock, TX. Selected species were: *Acer buergeranum* (trident maple), *A. campestre* (hedge maple), *Quecus muehlenbergii* (chinkapin oak), and *Q. robur* x *Q. bicolor* 'Asjes' (English oak). During Spring 2002, nine containerized (3 gal.) trees of each species were planted in a randomized block design. Irrigation regimes were based upon estimated soil surface area above the tree's root system (in^2) and local reference evapotranspiration (ETo (in)). During the dormant period after each growing season root area was estimated by removing soil from several trees. Climatic data was collected from an on site weather station. Irrigation regimes were: 100, 60, and 30% of ETo (high, medium, and low, respectively). If precipitation occurred, precipitation accumulation was subtracted from ETo. Trees were irrigated through a drip irrigation system. Each tree had 3, 2, or 1 emitters (1 gal hr^{-1}) placed at the base of the tree and trees were irrigated an equal amount of time twice each week. Trees were not fertilized or pruned during the experiment. During the 2002 growing season, all trees were irrigated at 100% ETo. Irrigation treatments began Spring 2003 and continued through the 2005 growing season. Trunk caliper increase and shoot elongation (10 randomly selected shoots from each tree) were collected at the end of each growing season. Data were subjected to ANOVA appropriate for a randomized block design. If treatment differences were found, means were separated by Fisher’s LSD. Due to page limitations and similarity of data between growing seasons, only 2005 data will be presented.

Results and Discussion: Climatic data from the 2005 growing season (1 April through 30 September) indicate total precipitation was 9.1 inches and total ETo was 43.4 inches. For each irrigation treatment, total irrigation volume applied to each tree ranged from to 123 gallons (low irrigation regime) to 410 gallons (high irrigation regime) (data not shown).

Data indicate irrigation treatment influenced growth of each species. When compared to high and medium irrigation treatments, shoot and caliper growth of each maple species was greatest for trees receiving the least amount of irrigation (Figs. 1 and 2). For oak species, growth varied between species and irrigation treatment. Chinkapin oak had greater shoot and caliper growth when trees were irrigated at the high irrigation level (Fig. 3). However, for English oak there was no difference for shoot growth between high and low irrigation treatments (Fig. 4). Caliper increase for English oak was greatest when trees received the low irrigation treatment.

This research indicates irrigation volume can influence gas exchange and growth of these FG tree species. It is interesting to note that for several species the greatest and growth was not necessarily associated with trees receiving the greatest amount of irrigation volume. In addition, despite limited irrigation all trees survived and were of similar aesthetic quality. Therefore, it appears for some tree species irrigation volume may be reduced and produce similar growth when compared to trees receiving greater irrigation volume. In addition, it appears the influence of irrigation volume on growth of these FG trees is plant structure and species specific. Data also suggests irrigation of FG trees based upon soil surface root area and local ETo measurements may be a means to conserve irrigation water and produce FG trees with acceptable growth. However, continued research on the influence of reduced irrigation on FG tree species is needed.

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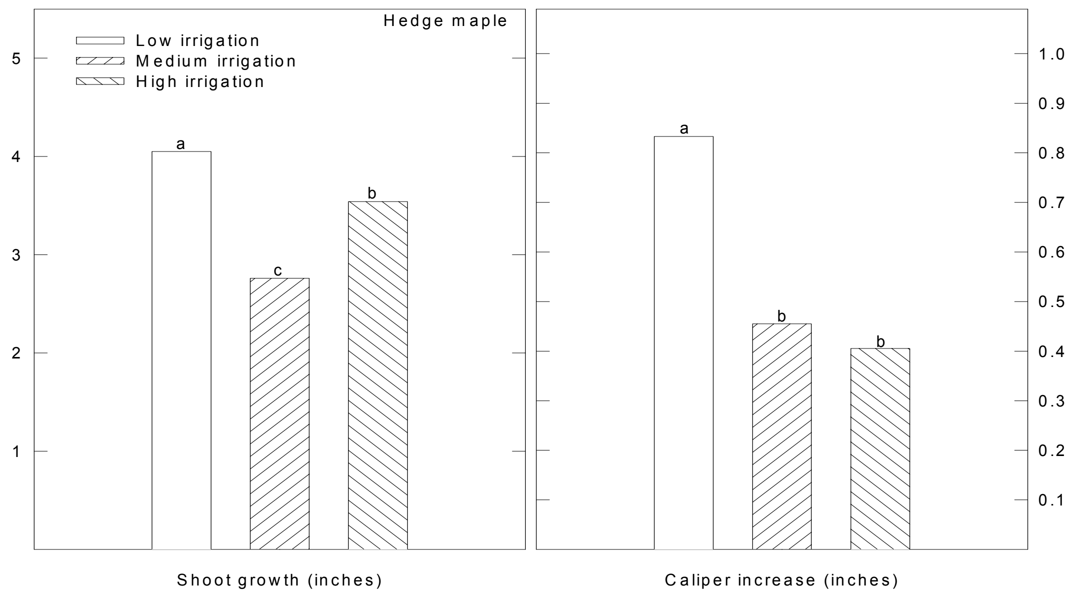

Figure 1. Shoot growth and caliper increase for field-grown hedge maple trees subjected to three irrigations regimes (100, 66, and 33% reference ET (high, medium, and low, respectively). Different letters indicate significant effects of irrigation regime (P ≤ 0.05).

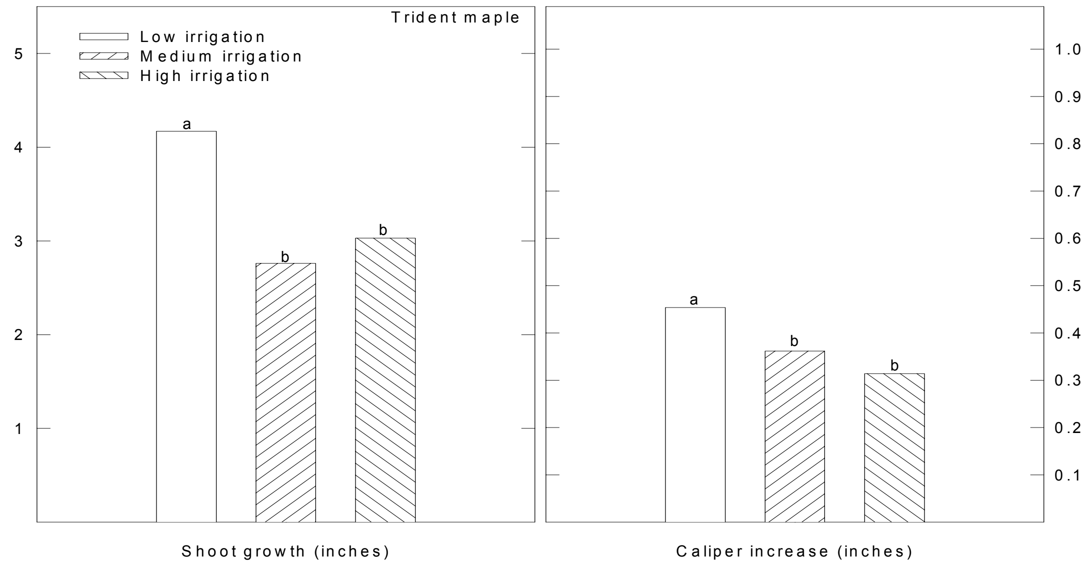

Figure 2. Shoot growth, caliper increase, and total leaf area for field-grown trident maple trees subjected to three irrigations regimes (100, 66, and 33% reference ET (high, medium, and low, respectively). Different letters indicate significant effects of irrigation regime ($P \leq 0.05$).

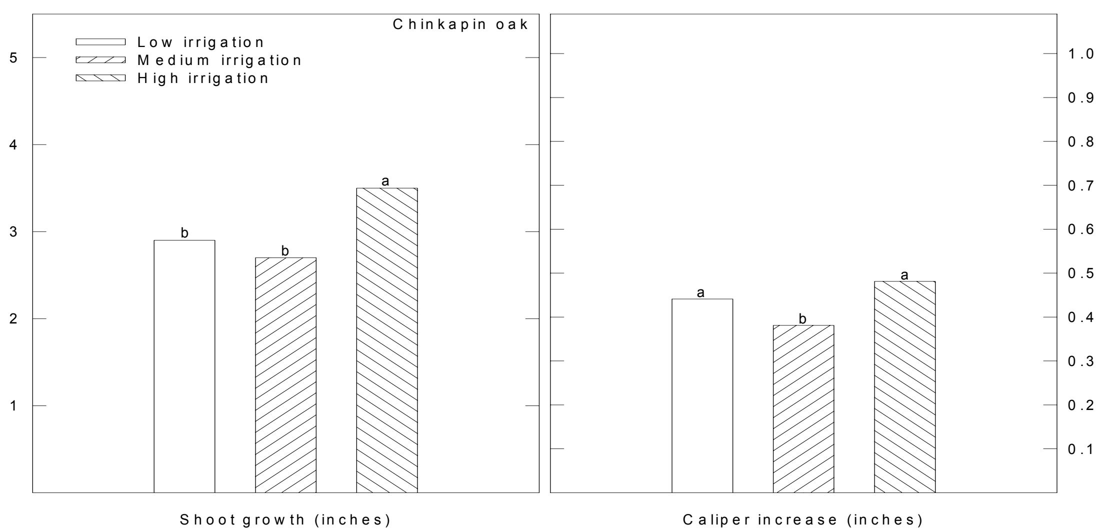

Figure 3. Shoot growth, caliper increase, and total leaf area for field-grown chinkapin oak trees subjected to three irrigations regimes (100, 66, and 33% reference ET (high, medium, and low, respectively). Different letters indicate significant effects of irrigation regime ($P \leq 0.05$).

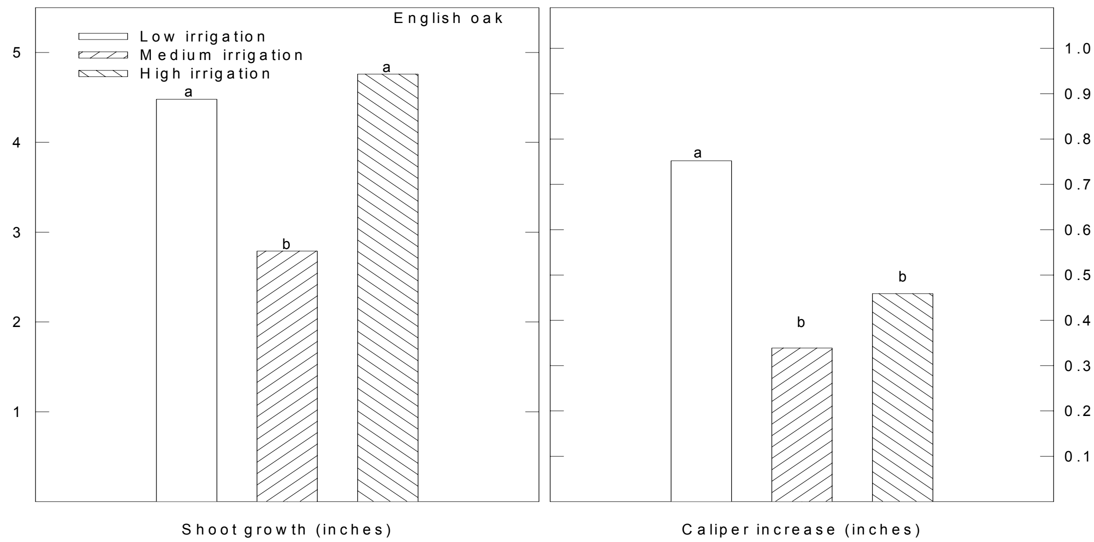

Figure 4. Shoot growth, caliper increase, and total leaf area for field-grown English oak trees subjected to three irrigations regimes (100, 66, and 33% reference ET (high, medium, and low, respectively). Different letters indicate significant effects of irrigation regime (P ≤ 0.05).

Effect of Nitrogen Source on Trunk Caliper Growth of Field-Grown Zelkova

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Significance to the Industry: Field-grown zelkova trees were fertilized with different nitrogen sources. Regardless of N source, there was no significant difference in trunk caliper after one or two growing seasons. Data from the Arkansas Delta region suggest that N source, when applied in the spring, has minimal effect in field production of zelkova trees.

Nature of Work: Limited data are available on the effect of nitrogen (N) rate on the growth of field-grown shade trees relative to container-grown ornamentals (8). Specific results are dependent on the N rate, time of application and species involved (3, 5, 6, 9). While nitrogen source has been extensively studied for greenhouse crops (2, 4, 7), less is known about the effect of nitrogen source on the growth of field-grown shade trees. The objective of this research was to evaluate the effect of N source on the growth of field-nursery grown shade trees in the Delta region of Arkansas.

The research was conducted at a commercial field shade-tree nursery in Harrisburg, AR. *Zelkova serrata* 'Green Vase' trees were planted as bareroot (BR) plants on 5 March 2005 by the nursery owner. Plants were watered as needed by drip irrigation. Tree spacing within a row was on 6 ft. centers and tree density was approximately 560 trees/acre.

Nitrogen fertilizer treatments were applied on March 30, 2005 and March 15, 2006 which is typically two to three weeks before bud break for northeast Arkansas. Urea (46-0-0) and ammonium nitrate (AN; 34-0-0) were broadcast by hand to the soil surface in an area 1 ft^2 within the tree trunk. The 12-14 month controlled release fertilizer PolyOn 17-5-11 (N-P_2O_5-K_2O analysis; Pursell Technologies, Sylacauga, AL), was applied on March 30, 2005 using the 'drill and fill' method (1). Treatments were assigned in a completely randomized design. Treatments were applied to single plants, which represented one replicate; the total number of replications was 17. Every year in June the soil was tested to establish P & K levels. Soil was sampled to a depth of 4-6". No additional P or K was required in 2005 or 2006 as indicated by the soil test.

Tree growth was evaluated by measuring the trunk caliber 1 m (~3 ft.) above the soil surface and tree height on 1 November 2005 and 30 October 2006. Data was analyzed by ANOVA procedures and mean separation by Tukey's HSD (p=0.05).

Results and Discussion:

Nitrogen source did not have a significant effect on the trunk caliper of 'Green Vase' Zelkova during the first and second seasons following BR planting in a field nursery in the Delta region of Arkansas (Table 1). Nitrogen in any form, when applied at 100 lb N/A for two growing seasons, did not increase caliper growth relative to an unfertilized control. The fact that nitrogen had minimal effect on caliper growth of field-grown shade trees is consistent with research conducted on other tree species in this region. Based on these data, it would appear that N input for Arkansas Delta field nurseries should be minimal, thus reducing nutrient input (fertilizer) costs.

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Table 1. Trunk caliper for *Zelkova serrata* 'Green Vase' fertilized with different N sources at a field shade tree nursery in Harrisburg, AR. Mean separation by Tukey's HSD (p=0.05)

N Fertilizer Treatment[z]		Mean Trunk Caliper (cm)	
2005	**2006**	**2005**	**2006**
Urea; 50 lb N/A	Urea; 50 lb N/A	2.1 a	3.4 a
AN; 50 lb N/A	AN; 50 lb N/A	2.1 a	3.5 a
PolyOn[y]; 100 lb N/A	----	2.2 a	3.4 a
Unfertilized check	Unfertilized check	2.0 a	3.3 a

[z] N was applied on March 30, 2005 and March 15, 2006. AN = ammonium nitrate (NH_4NO_3)
[y] PolyOn 17-5-11, 12-14 month controlled-release fertilizer applied with 'drill and fill' method