PERFORMANCE OF SUGAR MAPLE TAXA (*ACER SACCHARUM* MARSH.)

IN NORTH ALABAMA

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PERFORMANCE OF SUGAR MAPLE TAXA (*ACER SACCHARUM* MARSH.) IN NORTH ALABAMA

Kenneth Ray Blackwood

A Thesis

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PERFORMANCE OF SUGAR MAPLE TAXA (*ACER SACCHARUM* MARSH.)

IN NORTH ALABAMA

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VITA

Ken Blackwood, son of Carl Blackwood and Betty Blackwood, was born on April 15, 1961 in Hartselle, Alabama. After graduating from Falkville High School, Falkville, Alabama, 1979, he attended Auburn University in Auburn, Alabama. He received a Bachelor of Science Degree in Business Administration with emphasis in Industrial Operations Management in December 1983. After spending four years working as Personnel Manager for Sonoco Products Company in Granite Falls, North Carolina and in Decatur, Alabama, he attended Mid-America Baptist Theological Seminary in Memphis, Tennessee. He received a Masters of Divinity Degree in December 1991. He has served as pastor of First Baptist Church of Marvell, Arkansas and as pastor of First Baptist Church of Cuthbert, Georgia. In April 1997 he was appointed as career missionary of the International Mission Board of the Southern Baptist Convention. After studying Spanish at the Instituto de Lengua Español in San Jose, Costa Rica, he graduated with a diploma in Spanish. Since December 1998, he has served as a church planter in Mérida, Venezuela. In January 2006, he transferred to serve as a Strategy Coordinator in East Asia. In January 2002, he enrolled in the Graduate School at Auburn University.

THESIS ABSTRACT

PERFORMANCE OF SUGAR MAPLE TAXA (*ACER SACCHARUM* MARSH.)

IN NORTH ALABAMA

Kenneth Ray Blackwood

Master of Science, December 15, 2006
(M. Div. Mid America Baptist Theological Seminary, 1991)
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A sugar maple (*Acer saccharum* Marsh.) variety trial was initiated in March, 1999 at the North Alabama Horticulture Substation in Cullman, Ala. (USDA Zone 7). The purpose of the study was to identify superior sugar maple selections for landscape use in the Southeastern region of the United States, to evaluate growth (height and caliper increase), foliage characteristics (mean leaf area, petiole length, and chlorophyll content), and determine tolerance to the Japanese Beetle (*Popillia japonica* Newman). The study includes 22 sugar maple selections planted on a 6.1 m x 6.1 m (20 ft x 20 ft) spacing and fertilized with 454 g 13-13-13 per 2.54 cm (1 lb per 1 inch) of diameter at planting and in subsequent years in the winter months prior to budbreak. The study includes nineteen cultivars (‘Astis’ (Steeple™), ‘Autumn Faith’, ‘Autumn Blush’, ‘Barrett Cole’ (Apollo™), ‘Bonfire’ (Bonfire™), ‘Commemoration’, ‘Endowment’, ‘Fairview’

(Fairview™), ‘Fall Fiesta’ (Fall Fiesta™), ‘Flax Mill Majesty’, ‘Goldspire’, ‘Green Mountain’, ‘Legacy’, ‘Morton’ (Crescendo™), ‘Reba’ (Belle Tower™), ‘Seneca Chief’, ‘Sugar Queen’, ‘Sweet Shadow Cut-Leaf’, and ‘Moraine’ (Wright Brothers™); and three sugar maple seedling selections (from A. McGill and Sons Nurseries, Gervais, OR; Ellenburg Nursery, Baileyton, AL; and J. Frank Schmidt and Son Nurseries, Boring, OR). ‘Seneca Chief’ had the greatest height increase at 73.41 cm (28.9 in.) while ‘Barrett Cole’ had the least annual height increase at 14.22 cm (5.6 in.). The largest caliper increase occurred with Ellenburg, a southern seedling source at 1.35 cm (0.5 in.) annual increase. Cultivars ‘Barrett Cole’ and ‘Endowment’ had the smallest caliper increase at 0.64 cm (0.25 in.) and 0.66 cm (0.26 in.), respectively. ‘Goldspire’ and the A. McGill seedling selection had the largest leaves followed closely by cultivar ‘Green Mountain’. ‘Commemoration’ had the smallest leaves. ‘Green Mountain’ had the longest petioles at 13.1 cm (5.2 in.). ‘Morton’ had the shortest petioles at 6.7 cm (2.6 in.). ‘Barrett Cole’, ‘Autumn Blush’ and ‘Reba’ had the least damage from Japanese Beetle, neither cultivar having any visible beetle damage. ‘Fairview’ ranked last with the greatest Japanese Beetle damage in this study with 2.8 from a possible 3.0 damage rating. ‘Sweet Shadow Cut-Leaf’, with the most distinctive leaf of any selection in the study, ‘Autumn Faith’, ‘Green Mountain’, and ‘Reba’ had the highest chlorophyll content as determined by the SPAD-502 Leaf Greenness Meter. Using a Rating Index, the top five selections in our study were ‘Green Mountain’, ‘Reba’, ‘Autumn Blush’, ‘Sugar Queen’ and ‘Bonfire’. The selections with the poorest performance in our study, to date, were ‘Barrett Cole’, ‘Commemoration’, ‘Fairview’, ‘Legacy’, ‘Morton’, and ‘Moraine’.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Sugar maple (*Acer saccharum* Marsh) is well known as the source of the sweet sap used to make maple syrup and maple sugar. The lush canopy, vibrant autumn foliage, and distinctive bark also make sugar maple a prime selection as a home landscape tree (Ball, 2001). Sugar maple is often the dominant tree in deciduous forests of the Northeast, the popularity in that region attested to by its selection as the state tree for New York, Vermont, West Virginia, and Wisconsin (Calabrese, 1993).

While over thirty named cultivars of *A. saccharum* have been selected (Dirr, 1998; van Gelderen et al., 1994), no southern selection is a dominant choice in the marketplace. *A. saccharum* has not been evaluated extensively as a landscape ornamental tree in the Southeastern United States, however, and limited information is available regarding the suitability of various sugar maple cultivars in this region (St. Hilaire and Graves, 1999). Currently almost all sugar maples available in the United States have been selected outside of the Southeastern United States and are sold as seedlings; or cultivars budded onto seedling rootstock.

Differences in fall coloration among specific cultivars can be a determining factor for cultivar selection in landscapes where sugar maple thrives. Information on growth, pest resistance, viability, heat tolerance and required chilling to satisfy rest are additional criteria in need of evaluation in the Southeastern United States. Identification of superior cultivars for use in the Southeast presents opportunities for an expansion of sugar maple production and landscape use in the region.

Previous research of growth and development of *A. saccharum* has been limited to stands in the northern United States and in southern Canada. Effects of acid rain in eastern Canada and the Northeastern United States on sugar maple physiology, growth, and foliar nutrient concentrations have been studied (Hogan, 1998; Laurence et al., 1996). Stomatal conductance models for sugar maple have been studied on trees in Vermont (Yang et al., 1998). Leaf characteristics have long been broadly used as diagnostic characters in the genus *Acer* (Desmarais, 1952). This very common and variable tree has attracted the attention of many taxonomists and since 1753 it has been described under at least 17 specific, 18 varietal, and 18 formal names in more than 97 different combinations. However, the leaf itself is the character that shows the most striking variations and therefore is used most predominately as a reference point when describing the range, viability and distribution of *Acer* (Desmarais, 1952).

Observations conducted in the Sipsey Wilderness in Northwestern Alabama ranked *A. saccharum* as one of the top ten ecological species based on basal area (Zhang et al., 1999). However, at present, there are no reports for cultivar evaluations for landscape use in Alabama and the Southeast.

Studies have shown sugar maple to have an obligate chilling requirement, and therefore the species typically will only have one flush of growth in a growing season (Wood and Hanover, 1981). Although there are several cultivars with marketable names, there is little basis for promoting any particular cultivar in Southeast USDA Zones 7 to 8.

Sugar maple has difficulty thriving in urban bricked walkways (Schwets and Brown, 2000). Although *Acer saccharum* survived for up to 25 years when planted in a brick walkway, the surviving trees had lower canopy densities, higher amounts of twig die-back, and smaller canopy widths compared to trees planted in turfed areas, which performed better and were able to maintain form and structure. Those planted in a bricked walkway were more open-canopied and ragged in appearance when compared to those grown in turfed areas (Schwets and Brown, 2000).

A buried-pot study of 2-year-old sugar maple seedlings conducted in the Northeastern United States to test how liming influences growth and nutrient balances of this species showed a 37% larger growth on trees where lime was incorporated into the soil than non-limed control seedlings (Burke and Raynal, 1998). However, seedlings that received surface lime treatments were 9% smaller than control seedlings. Seedlings for this study were planted on May 9 and were harvested on August 30 of the same year. There is little information on the long-term effects of liming for *A. saccharum*.

Sugar maple use in areas where there is exposure to drying winds may be limited due to its sensitivity to desiccation (Cogliastro et al., 1997). Poor growth was observed for *A. saccharum* when situated on an elevated rise with no windbreak, even though the site had moderately well drained soil thus preventing “wet feet”.

Effect of wind on leaf size has been documented (Niklas, 1996). The influence of mechanical stimulation on the properties of mature *Acer saccharum* leaves was clearly discernible. Leaves harvested from a sapling growing in a windy site were smaller in every measured respect compared with their closed site counterparts.

In a study conducted in northwest Connecticut (Finzi and Canham, 2000), six species under varying light and nitrogen (N) conditions were evaluated. Only red maple (*Acer rubrum* L.) and sugar maple (*Acer saccharum*) showed growth rates significantly related to N availability, where N availability increased sugar maple growth under low light but did not change growth under high light (Finzi and Canham, 2000). Twenty-five percent or less of the variation in sugar maple sapling growth was attributed to variation in light availability and nitrification.

Roadside sugar maple trees in urban areas suffer localized root mortality due to severely limited infiltration rates and gaseous exchange in devegetated and compacted soils along roadways (Ruark et al., 1983). These adverse conditions are most common along roadsides in northern latitudes where salt is used to melt snow. After several years the ground succumbs to these adverse conditions and the site is denuded. Surface soil crusts may develop from raindrop impact as well as physical trampling of this devegetated soil (Ruark et al., 1983). However, roadside conditions in southern climes might be more accommodating to sugar maple because of the lessened frequency of salt application. This needs further study.

Close et al. (1996) conducted a study demonstrating the sensitivity of sugar maple to water deficits. Pair (1993) has shown that certain cultivars of sugar maple have a greater tolerance to drought stress.

Few studies have evaluated sugar maple response to insect damage. Damage from pear thrips (*Taeniothrips inconsequens* Uzel) has been noted on sugar maple (Gale Group, 1992). The tiny, comma-sized insect bores into the buds where the tender, folded leaves are vulnerable. In 1988 pear thrips caused the defoliation of a half million acres of maple forest in Vermont.

Damage to landscape trees from Japanese beetles (*Popillia japonica* Newman) has increased dramatically in recent years in the Southeast (Pettis et al., 2005). The southern movement of Japanese beetles has been documented (NAPIS, 2003), creating a need to determine Japanese beetle feeding preferences for the landscape (Gu et al., 2005; Held, 2004; and Stafne et al., 2005). The most comprehensive study to date (Held, 2004) on susceptibility to Japanese beetle across a wide range of woody landscape plants noted that some species of *Acer* have demonstrated resistance to Japanese beetle. However, distinction of cultivar specific resistance for *A. saccharum* selections was not a part of the study (Held, 2004).

Experiments were conducted in Griffin, GA to evaluate the suppression of naturally occurring Japanese beetles and crapemyrtle aphids (*Tinocallis kahawaluokalani* Kirkaldy) on containerized ‘Muskogee’ crapemyrtles (*Lagerstroemia* spp.) (Pettis et al., 2005). Both a field trial and a screen house trial were conducted. Eleven insecticides were evaluated in the field trial and seven insecticides were evaluated in the screen house trial. Greatest reduction in Japanese beetle damage was evident with Talstar (bifenthrin) and Scimitar (lambda-cyhalothrin). Additionally, Tame (fenpropathrin), a synthetic pyrethroid, resulted in moderate to good control of both Japanese beetle and crapemyrtle aphid. Whether these same insecticides might prove useful in the suppression of Japanese beetle on *A. saccharum* is yet to be determined.

Sugar maples are among the more valued landscape trees throughout the United States due to fall color, crown shape, and relatively few disease or pest problems.

However, most cultivars have been selected for traits other than stress and insect tolerance. For example, 'Sweet Shadow Cut-Leaf' has the most unusual leaf shapes of any sugar maple in the marketplace. The species has also been noted to have larger leaves from more northern climes than those populations found in the southern part of the native range (Desmarais, 1952). Many criteria are used to evaluate a tree's landscape value. In the future, one of the great concerns for homeowners will be pest tolerance. Determination of suitable sugar maple selections for the Southeast with regard to insect feeding preference in addition to growth and environmental response will provide valuable information for producers and the landscape industry.

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CHAPTER II

PERFORMANCE OF SUGAR MAPLE TAXA IN NORTH ALABAMA

Abstract: A sugar maple (*Acer saccharum* Marsh.) variety trial was initiated in March 1999 at the North Alabama Horticulture Substation in Cullman, Ala. (USDA Cold Hardiness Zone 7). The purpose of the study was to identify superior sugar maple selections for landscape use in the Southeastern region of the United States, to evaluate growth (height and caliper increase), foliage characteristics (mean leaf area, petiole length, and chlorophyll content), and determine tolerance to the Japanese Beetle (*Popillia japonica* Newman). The study includes 19 named sugar maple cultivars planted on a 6.1 m x 6.1 m (20 ft x 20 ft) spacing and fertilized with 59 g of nitrogen (N), 25 g of phosphorus (P), and 49 g of potassium (K) as 13N – 5.6P_2O_5 – 10.8K_2O (13-13-13) per 2.54 cm (1 inch) of diameter (caliper) at planting and in subsequent years in the winter months prior to budbreak. The 19 cultivars (‘Astis’ (Steeple™), ‘Autumn Faith’, ‘Autumn Blush’, ‘Barrett Cole’ (Apollo™), ‘Bonfire’ (Bonfire™), ‘Commemoration’, ‘Endowment’, ‘Fairview’ (Fairview™), ‘Fall Fiesta’ (Fall Fiesta™), ‘Flax Mill Majesty’, ‘Goldspire’, ‘Green Mountain’, ‘Legacy’, ‘Morton’ (Crescendo™), ‘Reba’ (Belle Tower™), ‘Seneca Chief’, ‘Sugar Queen’, ‘Sweet Shadow Cut-Leaf’, and ‘Moraine’ (Wright Brothers™); and three sugar maple seedling selections (from A. McGill and Sons Nurseries, Gervais, OR; Ellenburg Nursery, Baileyton, AL; and J. Frank Schmidt and Son Nurseries, Boring, OR) provide the largest collection of sugar maple germplasm

in the United States. ‘Seneca Chief’ had the greatest annual average height increase at 73.41 cm (28.9 in.) per year while the ‘Barrett Cole’ (Apollo™) cultivar had the least annual height increase at 14.22 cm (5.6 in.). The largest caliper increase was measured in Ellenburg, a southern seedling source at a 1.35 cm (0.5 in.) annual increase. Two cultivars (‘Barrett Cole’ (Apollo™) and ‘Endowment’) had the smallest caliper increase at 0.64 cm (0.25 in.) and 0.66 cm (0.26 in.), respectively. ‘Goldspire’ and the A. McGill seedling selection had the largest leaves followed closely by cultivar ‘Green Mountain’. ‘Commemoration’ had the smallest leaves. ‘Green Mountain’ had the longest petioles at 13.1 cm (5.2 in.). ‘Morton’ (Crescendo™) had the shortest petioles at 6.7 cm (2.6 in.). ‘Barrett Cole’ (Apollo™), ‘Autumn Blush’ and ‘Reba’ (Belle Tower™) had the least damage from Japanese Beetle, neither cultivar having any visible beetle damage. ‘Fairview’ ranked last with the greatest Japanese Beetle damage in our study with 2.8 from a possible 3.0 damage rating. ‘Sweet Shadow Cut-Leaf’, with the most distinctive leaf of any selection in the study also had the highest chlorophyll content as determined by the SPAD-502 Leaf Greenness Meter. Using a Rating Index, the top five selections in our study were Green Mountain®, ‘Reba’ (Belle Tower™), ‘Autumn Blush’, ‘Sugar Queen’ and ‘Bonfire’ (Bonfire™). The selections with the poorest performance in our study, to date, were ‘Barrett Cole’ (Apollo™), ‘Fairview’ (Fairview™), ‘Commemoration’, ‘Legacy’, ‘Morton’ (Crescendo™), and ‘Moraine’ (Wright Brothers™). This study is the first to report on performance of sugar maples as a landscape tree in the Southeastern United States.

Introduction

Demand for ornamental plants and trees for use in private landscapes is a multimillion-dollar business. Suppliers of landscape materials providing consumers with hardy, insect and disease resistant, and aesthetically pleasing ornamental plants and trees fill a market niche that has explosive financial potential. Sugar maple (*Acer saccharum*) is considered a prime selection as a home landscape tree due to its characteristic lush canopy, vibrant autumn foliage, and distinctive bark (Ball, 2001). While over thirty named cultivars of *A. saccharum* have been selected (Dirr, 1998; van Gelderen et al., 1994), no southern selection is a dominant choice in the marketplace. Identification of superior cultivars in the southeast presents opportunities for an expansion of sugar maple production and landscape use in the region. Expansion of this market into new geographical areas will mean more potential profits for nurseries seeking to meet the consumer demand.

Taxonomy and Growth Habit

The species *Acer saccharum* belongs to the Aceraceae family of the order Sapindales of the Magnoliophyta division. Native to North America, sugar maple is a large tree averaging from 60 feet to 100 feet in height, with a trunk diameter from 2 to 4 feet. Sugar maple has a large, lush canopy measuring 40 feet to 60 feet in width and offering vibrant fall foliage. Although sugar maple is a hardwood and resistant to storm damage, this species prefers well-drained soils and is not generally tolerant of crowded or polluted conditions (Dirr, 1998; Radford et al., 1968). The effects of acid rain in Eastern Canada and the Northeastern United States on sugar maple physiology, growth, and foliar nutrient concentrations have been studied (Hogan, 1998; Laurence et al., 1996).

Although there are several cultivars with marketable names, *A. saccharum* has not been evaluated extensively as a landscape ornamental tree in the Southeastern United States and limited information is available regarding the suitability of various sugar maple cultivars in this region (St. Hilaire and Graves, 1999). Observations conducted in the Sipsey Wilderness in Northwestern Alabama ranked *A. saccharum* as one of the top ten ecological species based on basal area (Zhang et al., 1999). Stomatal conductance models for sugar maple have been studied on trees in Vermont (Yang et al., 1998). However, at present, there are no reports for cultivar evaluations for landscape use in Alabama and the Southeast, and therefore there is no basis for promoting any particular cultivar in Southeast USDA Zones 7 to 8. Previous research of growth and development of *A. saccharum* has been limited to stands in the northern United States and in southern Canada. Currently almost all sugar maples available in the United States have been selected outside of the Southeastern United States and are sold as seedlings or cultivars budded onto seedling rootstock.

Japanese Beetle predation is a critical factor in the selection of sugar maples for landscape use. Although damage to landscape trees from Japanese beetles (*Popillia japonica*) has increased dramatically in recent years in the Southeast (Pettis et al., 2005), no study to date to has determined cultivar specific resistance to Japanese Beetle for *A. saccharum* selections. The southern movement of Japanese beetles has been documented (NAPIS, 2003), creating a need to determine Japanese beetle feeding preferences for the landscape (Gu et al., 2005; Held, 2004; and Stafne et al., 2005).

Experiments were conducted in Griffin, GA to evaluate the suppression of naturally occurring Japanese beetle (*Popillia japonica*) and crapemyrtle aphid (*Tinocallis* *kahawaluokalani* Kirkaldy) on containerized 'Muskogee' crapemyrtles (*Lagerstroemia* spp.) (Pettis et al., 2005). Both a field trial and a screen house trial were conducted. Eleven insecticides were evaluated in the field trial and seven insecticides were evaluated in the screen house trial. Greatest reduction in Japanese beetle damage was evident with Talstar (bifenthrin) and Scimitar (lambda-cyhalothrin). Additionally, Tame (fenpropathrin), a synthetic pyrethroid, resulted in moderate to good control of both Japanese beetle and crapemyrtle aphid. Whether these same insecticides might prove useful in the suppression of Japanese beetle on *A. saccharum* is yet to be determined.

The most comprehensive study to date (Held, 2004) on susceptibility to Japanese beetle across a wide range of woody landscape plants noted that some species of *Acer* have demonstrated resistance to Japanese beetle. However, distinction of cultivar specific resistance for *A. saccharum* selections was not a part of the study (Held, 2004).

Objectives

The objectives of this research were to identify superior cultivars of *Acer saccharum* for landscape use in the Southeastern region of the United States, to evaluate growth and foliage characteristics of these cultivars, and to determine their tolerance to the Japanese Beetle. This research will help provide a basis for selecting sugar maple cultivars for nursery production and landscape use in the Southeast.

Significance

Expansion of the geographical market for sugar maple (*Acer saccharum*) into the Southeastern United States holds the potential of great financial profits for the landscape industry. The native range of sugar maple, which extends southward from Southern Canada and the Northeastern and North-central United States to as far south as 35 degrees north latitude (Flint, 1997), limits or excludes sugar maple production and sales in the major cities of the Southeastern United States. The identification of superior cultivars of *A. saccharum* for landscape use in the Southeast will enable growers to offer consumers in this region the opportunity to include one of the dominant trees of the deciduous forests of such states as New York, Vermont, West Virginia, and Wisconsin in southern landscapes (Calabrese, 1993).

Height growth is an important indicator of overall health and viability of the selection, as well as an important consideration in tree placement within the landscape. Sugar maple is a large tree when mature and a suitable physical location must provide room for a large canopy of up to 60’ and an eventual height of up to 100’ (Dirr, 1998; Radford et al., 1968). Consumers desiring to purchase a tree that will provide shade relatively quickly will prefer selections that have faster growth rates. Census surveys show that the average tenure of residence for U.S. homeowners is only about 7 years (Schachter and Kuenzi, 2002). An ornamental landscape tree with a faster growth rate will likely be more appealing to many homeowners who want to plant sugar maple in their landscape but who will not likely be living in the same location when the tree reaches maturity. Their preference will be for faster growing selections that will provide shade in the summer and color in the fall in the shortest possible time.

Caliper growth is important both as an indicator of overall health and viability of the selection, and because stronger trunk structures are more stable in windy conditions. Sugar maple use in areas where there is exposure to drying winds may be limited due to its sensitivity to desiccation (Cogliastro et al., 1997). Poor growth was observed for *A.*

saccharum when situated on an elevated rise with no windbreak, even though the site had moderately well drained soil thus preventing “wet feet”.

Leaf area is an important factor for the tree’s ability to photosynthesize. By exposing more leaf surface area to sunlight, larger leaves contribute to the tree’s ability to convert sunlight energy into usable chemical energy. The effect of wind on leaf size has also been documented (Niklas, 1996). Leaf characteristics have long been broadly used as diagnostic characters in the genus *Acer* (Desmarais, 1952). This very common and variable tree has attracted the attention of many taxonomists and since 1753 it has been described under not less than 17 specific, 18 varietal, and 18 formal names in more than 97 different combinations (Desmarais, 1952).

Leaf area and petiole length also influence aesthetic differences among selections. The leaf itself is the character that shows the most striking variations and therefore is used most predominately as a reference point when describing the range, viability and distribution of *Acer* (Desmarais, 1952). While subjective, larger leaves and longer petioles could potentially offer aesthetically induced preference for one selection over another. Larger leaves contribute to canopy size, shape and fullness, as well as to fall color, thereby making selections with larger leaves preferable to those who consider these factors important. This preference, however, is nullified if the leaves are so large that they cause the tree to be more susceptible to wind damage because of canopy resistance to wind.

Longer petioles contribute to the overall beauty of the tree canopy by placing the leaves further from the limb thereby allowing the leaves more freedom to move in light winds. Short petioles make the tree look stiff and less attractive. Therefore longer petioles are desirable for aesthetic reasons. Cultivars like ‘Autumn Blush’, which exhibit striking red petioles in the summer, take advantage of longer petioles, making the tree’s appearance more aesthetically appealing. The combination of colorful and longer petioles give ‘Autumn Blush’ a shimmering appearance that makes it commercially appealing for both homeowners and landscape professionals.

Materials and Methods

This field trial was initiated in March, 1999 at the North Alabama Horticultural Substation in Cullman, Ala. (USDA Cold Hardiness Zone 7, Latitude 34° 19’ x Longitude 86° 8’) in a Hartsell Fine Sandy Loam soil. Trees were arranged in a completely randomized design on a 20 foot x 20 foot spacing. The 1999 installation included 13 sugar maple selections (‘Astis’ (Steeple™), ‘Autumn Blush’, ‘Bonfire’ (Bonfire™), ‘Commemoration’, ‘Fairview’ (Fairview™), ‘Fall Fiesta’ (Fall Fiesta™), ‘Goldspire’, ‘Green Mountain’, ‘Legacy’, and ‘Sweet Shadow Cut-Leaf’; and three sugar maple seedling selections (from A. McGill and Sons Nurseries, Gervais, OR; Ellenburg Nursery, Baileyton, AL; and J. Frank Schmidt and Son Nurseries, Boring, OR). Five additional selections were added to the study in 2001 (‘Autumn Faith’, ‘Endowment’, ‘Flax Mill Majesty’, ‘Sugar Queen’, ‘Moraine’ (Wright Brothers™)), three additional selections were added in 2003 (‘Barrett Cole’ (Apollo™), ‘Morton’ (Crescendo™), ‘Seneca Chief’) and one additional selection was added in 2006 (‘Reba’ (Belle Tower™)), to conclude with a total of 22 selections, with 19 of about 32 named cultivars and 3 seedling sources. All trees were fertilized with 59 g of nitrogen (N), 25 g of phosphorus (P), and 49 g of potassium (K) as $13N – 5.6P_2O_5 – 10.8K_2O$ (13-13-13) per 2.54 cm (1 inch) of diameter (caliper) at planting and in subsequent years in the winter months prior to budbreak. Trees were irrigated at planting and on an as-needed basis. Maple tip borer and other insect pests, excepting Japanese Beetle, were controlled as needed with appropriate chemicals.

Height and caliper were measured at planting and after each growing season in December at one foot above the soil line in a North:South transect (Table 1; Table 2).

Leaf area was determined using a Transparent Belt Conveyor Accessory Leaf Area Meter, LI-COR Model LI-3050A (Li-COR Inc., Lincoln, Neb.). Ten fresh leaves were harvested at random from each tree in June, 2006. Leaves were transported in a cooler to a lab at Auburn University where total leaf area and petiole length from the base of the leaf to the end of the peduncle measurements were determined (Table 3).

A single SPAD-502 Chlorophyll Meter (Minolta Camera Co., Ltd., Japan) was used to assess leaf greenness in June, 2006. Three measurements were taken on leaves for each of the 10 trees of each selection in an arbitrary and nondestructive manner while still attached to the tree (Table 3).

Resistance to Japanese Beetle (*Popillia japonica*) was evaluated in July 2004, 2005 and 2006 based on a rating for each treatment with a 0 to 3 scale where 0 = 0 to 24% injury, 1 = 25 to 49% injury, 2 = 50 to 74% injury, and 3 = 75 to 100% injury. A visual inspection of Japanese Beetle damage was assessed subjectively because more objective measurements would have required further stress to the trees when obtaining physical samples. All 22 selections in the trial were ranked, with lower rankings indicating less predation or more resistance (Table 4).

Statistical analysis was carried out as a one-way analysis of variance (ANOVA) using the GLM procedure of SAS (SAS Version 9.1, Cary NC), with multiple comparisons made using the Waller-Duncan Test at $P = 0.05$. A summary variable, Rating Index, was calculated for each tree as the mean of the standardized values of the six variables of Height Increase, Caliper Increase, SPAD values, Leaf Area, Petiole Length, and Japanese Beetle Damage with the exception of 'Reba' (Belle Tower™) for which Height Increase and Caliper Increase were not included (Table 5). Values were standardized by subtracting the overall mean for the specific variable from the data value and dividing this difference by the standard deviation (square root of the mean squared error).

Results and Discussion

Final height measurements were taken in 2006 and compared to measurements taken in 1999. The Ellenburg southern seedlings had the tallest final height, however, 'Seneca Chief' had the singularly largest average height increase at 73.41 cm (28.9 in.) per year followed by Bonfire™ at an average height increase of 54.61 cm (21.5 in.) per year (Table 1). Other good height increase performers were the Ellenburg seedlings, the J. Frank Schmidt seedlings, Steeple™, and 'Sweet Shadow Cut-Leaf' (Table 1), all with an average height increase of about 45.72 cm (18 in.) a year. Although these four selections had average height increases statistically similar with each other and to Bonfire™, they were statistically dissimilar to 'Seneca Chief' and these four selections occupy a second tier with 'Seneca Chief' occupying the sole position on the first tier as the statistically unique selection with the best height increase performance. The least average height increase was with 'Barrett Cole' (Apollo™) with an average height increase of 14.22 cm (5.6 in.), and while different from other selections would not be considered different than 'Endowment' at 21.34 cm (8.4 in.) per year and Crescendo™ at 21.84 cm (8.6 in.) of height growth per year (Table 1).

Final caliper measurements were taken in 2006 and compared to measurements taken in 1999. The Ellenburg southern seedlings had both the largest final caliper measurement and the largest average caliper increase source at 1.35 cm (0.5 in.) annual increase during the course of the field study. Average caliper increase for 'Autumn Blush', 'Commemoration', Fairview™, Fall Fiesta™, 'Morton' (Crescendo™), and 'Seneca Chief' was statistically similar to that for Ellenburg Southern seedlings (Table 2). Cultivars 'Barrett Cole' (Apollo™) and 'Endowment', had the smallest caliper increase at 0.64 cm (0.25 in.) and 0.66cm (0.26 in.), respectively.

'Sweet Shadow Cut-Leaf', 'Autumn Faith', Green Mountain®, and 'Reba' (Belle Tower™) had the highest chlorophyll content as determined by the SPAD-502 Leaf Greenness Meter (Table 3). While SPAD units are not standard across all species, comparisons can be made within a species. As such, 'Autumn Faith', Green Mountain®, and 'Reba' (Belle Tower™), all with chlorophyll levels of about 39 were 40% greener than the Ellenburg seedlings, the least green trees in the study with relative chlorophyll levels of 27.8.

'Goldspire' and the A. McGill seedling selections had the largest mean leaf area, each at 110.9 cm^2, and followed closely by Green Mountain® at 107.5 cm^2 (Table 3). Others that had statistically similar mean leaf areas to Green Mountain® were 'Autumn Faith', 'Endowment', and the J. Frank Schmidt seedlings. The smallest leaves were recorded for 'Commemoration' at 47.7 cm^2, with 'Legacy' only slightly larger at 54.8 cm^2.

The longest mean petiole length measured was for Green Mountain® at 13.1 cm (5.2 in.) (Table 3). Statistically similar petiole lengths were measured for ‘Autumn Faith’, ‘Autumn Blush’, Bonfire™, ‘Goldspire’, and the J. Frank Schmidt seedlings (Table 3). Although not different than ‘Barrett Cole’ (Apollo™), ‘Commemoration’, ‘Legacy’, ‘Sweet Shadow Cut-Leaf’, and ‘Moraine’ (Wright Brothers™), ‘Morton’ (Crescendo™) had the shortest petioles at 6.7 cm (2.6 in.).

Japanese Beetle predation was highly selective and cultivar-specific in our field study (Table 4). Some selections, like ‘Green Mountain’, remained virtually untouched while other selections immediately adjacent, like the J. Frank Schmidt seedlings, were virtually stripped of their leaves. Neither ‘Barrett Cole’ (Apollo™), ‘Autumn Blush’ nor ‘Reba’ (Belle Tower™), suffered any visible damage from Japanese Beetle. Although several other cultivars/selections had statistically similar damage to ‘Barrett Cole’ (Apollo™), ‘Autumn Blush’ and ‘Reba’ (Belle Tower™), ‘Sugar Queen’ was the only other cultivar that had less than a 0.15 damage rating.

‘Fairview’ suffered the most damage from Japanese Beetles, with a 2.8 damage rating from a possible 3.0 (Table 4). ‘Fairview’ trees were almost completely stripped of all leaves, as were those of the slightly less damaged selection ‘Seneca Chief’. ‘Goldspire’, ‘Commemoration’, and the A. McGill and J. Frank Schmidt seedlings were also very susceptible to Japanese Beetle in our study. Although ‘Goldspire’ had the favorable characteristic of large leaves, it also was one of the least resistant to damage from Japanese Beetle. This information would be very valuable to nursery suppliers as well as to consumers intent on purchasing a sugar maple tree for long-term use in their landscape.

A summary variable, Rating Index, was calculated for each tree as the mean of the standardized values of the six variables of Height Increase, Caliper Increase, SPAD values, Leaf Area, Petiole Length, and Japanese Beetle Damage, with the exception of 'Reba' (Belle Tower™) for which Height Increase and Caliper Increase were not included (Table 5). Using this Rating Index, the top five selections in our study were Green Mountain[R], 'Reba' (Belle Tower™), 'Autumn Blush', 'Sugar Queen' and 'Bonfire' (Bonfire™). The selections with the poorest performance in our study, to date, were 'Commemoration', 'Morton' (Crescendo™), and 'Moraine' (Wright Brothers™).

Green Mountain[R] introduced by Princeton Nurseries in 1964 (van Gelderen et al, 1994) has a long history in the nursery trade with reliable fall color and broadly pyramidal growth habit. 'Reba' (Belle Tower™) is a new release (2006) from J. Frank Schmidt & Son Nursery selected by Jeff Sibley that originated from a population in Pulaski, Tennessee. The parent tree is located in Mt. Hope, Ala. (USDA Hardiness Zone 7) and has a fastigate growth habit and yellow-gold fall color. 'Autumn Blush', another cultivar selected by Jeff Sibley has not yet been released to the trade. The original tree was planted in Southeast Alabama on the Auburn University Campus in 1962 (USDA Hardiness Zone 8) and was noted to have orange-red fall color and a broader than tall growth habit. 'Sugar Queen' was introduced by John Holmlund Nursery in Boring, Oregon about 1995. 'Sugar Queen' has attractive foliage with the lobes curling downward to almost have a teardrop appearance. However, in our study 'Sugar Queen' has been prone to leaf scorch. 'Bonfire' (Bonfire™) was released by J. Frank Schmidt & Son Nursery in about 1965 (van Gelderen et al, 1994) and has performed well in a variety of climatic conditions. Bonfire™ has an upright form, is a vigorous grower and typically has orange-red fall color.

Conclusions

Many criteria are used to evaluate a tree's landscape value. Sugar maples are among the more valued landscape trees throughout the United States due to fall color, crown shape, and relatively few disease or pest problems. However, most cultivars have been selected for traits other than stress and insect tolerance. For example, 'Sweet Shadow Cut-Leaf' has the most unusual leaf shape of any sugar maple in the marketplace. The species has also been noted to have larger leaves, typical of selections from more northern climes than those populations found in the southern part of the native range (Desmarais, 1952). In the future, one of the great concerns for homeowners will be pest tolerance. Determination of suitable sugar maple selections for the Southeast with regard to insect feeding preference in addition to growth and environmental response will provide valuable information for producers and the landscape industry.

Further Research

This study is the first to report on performance of sugar maples as a landscape tree in the Southeastern United States. The study offers the landscape industry additional data that will help producers and consumers make informed choices when choosing sugar maple selections for landscape applications in the Southeast. Still, further research needs to be done so that nurseries and homeowners can continue to make more informed landscape choices. Differences in fall coloration among specific cultivars can be a determining factor for cultivar selection in landscapes where sugar maple thrives.

Information on growth, pest resistance, viability, heat tolerance and required chilling to satisfy rest are additional criteria in need of evaluation in the Southeastern United States.

Studies have shown sugar maple to have an obligate chilling requirement, and therefore the species typically will only have one flush of growth in a growing season (Wood and Hanover, 1981). Sugar maple has difficulty thriving in urban bricked walkways (Schwets and Brown, 2000). Although *Acer saccharum* survived for up to 25 years when planted in a brick walkway, the surviving trees had lower canopy densities, higher amounts of twig die-back, and smaller canopy widths compared to trees planted in turfed areas, which performed better and were able to maintain form and structure. Those planted in a bricked walkway were more open-canopied and ragged in appearance when compared to those grown in turfed areas (Schwets and Brown, 2000). Research to determine appropriate selections for these environments would be helpful.

A buried-pot study of 2-year-old sugar maple seedlings conducted in the northeastern United States to test how liming influences growth and nutrient balances of this species showed a 37% larger growth than control seedlings when the treatments were incorporated into the soil (Burke and Raynal, 1998). However, seedlings that received surface lime treatments were 9% smaller than control seedlings. Seedlings for this study were planted on May 9 and were harvested on August 30 of the same year. There is little information on the long-term effects of liming for *A. saccharum*.

Further study and clarification of these and other criteria will give nursery providers and consumers in the Southeastern United States more confidence that their incorporation of *Acer saccharum* in the southern landscape will result in long-term success and sustainable market growth for sugar maple outside its native growing range.

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Table 1. Final height and average annual height increase for sugar maple selections in a North Alabama field trial.[Z]

Selection	Final Height		Average Height Increase	
A. McGill Seedling	189.00	cde[Y]	16.71	de
Autumn Faith	118.67	i	11.73	ghi
Autumn Blush	193.22	bcd	17.32	cde
Barrett Cole (Apollo™)	52.89	k	5.63	j
Bonfire™	210.25	ab	21.46	b
Commemoration	179.38	cdef	15.34	defg
Ellenburg Southern Seedling	216.56	a	20.65	bc
Endowment	90.00	j	8.40	ij
Fairview™	188.90	cde	16.70	de
Fall Fiesta™	180.00	cdef	17.14	cde
Flax Mill Majesty	132.00	hi	14.40	efgh
Goldspire	172.50	def	16.07	def
Green Mountain[R]	175.44	def	14.78	efg
J. Frank Schmidt Seedling	184.70	cde	17.81	bcde
Legacy	160.30	fg	12.61	fgh
Morton (Crescendo™)	61.70	k	8.57	ij
Seneca Chief	146.78	gh	28.93	a
Steeple™	198.25	abc	18.04	bcde
Sugar Queen	147.57	gh	17.51	cde
Sweet Shadow Cut-Leaf	169.17	ef	19.02	bcd
Wright Brothers	113.44	i	10.69	hi

[Z] Planting of accessions began in March 1999 with growth measured in inches annually in December.
[Y] Values within columns followed by the same letter are considered different based on mean separation by Waller-Duncan's Multiple k ratio t-Test at 0.05.

Table 2. Final caliper and average annual caliper increase for sugar maple selections in a North Alabama field trial.[Z]

Selection	Final Caliper		Average Caliper Increase	
A. McGill Seedling	3.00	def[Y]	0.36	bcdefghi
Autumn Faith	1.83	hi	0.29	fghi
Autumn Blush	3.39	bcd	0.42	abc
Barrett Cole (Apollo™)	1.08	J	0.25	i
Bonfire™	3.30	cde	0.37	bcdefgh
Commemoration	3.72	bc	0.46	ab
Ellenburg Southern Seedling	4.20	a	0.53	a
Endowment	1.70	hi	0.26	hi
Fairview™	3.27	cde	0.40	bcdefg
Fall Fiesta™	3.81	ab	0.42	abcd
Flax Mill Majesty	2.04	h	0.33	cdefghi
Goldspire	2.64	F	0.30	defghi
Green Mountain[R]	3.24	de	0.40	bcdef
J. Frank Schmidt Seedling	2.85	ef	0.33	cdefghi
Legacy	3.21	de	0.40	bcdef
Morton (Crescendo™)	1.43	ij	0.41	abcde
Seneca Chief	1.66	hi	0.42	abc
Steeple™	3.30	cde	0.37	bcdefghi
Sugar Queen	2.11	gh	0.34	cdefghi
Sweet Shadow Cut-Leaf	2.55	fg	0.30	efghi
Wright Brothers	1.80	hi	0.28	ghi

[Z]Planting of accessions began in March, 1999 with growth measured in inches annually in December.
[Y]Values within columns followed by the same letter are considered different based on mean separation by Waller-Duncan's Multiple k ratio t-Test at 0.05.

Table 3. Chlorophyll content, mean leaf area and mean petiole length for sugar maple selections in a North Alabama field trial.[Z]

Selection	Chlorophyll content (SPAD)		Mean Leaf Area (cm^2)		Mean Petiole Length (cm)	
A. McGill Seedling	28.0	gh[Y]	110.85	a	10.8	bcde
Astis (Steeple™)	29.3	fgh	82.35	cdefg	9.6	def
Autumn Faith	39.4	a	92.67	bcd	11.2	abcd
Autumn Blush	31.8	cdef	90.67	cde	12.1	ab
Bailsta (Fall Fiesta™)	32.0	bcdef	87.29	cdef	10.0	cdef
Barrett Cole (Apollo™)	34.5	bc	71.70	ghij	8.2	fghij
Bonfire™	32.8	bcde	65.73	hijk	11.7	abc
Commemoration	31.2	defg	47.70	l	7.3	ghij
Ellenburg Southern Seedling	27.8	h	89.80	cde	9.5	def
Endowment	31.2	defg	94.29	bc	9.3	defg
Fairview™	30.5	defgh	78.00	defghij	9.6	def
Flax Mill Majesty	31.2	defg	77.10	efghij	10.2	bcdef
Goldspire	31.0	defgh	110.89	a	12.1	ab
Green Mountain®	38.5	a	107.53	ab	13.1	a
J. Frank Schmidt Seedling	29.9	efgh	93.02	bcd	11.2	abcd
Legacy	33.7	bcd	54.78	kl	6.9	ij
Morton (Crescendo™)	33.6	bcd	63.40	k	6.7	j
Reba (Belle Tower™)	38.4	a	79.94	cdefghi	8.8	efghi
Seneca Chief	29.9	efgh	65.20	ijk	9.0	efgh
Sugar Queen	32.5	bcdef	81.46	cdefg	10.3	bcdefg
Sweet Shadow Cut-Leaf	35.1	b	80.38	cdefgh	7.0	hij
Wright Brothers	29.7	efgh	72.64	fghi	8.1	fghij

[Z] Planting of accessions began in March 1999 with measurements taken in June and July 2006.
[Y] Values within columns followed by the same letter are considered different based on mean separation by Waller-Duncan's Multiple k ratio t-Test at 0.05.

Table 4. Japanese beetle feeding preference among sugar maple selections in a North Alabama field trial.[Z]

Selection	Damage Rating[Y]	Rank[X]
Barrett Cole (Apollo™)	0.00 a	1
Autumn Blush	0.00 a	1
Reba (Belle Tower™)	0.00 a	1
Sugar Queen	0.14 ab	2
Legacy	0.30 abc	3
Autumn Faith	0.40 abc	3
Bonfire (Bonfire™)	0.50 abcd	4
Ellenburg, Southern Seedling	0.70 abcd	4
Astis (Steeple™)	0.75 bcd	5
Bailsta (Fall Fiesta™)	0.78 bcd	5
Green Mountain (Green Mountain®)	0.80 bcde	6
Sweet Shadow Cut-Leaf	0.80 bcde	6
Morton (Crescendo™)	0.90 cde	7
Endowment	1.00 cde	7
Flax Mill Majesty	1.14 def	8
Wright Brothers (formerly 'Moraine')	1.14 def	8
Goldspire	1.50 efg	9
A. McGill Seedling	1.78 fg	10
Commemoration	1.88 g	11
J. Frank Schmidt Seedling	1.90 gh	12
Seneca Chief	2.60 hi	13
Fairview (Fairview™)	2.80 i	14

[Z] Evaluations made in July 2004, 2005 and 2006 in a sugar maple field trial in Cullman, Alabama (USDA Hardiness Zone 7) planted from 1998 to 2006. Data presented is from 2004.
[Y] Rating determined on a 0 to 3 scale where 0 = 0 to 24% injury, 1 = 25 to 49% injury, 2 = 50 to 74% injury, and 3 = 75 to 100% injury. Rating followed by mean separation by Waller-Duncan's Multiple k ratio t-Test at 0.05.
[X] All 22 selections in the trial were ranked, where 1 is least damaged and 14 is most damaged tree.

Table 5. Growth and quality summary rating index for sugar maple field trial in Cullman, Alabama (USDA Hardiness Zone 7) planted from 1998 to 2006.[Z]

Selection	Average Rating Index[Y]		Order[X]
Green Mountain (Green Mountain[R])	0.800	a	1
Reba (Belle Tower[TM])	0.692	ab	2
Autumn Blush	0.654	abc	3
Sugar Queen	0.404	abcd	4
Bonfire (Bonfire[TM])	0.354	abcde	5
Ellenburg, Southern Seedling	0.313	bcde	6
Autumn Faith	0.246	bcdef	7
Bailsta (Fall Fiesta[TM])	0.228	cdef	8
Goldspire	0.191	def	9
Sweet Shadow Cut-Leaf	0.095	defg	10
Seneca Chief	0.058	defg	11
Astis (Steeple[TM])	0.002	defgh	12
A. McGill Seedling	-0.048	efghi	13
J. Frank Schmidt Seedling	-0.078	efghij	14
Endowment	-0.162	fghij	15
Flax Mill Majesty	-0.201	fghij	16
Legacy	-0.289	ghijk	17
Barrett Cole (Apollo[TM])	-0.433	hijk	18
Fairview (Fairview[TM])	-0.446	ijk	19
Wright Brothers (formerly 'Moraine')	-0.480	ijk	20
Morton (Crescendo[TM])	-0.509	jk	21
Commemoration	-0.671	k	22

[Z] Rating index was calculated for each tree as the mean of the standardized values of the six variables of Height Increase, Caliper Increase, SPAD values, Leaf Area, Petiole Length, and Japanese Beetle Damage with the exception of ‘Reba’ (Belle Tower™) for which Height and Caliper were not included. Values were standardized by subtracting the overall mean for the specific variable from the data value and dividing this difference by the standard deviation (USDA Hardiness Zone 7) planted from 1998 to 2006.

[Y]Average Rating Index where values followed by the same letter are considered different based on mean separation by Waller-Duncan’s Multiple k ratio t-Test at 0.05.

[X] All 22 selections in the trial were ranked in order as most suitable to least suitable.