PERFORMANCE OF ELM TAXA IN AUBURN, AL

by

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Abstract

The National Elm Trial (NET) was started in 2005 by Colorado State University and has 16 sites in 15 states throughout the United States. The NET a collective effort to evaluate commercially available elms (*Ulmus* sp.) that have previously shown Dutch elm disease resistance. Fourteen cultivars were chosen by Colorado State University, and five more cultivars were added to the Auburn site. Five replications of each cultivar were planted on 25 May 2007 in a complete block design. Data collected for the Auburn elm trial included tree height, trunk diameter, crown width, fall color, and insect and disease pressure. *U.* 'Morton Red Tip', *U. americana* 'Lewis & Clark', *U.* 'New Horizon', *U. parvifolia* 'BSNUPF' were the largest across the three growth variables, and *U.* 'Morton Plainsman', *U.* 'Morton Glossy', and *U. propinqua* 'JFS- Bieberich' were the poorest performers with poor growth and survival rates.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Elms in the American Landscape

American elms (*Ulmus americana* L.) were once widely used in urban environments (Dirr, 2009). Elms lined the streets of many Midwestern and New England towns, but Dutch elm disease (DED) decimated many of the trees. By the late 1950's, in Illinois, almost 80 percent of the American Elms had succumbed to DED and had to be removed, reducing landscape value, shade, and ecosystem quality in many cities (Miller, 2002).

Historically, the American elm is one of the most prized trees in terms of form, vigor and toughness (Miller, 2000). By the 1920's in America, elm trees had become iconic in New England towns (Campanella, 2003). While European settlers may have made the elm tree popular, the native inhabitants of New England were the ones who shaped the landscape long before English immigrants. Native Americans used fire as their tool for clearing land. While they were somewhat selective about their burning, they could not as easily burn moist bottomlands as they could dry uplands. Since *Ulmus americana* originates in the moist bottomlands, they were left to mature because the fires could not reach them. Since elm trees were left in the forests, many Native American tribes found use for them. The bark was used in many different ways: for covering longhouses of the Huron, being used as canoes and rope by the Iroquois, for food

storage by the Algoquin, and medicinally by the Penobscot, Mohegans and Iroquois to treat many different ailments from internal bleeding to colds and coughs (Campanella, 2003).

As the European settlers moved into New England, they created open areas for better settlements and agriculture (Campanella, 2003). Initially, the settlers inhabited the clearings that the Native Americans had previously made, but when the pioneers realized that the soil in these areas had been depleted of its nutrients, they began clearing the bottomlands left alone by Native Americans. The pioneers soon realized that elms grew in rich soil, and anywhere elms were found was a good place to grow crops. Most farmers left the elms standing because they were usually not in the way and their timber was of low value. Elm wood was used by pioneers as hubs for cart wheels, flooring, and whips, but since it is tough and fibrous and takes a long time to dry out, it was not used by carpenters to make houses or other structures. Instead, elms were used by farmers as shade for livestock and as property boundary markers (Campanella, 2003).

As elm tree numbers grew, so did their popularity as a presence in the community for many New Englanders (Campanella, 2003). Elms were planted as domestic ornaments, shelter for homes during storms, and to mark weddings and births. Elms became centerpieces in towns and used to commemorate significant people, and historical events, and soon became commonplace in literature written about New England. Writers such as Henry David Thoreau, Nathanial Hawthorne, Charles Dickens, Henry Wadsworth Longfellow and Edith Wharton tried to capture the grandeur of the elm through their stories, poems, and plays (Campanella, 2003).

Dutch Elm Disease

DED was first detected in the United States in 1931 by Curtis May of the United States Department of Agriculture near Cleveland, OH and in Cincinnati, OH (Campanella, 2003). DED is caused by the fungus *Ophiostoma ulmi* (Buism.) Nannf. (Jeng, 1993). Three subpopulations of

the *O. ulmi* pathogen exist; the Eurasian (EAN), the North American (NAN), and a weak nonaggressive race. To separate the nonaggressive and aggressive groups of *O. ulmi*, the aggressive group was renamed *O. novo-ulmi* sp. nov (Brasier et al., 1993). DED had been spreading through Europe since 1918, and research to identify DED resistant elm cultivars began in the Netherlands in 1928 with funding from a private firm called Dutch Heath Company (Smalley et al., 1993). A fundraising group, Elm Disease Committee, took over research efforts soon after, and that group was eventually absorbed into the Government Forestry Research programs that began after World War II. In the beginning, researchers in the Netherlands were looking for cultivars to replace the Dutch elm (*U. hollandica* 'Belgica'), focusing on other European elms previously showing some DED resistance; more specifically, *U. glabra* and *U. carpinifolia*.

Elms have been an important part in the UK landscape since the sixteenth century (Potter et al., 2011). *U. procera*, the English elm, was planted at this time as a hedgerow tree, becoming a staple in the lowland rural landscape by the eighteenth century. DED was first discovered in the UK in the late 1920's. The mortality rate of DED outbreaks was only 20 percent up until 1969 when the disease became much more aggressive. Dieback was widely reported of *U. minor*, *U. procera*, and *U. glabra*, which were the European species researchers in the Netherlands focused on due to their DED resistance. After further study, researchers realized that the DED strain affecting the UK was in fact a more aggressive form that had been transmitted from North America. *O. ulmi* was the strain associated with the first outbreak of DED in the Netherlands and UK. The second more deadly strain that showed up in the 1970's and has since been killing elms in Europe and North America is the *O.novo-ulmi* strain (Brasier et al., 1993). More specifically, the EAN form of *O. novo-ulmi* was spread throughout Europe to the east and west in the 1940's.

Eventually, *O. novo-ulmi* was imported into North America in the Indiana/Illinois area, where it evolved into the NAN race. After the mutation, the more aggressive NAN form was introduced back into the UK around the 1960's, where it spread and eventually crossed paths with the EAN form. The second outbreak of DED in Great Britain in the 1970's followed typical disease spread: the initial phase built slowly, then increased rapidly as the disease spread, and finally slowed and trailed off once the host was eliminated. Researchers began breeding with the Asian elm *U. wallichiana* to add more DED resistant genes into the new cultivars (Potter et al., 2011).

Soon after the disease began to spread across the United States, many plant breeders and geneticists joined together to try to identify new elm species and/or hopefully discover new hybrids that would have increased DED resistance (Miller, 2002). When DED became prevalent in the United States, the USDA was pressured into providing funding for elm breeding and research. The Division of Forest Pathology, Bureau of Plant Industry, Soils and Engineering (now USDA, Nursery Crops Research) began research seeking DED and Elm Yellows resistant cultivars in 1937 (Smalley et al., 1993). However, this was not the first instance of research to identify DED resistant cultivars in the United States. An extensive collection of American elms, approximately 21,000 seedlings, were collected from the northern half of the elms geographic range and placed at a nursery in Yonkers, NY for data collection on DED resistance. One hundred sixty-eight of the surviving trees were moved to a nursery in Ithaca, NY, where research was conducted on the trees until 1965. Out of this research project, there were no good candidates for DED resistance. Since DED caused such disastrous effects throughout the United States, there became a need for genetically diverse cultivars (Slavicek and Knight, 2012). The main goals of elm researchers in the United States were to locate American elms that had resistance to DED and Eurasian elms that were pest-resistant and ornamentally valuable.

The major problem with trying to cross American elms with other elm species is that American elms have double the number of chromosomes as other elm species (Miller, 2002). With a total of 56 chromosomes, the American elm is the only tetraploid species in the genus (Santamour, 1993). In the beginning, attempts to cross a diploid Asiatic species with an American elm were unsuccessful, because of sexual incompatibility between the species. Breeding programs began using Asian elms as a source of disease and insect resistance, and they are now a major repository for disease resistant genes in elms (Smalley and Guries, 2000). Many Asian elms develop unwanted characteristics outside of their native climate and can succumb to cold damage in northern parts of the United States. Researchers have worked to cross American and Asian elm species in order to obtain desired cold hardiness of the American elm with the DED resistance of Asian elm species. Identification of American elm selections that have DED resistance is still a main focus, but since evaluating for actual DED resistance takes so long, researchers began using germplasm from the Asian elms *U. pumila* and *U. parvifolia*.

There has been much work to develop DED resistant cultivars, with DED-resistant American elms being the focus of research recently. In one study, 19 American elm cultivars and two non-American elm cultivars were inoculated with DED (Townsend et al., 2005). *U. americana* 'Valley Forge', *U. americana* 'Princeton', *U. americana* 'Delaware', and *U. americana* 'New Harmony' were determined to have the most DED tolerance. This confirmed another study done in 2001 on American elms with DED resistance (Townsend and Douglass, 2001). This study inoculated 8 American elm cultivars and two non-American elm cultivars, *U. wilsoniana* 'Prospector' and *U.* 'Frontier'. The trees were inoculated with DED and crown dieback and survival were recorded for 7 years after inoculation. In this study, *U. americana* 'Valley Forge', *U. americana* 'Princeton', *U. americana* 'New Harmony', and *U. americana*

'Delaware' were found to have the least amount of crown dieback and mortality. *U. wilsoniana* 'Prospector' and *U.* 'Frontier' also had DED-resistance comparable to the DED- resistant American elm cultivars.

There is a need for more landscape performance evaluations, particularly in the deep South, before elms can retake a prominent place in the landscapes of the United States. New cultivars are still being developed, creating a need for more laboratory testing, field evaluations, and sustainability studies (Miller, 2000). Also, a need exists for resistance and sustainability characteristics to be identified and preserved so that future elm breeding with these desirable traits can be kept. Many of the new cultivars need to be tested in different geographic areas before their performance can be reported (Townsend and Douglass, 2004). The case is the same for testing new cultivars for DED resistance and elm leaf beetle resistance. Once evaluated in different climate regimes, any problems with new cultivars can be backcrossed to get better results. Evaluation of site adaptation as well as the form and utility in the landscape is needed before homeowners and arborists will begin planting elms in abundance again (Kuser and Polanin, 2001).

National Elm Trial

In 2005, Colorado State University coordinated a multi-state effort to evaluate 17 commercially available elm cultivars in different climates and hardiness zones throughout the United States with 16 trial locations in 15 different states (Jacobi). It is recommended that all sites periodically record height, diameter, crown characteristics, fall color, response to vascular diseases, foliar diseases, scale insect infestations, foliar-feeding insect infestations, bark beetle infestations, and abiotic damages, including frost/freeze, wind, winter dieback, sunscald, and insufficient soil moisture. Trials are located at Auburn University, Colorado State University,

Iowa State University, Kansas State University, Michigan State University, North Dakota State Forest Service, North Dakota State University, Purdue University, Rutgers University, State University of New York, the USDA Forestry Service Pacific Southwest Region Station in Davis, California, University of Kentucky, University of Vermont, USDA Forest Service in West Lafayette, Indiana, Washington State University, and West Virginia University. Fourteen cultivars were specified by Colorado State University, while selections for the remaining three cultivars used in each trial site were left up to the local researchers. The objectives of the trial are to determine the growth and horticultural performance of commercially available DED-resistant elm cultivars in various climate regimes in the United States, to determine the relative disease, insect, and abiotic stress tolerance of these cultivars, and to promote the propagation and use of elms through local, regional, and national reporting of the trial results to wholesale tree propagators and growers, retail nursery and garden center operators, landscape designers, arborists, and the general public (Jacobi, 2015).

Of the 16 sites throughout the country, Iowa State University, University of Kentucky, and UC Davis have published reports of results as a part of the National elm trial. Iowa State University made recommendations based on best branch angles, best overall tree health and performance, and best leaf quality for central Iowa (Batzer and Gleason, 2013). *Ulmus* (*pumila* x *japonica* x *wilsoniana*) 'Morton Glossy' Triumph™ was the highest recommended cultivar. The next highest cultivars were *U.* (*pumila* x *japonica*) 'Morton Plainsman' Vanguard™ and *U.* (*carpinfolia* x *pumila* x *wilsoniana*) 'Morton Stalwart' Commendation™. *U.* (*carpinifolia* x *parvifolia*) 'Frontier' and *U. propinqua* 'JFS-Bieberich' Emerald Sunshine® are not recommended for central Iowa because of narrow branch angles, which in turn caused the branches to split. *U.* 'Frontier' also had sunscald on the trunks of 3 of the remaining 4 trees in the

trial. *U. americana* 'Princeton' and *U. americana* 'Lewis and Clark' Prairie Expedition® were some of the poorest performers, while the rest of the cultivars in the trial *U.* (*pumila* x hybrid N 215) 'Homestead', *U.* ('Urban' x *wilsoniana* 'Prospector') 'Patriot', *U.* (*glabra* x *carpinfolia*) 'Pioneer', *U.* (*japonica* x *wilsoniana*) 'Morton' Accolade™, *U. wilsoniana* 'Prospector') performed moderately well (Batzer and Gleason, 2013).

At the National Elm Trial location at the University of Kentucky, preliminary results show that the trees did not remain dormant in April. The trees had some freeze damage to new growth, but the secondary buds were not damaged. As a result, the trees re-leafed later in the season (Hartman et al., 2007). Freeze damage to trunks was observed on *U. parvifolia* 'Emer II' Allee®, *U.* 'Homestead', *U.* 'Morton Glossy' Vanguard™, *U.* (*japonica* x *wilsoniana*) 'Morton Red Tip' Danada Charm™, *U.* 'Morton' Accolade™, *U.* (*pumila* x *davidiana* var. japonica) 'New Horizon', *U. wilsoniana* 'Prospector', and *U. americana* 'Princeton'. The Kentucky trees also showed differences in the average damage from Japanese beetles. Cultivars with the most Japanese beetle damage were *U.* 'Homestead', *U.* 'Morton' Accolade™, *U.* 'Morton Plainsman' Vanguard™, *U.* 'Pioneer', and *U.* 'Morton Glossy' Triumph™. The cultivars with the least amount of Japanese beetle damage were *U. parvifolia* 'Emer II' Allee®, *U. parvifolia* 'BSNUPF' Everclear®, *U.* 'Frontier', *U. parvifolia* 'Emer I' Athena®, and *U. propinqua* 'JFS-Bieberich' Emerald Sunshine®.

At the National Elm Trial location at UC Davis in Northern California, diameter at breast height (DBH), crown diameter, height, pruning requirements, pests, disease and abiotic disorders were measured and analyzed (McPherson et al., 2009). One *U.* 'Frontier' and all *U. parvifolia* 'Emer II' Allee® died within the first year after the trees were planted. The cultivars with the fastest increase in DBH after three years of evaluation were *U.* 'New Horizon', *U.* 'Morton

Plainsman' Vanguard™ and *U.* 'Homestead'. *U. propinqua* 'JFS-Bieberich' Emerald Sunshine®, *U.* 'Froniter', and *U.* 'Morton' Accolade™ were the slowest growing cultivars in regards to DBH. Overall in respect to the three growth variables measured (height, DBH, and crown diameter), the fastest growing cultivars were *U.* 'Homestead' and *U.* 'Morton Stalwart' Commendation™ and the slowest were *U.* 'Frontier', *U. propinqua* 'JFS-Bieberich' Emerald Sunshine®, and *U. wilsoniana* 'Prospector'. There were a few exceptions, such as relatively fast annual tree height growth for *U. americana* 'New Harmony' and slow growth for *U. americana* 'Valley Forge' and *U. wilsoniana* Vanguard™. Cultivars with the highest pruning requirements were *U. americana* 'Valley Forge', *U.* 'Morton Plainsman' Vanguard™, *U.* 'Pioneer' and *U. americana* 'Princeton'. Cultivars with the lowest pruning requirements were *U.* 'Frontier', *U. propinqua* 'JFS-Bieberich' Emerald Sunshine®, and *U.* 'Morton' Accolade™. The rest of the cultivars in the trial were considered to have intermediate pruning requirements (McPherson et al., 2009).

In northern California the main pests of elms that require management are the elm leaf beetle (*Xanthogaleruca luteola*) and honeydew-producing aphids and scale insects (McPherson et al., 2009). DED and bark beetles have been a problem in the San Francisco Bay area, but at the elm trial at UC Davis there was no DED or bark beetle boring damage on any of the cultivars in the years 2005-2007. Elm leaf beetle was the only invertebrate problem, with about one-half of the cultivars showing 30 percent or more damage within just a few months of planting. The American elm cultivars 'Princeton' and 'Valley Forge' had leaf curling aphid (*Eriosoma* sp.) infestations, while the rest of the American elms and other cultivars had no damage. Elms with Asian and European parentage had pouch gall aphid (probably *Tetraneura nigriabdominalis*) infestations in the spring. While this aphid produced brown, pink, and green galls on elm leaves,

it was not a serious pest problem. On some cultivars, European elm scale (*Gossyparia spuria*) and European fruit lecanium scale (*Parthenolecanium corni*) were present, but further study and artificial inoculation is needed to determine the susceptibility of specific cultivars. Abiotic disorders were assessed but did not cause any problems with tree health or survival (McPherson et al., 2009).

Elms in general are desired in the landscape because of their tolerance to poor environmental conditions such as de-icing salts, soil compaction, drought, and air pollution as well as the ability to survive where other trees have failed (Townsend, 2000). With the introduction of new cultivars of elms with increased insect and disease resistance, elms can once again be used in urban areas and landscapes. Further research on elms to create genetically diverse groups in terms of size, shape, and other desirable horticultural characteristics is needed. There have been many elm cultivar trials throughout the United States, but extensive trials in the Southeastern U.S. have not been completed or have been minimally reported. The growth, horticultural tolerance, and insect, disease and stress tolerance need to be evaluated so that producers and the landscape industry can market and sell elm cultivars most suitable for their region (Jacobi, 2015).

LITERATURE CITED

Batzer, J.C., and M.L. Gleason. 2013. National Elm Trial. Iowa State Research Farm Progress Reports. Paper 1901. 27 May 2015.

Braiser, C.M., M.R. Bates, N.W. Charter, and K.W. Buck. 1993. DNA polymorphism, perithecial size, and molecular aspects of D factors in *Ophiostoma-ulmi* and *O. novo-ulmi*, p. 308-321. In: M.D. Stricklen and J.L. Sherald (eds.). Dutch elm disease research: Cellular and molecular approaches. Springer-Verlag, New York, NY.

Campanella, T.J. 2003. Republic of Shade: New England and the American Elm. Yale University, New Haven, Conn.

Dirr, M.A. 2009. Manual of Woody Landscape Plants: Their Identification, Ornamental Characteristics, Culture, Propagation and Uses. Stipes Publishing, Champaign, IL.

Hartman, J., E. Dixon, D. Potter, C. Brady, J. Edelen, and J. Hart. 2007. National Elm Trial: Kentucky data, 2007. UK Nursery and Landscape Program Prog. Rep. PR-571.

Jacobi, William. "National Elm Trial." Colorado State University, 2015. Accessed May 4, 2015. <http://bspm.agsci.colostate.edu/people-button/faculty-new/william-jacobi/national-elm-trial>.

Jeng, R.S. 1993. Characterization of isolates of *Ophiostoma ulmi* by molecular techniques, p. 216-226. In: M.D. Stricklen and J.L. Sherald (eds.). Dutch elm disease research: Cellular and molecular approaches. Springer-Verlag, New York, NY.

Kuser, J. and N. Polanin. 2001. Comparative test of six DED-tolerant elms: A preliminary report on nursery performance. J. Arboriculture 27(5):281-282.

McPherson, G., L. Costello, J. Harding, M.L. Flint, and S. Mezger. 2009. National Elm Trial: Initial report from Northern California. Western Arborist. Fall 2009:32-36.

Miller, F. 2000. Insect resistance of elm genotypes, p. 137-154. In: C.P. Dunn (ed.). The Elms: Breeding, Conservation, and Disease Management. Kluwer Academic Publishers. Boston, Mass.

Miller, F. 2002. New elms for the landscape and urban forest. July 2015. <http://www.olparks.com/images/Docs/New_Elms.pdf.>

Potter, C., T. Harwood, J. Knight, and I. Tomlinson. 2011. Learning from history, predicting the future: the UK Dutch elm disease outbreak in relation to contemporary tree disease threats. Phil. Trans. R. Soc. B. 366:1966-1974.

Santamour F.S. Jr., 1993. Cytological and biochemical aspects of elm improvement, p. 69-74. In: M.D. Stricklen and J.L. Sherald (eds.). Dutch elm disease research: Cellular and molecular approaches. Springer-Verlag, New York, NY.

Slavicek, L.M. and K.S. Knight. 2012. Generation of American elm trees with tolerance to Dutch elm disease through controlled crosses and selection. Proc. 4th Intl. Wkshp on Genetics of Host-Parasite Interactions in Forestry 342-346.

Smalley, E.B., R.P. Guries, and D.T. Lester. 1993. American liberty elms and beyond; Going from the impossible to the difficult, p. 26-45. In: M.D. Stricklen and J.L. Sherald (eds.). Dutch elm disease research: Cellular and molecular approaches. Springer-Verlag, New York, NY.

Smalley, E.B. and R.P. Guries. 2000. Asian elms: Sources of disease and insect resistance, p. 215-230. In: C.P. Dunn (ed.). The elms: Breeding, conservation, and disease management. Kluwer Academic Publishers. Boston, Mass.

Townsend, A.M. 2000. USDA genetic research on elms, p. 273-278. In: C.P. Dunn (ed.). The elms: Breeding, conservation, and disease management. Kluwer Academic Publishers. Boston, Mass.

Townsend, A.M. and L.W. Douglass. 2004. Evaluation of elm clones for tolerance to Dutch elm disease. J. Arboriculture 30(3):179-184.

CHAPTER II

GROWTH OF ELM TAXA IN AUBURN, ALABAMA

Elms (*Ulmus* sp.) became a symbol of the native forests in America because they survived pioneers and domestication (Campanella, 2003). Early settlers chose to leave elms when clearing land because they had low commercial value, did not impede farm land, and offered shade to livestock. The history of the American elm began in New England, but soon the popularity of the American elm took root and spread all over the United States. Elms became the universal element of the urban landscape by the 1920's, and by 1937, a survey indicated more than 25 million elms had been planted in the country (Campanella, 2003).

Since the American elm collectively formed the largest urban forest ever planted (Campanella, 2003), the devastation by the two pathogens causing Dutch elm disease, *Ophiostoma ulmu* and *O. novo-ulmi*, was greater than any other tree pathogen to date (Heybroek, 1993). After World War II began, containment efforts were abandoned due to national defense taking priority. By 1968, the disease had spread across the Great Plains into Colorado. Since then, DED has been found in 42 of the 48 contiguous United States (Schreiber, 1993).

Maximizing genetic diversity within the nation's urban forests is important due to increasing threats from exotic pathogens and insects, and the American elm is no longer widespread in the nation's urban forests due to DED (Jacobi, 2015). Because of this, Colorado State University began the National Elm Trial in 2005, with the following objectives: to determine the growth and horticultural performance of commercially available DED-resistant

elm cultivars in different climate regimes in the United States; To determine the relative disease, insect, and abiotic stress tolerance of these cultivars; And to promote the propagation and use of elms through local, regional, and national reporting of the trial results to wholesale tree propagators and growers, retail nursery and garden center operators, landscape designers, arborists, and the general public(Jacobi, 2015). There are 16 trial sites in 15 states, each evaluating a minimum of 17 cultivars.

MATERIALS AND METHODS

The National Elm Trial in Auburn, Alabama was planted on 25 May 2007 in a complete block design at 32° 35' 46.5036" N and 85° 29' 36.8952" W. The trees are on a 7.4% slope, and the elevation of the central most point of the planting is 190 meters above sea level. The soil type is a clay loam. The pH was 7.3 at the top of the slope and 6.9 at the bottom of the slope as of 2014. Trees were planted 6.1 meters apart within six rows spaced 7.6 meters apart running North to South. In spring of 2008, 49 of the 100 trees had died since planting. These were replaced spring of 2008. In 2010, the sixth row was removed due to construction of the Auburn University Soccer Complex. The four surviving trees were relocated to spaces in the other five rows where other trees had died. However, the four transplanted trees died by 2013.

A total of 19 cultivars were planted at Auburn: *Ulmus americana* ‘Jefferson’, *U. americana* ‘Princeton’, *U. americana* ‘Valley Forge’, *U.* ‘Morton’ Accolade™, *U.* ‘Morton Stalwart’ Commendation™, *U.* ‘Morton Red Tip’ Danada Charm™, *U.* ‘Frontier’, *U.* ‘Homestead’, *U.* ‘New Horizon’, *U.* ‘Patriot’, *U.* ‘Pioneer’ *U. wilsoniana* ‘Prospector’, *U.* ‘Morton Glossy’ Triumph™, *U.* ‘Morton Plainsman’ Vanguard™, *U. parvifolia* ‘Emer I’

Athena®, *U. parvifolia* 'BSNUPF' Everclear®, *U. propinqua* 'JFS-Bieberich' Emerald Sunshine®, *U. americana* 'Lewis & Clark' Prairie Expedition®, *U. parvifolia* 'Emer II' Allee®. Each cultivar was replicated in five blocks, each block containing one tree of each cultivar. The only exception was *U. americana* 'Jefferson' which had ten replications. After planting, pine bark mulch was placed around the trees 10 centimeters deep in a square that measured 1.2 meters by 1.2 meters. The trees were watered at planting and throughout the first summer as needed, after which no herbicides, pesticides, or supplemental irrigation was used. Trees were measured for initial height and DBH at planting. The planting site was initially bare-ground. In 2008, the entire site was covered with Meyer Zoysia (*Zoysia japonica* 'Meyer') sod and irrigated overhead until the turfgrass was established.

After the summer of 2008, the project was left unattended other than mowing until the summer of 2013 to simulate low-maintenance landscape practices. Tree height was measured on 19 September 2013, 26 June 2014, and 17 March 2015 using a telescoping meter pole from same grade as tree trunk to tallest point. Trunk diameter from East to West at 30.5 cm was measured on 15 November 2013, 1 July 2014, and 17 March 2015 using a tree caliper. While other sites measured trunk diameter at breast height (1.4 m), trunk diameter at 30.5 cm was measured since many trees had split trunks below breast height. Crown width from North to South was measured on 27 June 2014 and 17 March 2015 using a tape measure.

Date of first visible onset of fall color was recorded fall of 2013. Trees were evaluated twice a week starting mid-September until all trees displayed fall color. Date of fall color onset was converted to Julian Day Number for analysis.

Insect pressure was scouted on 13 May 2014 and 23 July 2014, with Auburn University Associate Entomology professor Dr. David Held. Shot hole damage, number of flea beetles and

number of foliage galls were recorded. Sap-sucker damage was rated on each tree where 0 equaled no damage and 5 equaled severe damage.

Disease pressure was assessed in August 2014 with Auburn University Plant Pathology professor Dr. Austin Hagan. Any disease present was identified. A disease incidence rating was assigned on a scale of 0 to 4 where 0 equaled no disease present, 1 equaled 1% to 25% of leaves affected, 2 equaled 26 % to 50% of leaves affected, 3 equaled 51% to 75% leaves affected, and 4 equaled 76% to100% of leaves affected.

An analysis of variance was performed on all responses using PROC GLIMMIX in SAS version 9.3 (SAS Institute, Cary, NC). Although the cultivars were originally arranged in a complete block design, blocks were not included in the model due to replanting some of the trees in 2008 and to the required relocation of some trees in 2010. Planting date was included in the models as a random variable to account for any variation due to different planting dates. Height and trunk diameter data were analyzed as a factorial combination of 17 cultivars and three data collection dates, while crown width data were analyzed as a factorial combination of 17 cultivars and two data collection dates. The treatment design for date of fall color and disease incidence and severity only included cultivar. Disease incidence and severity were analyzed using the multinomial probability distribution. Mean separation of least square means were performed using the Shaffer Simulation method due to the large number of comparisons.

RESULTS

Tree Growth

When dead trees were replaced in 2008, one tree each of *U.* 'Morton Red Tip' and *U.* 'Morton Stalwart' had died, however 2 trees of each were planted. As a result, each of these

cultivars had six replications after 2008. As of summer 2015, all six replications of *U.* 'Morton Red Tip' and *U.* 'Morton Stalwart' were aliv,. *U.* 'Morton' had one tree replaced in 2008, and *U.* 'Frontier' had three trees replaced in 2008. *U.* 'Morton' and *U.* 'Frontier' now had five replications remaining as of summer 2015. *U. parvifolia* 'BSNUPF', *U.* 'Homestead', *U.* 'Morton Glossy', *U.* 'Patriot', *U. americana* 'Princeton' and *U.* 'New Horizon' each had four replications remaining. *U. parvifolia* 'BSNUPF' had one tree replaced in 2008. *U.* 'Homestead had two trees replaced in 2008. *U.* 'Morton Glossy' had three trees replaced in 2008. *U.* 'Patriot' had four trees replaced in 2008. *U. americana* 'Princeton' and *U.* 'New Horizon' each had five trees replaced in 2008. *U. americana* 'Lewis and Clark', *U. parvifolia* 'Emer I', *U. propinqua* 'JFS-Bieberich', *U.* 'Morton Plainsman', and *U. wilsoniana* 'Prospector' had three replications remaining as of summer 2015. *U. americana* 'Lewis and Clark' had no trees replaced in 2008. *U. parvifolia* 'Emer I' had 1 tree replaced in 2008. *U. propinqua* 'JFS-Bieberich' had 2 trees replaced in 2008. *U.* 'Morton Plainsman' had three trees replaced in 2008. *U. wilsoniana* 'Prospector' had four trees replaced in 2008. *U.* 'Pioneer' had three trees replaced in 2008 and has two replications remaining, while *U. parvifolia* 'Emer II' had six trees replaced in 2008 and has one replication remaining. The survival rate of *U. americana* 'Jefferson' and *U. americana* 'Valley Forge' was 0% (Table 1).

Height was similar between cultivars within each data collection date, however, cultivar had a significant effect on height when averaged across all three data collection dates. Height and trunk diameter for all trees in the trial increased from 2013 to 2015 in a linear response at ≤ 0.01 probability level (data not shown). Planting date of 2007 verses 2008 had a significant effect on height (Pr = 0.04), but not on crown width or trunk diameter (data not shown).

The least square means of tree height of *U.* 'Morton Red Tip', *U. parvifolia* 'BSNUPF', *U. americana* 'Lewis & Clark', *U.* 'Patriot', and *U.* 'New Horizon' averaged across three years ranged from 5.9 meters to 6.5 meters and were significantly taller than *U. parvifolia* 'Emer I', *U.* 'Morton Glossy', and *U.* 'Morton Plainsman', which ranged from 3.2 meters to 3.6 meters (Table 2). Actual mean height measurements recorded each year for each cultivar are reported in Table 3.

For trunk diameter, *U. americana* 'Lewis & Clark', *U.* 'Morton Red Tip', *U.* 'New Horizon', and *U.* 'Homestead' were significantly larger than *U.* 'Morton Plainsman' (Table 4). Trunk diameter ranged from the largest average of 13.0 centimeters (*U. americana* 'Lewis & Clark') to 4.8 centimeters (*U.* 'Morton Plainsman'). Actual mean trunk diameter measurements recorded each year for each cultivar are reported in Table 5. Crown width yielded similar results as trunk diameter. *U. americana* 'Lewis & Clark' had an average crown width of 26.2 meters and was significantly wider than *U. parvifolia* 'BSNUPF', *U.* 'Morton Plainsman', *U.* 'Morton', *U.* 'Morton Glossy', *U. americana* 'Princeton' and *U. propinqua* 'JFS-Bieberich' which had average crown widths ranging from 1.3 meters to 2.9 meters (Table 6). Actual crown width measurements recorded each year for each cultivar are reported in Table 7.

Fall Color

Average date of fall color onset occurred between 2 October 2013 and 29 October 2013 for all trees in the Auburn trial. *U.* 'Morton Glossy' and *U.* 'Morton Stalwart' had the earliest average onset of fall color on 2 October 2013 and 5 October 2013, respectively. *U.* 'Pioneer' and *U.* 'Homestead' had the latest average date of onset at 28 October 2013 and 29 October 2013, respectively (Table 8).

Disease and Insect Pressure

On 23 May 2014, there was minimal sap sucker damage on a few trees but was not cultivar specific. Flea beetles were also present but not cultivar specific. On 23 July 2014, percent defoliation due to Japanese beetles and flea beetles averaged 9.8%, but the damage was not cultivar specific.

No incidence of DED recorded at the Auburn Elm Trial. Anthracnose and powdery mildew were found on some trees but was not cultivar specific. However, *U. americana* 'Princeton' and *U. americana* 'Lewis & Clark' had the highest disease pressure, with greater than 50% of the leaves affected.

DISCUSSION

U. 'Morton Red Tip', *U. americana* 'Lewis & Clark', *U.* 'New Horizon', *U. parvifolia* 'BSNUPF' were among the largest across all three growth variables at the Auburn elm trial. *U.* 'Morton Red Tip' had an 86% survival rate, was the tallest, had one of the largest crown widths and had the second largest trunk diameter. *U.* 'Morton Red Tip' was also a top performer at the trials at Colorado State University, Kansas State University, Michigan State University, North Dakota State Forestry Service, Rutgers University, State University of New York, University of Kentucky, and Washington State University with survival rates of 80%, 100%, 80%, 100%, 60%, 100%, 100%, 100%, respectively (Jacobi, 2015). It was also the tallest at the State University of New York trial. *U.* 'Morton Red Tip' was a poor performer at the trial at Iowa State University, where it had 0% survival. At the Auburn elm trial, *U. americana* 'Lewis &

Clark' was the third tallest, had the widest crown width, the largest trunk diameter, and had a survival rate of 60%. This cultivar was not a top performer at any other trial locations. It was a considerably poor performer at the trials at Colorado State University, Iowa State University, and University of Vermont. At the Colorado State University trial it was a poor performer due to winter damage or scale damage. At Iowa State University, it was not recommended because of a low survival rate of 40%. At the University of Vermont it was not recommended because it was a weak grower.

U. 'New Horizon' had a poor survival rate of 40% in the Auburn trial, but was the fifth tallest and had the third largest trunk diameter. It was also a top performer at the trials at Kansas State University, Rutgers University, State University of New York, and University of Vermont with survival rates of 100%, 100%, 80% and 100%, respectively (Jacobi, 2015). Interestingly, at the UC Davis trial, *U.* 'New Horizon had the fastest annual DBH growth but had the slowest height and crown width growth. It was not recommended at the Iowa State University trial where it had a 0% survival rate. *U. parvifolia* 'BSNUPF' had a survival rate of 67% and was the second tallest, but was not in the top of the other growth categories due to its tall and narrow growth habit. It was a poor performer at the trial at the University of Vermont with an 80% survival rate and had yellow, chlorotic leaves possibly from frost damage. It also had very poor growth and branch development.

Aside from *U. americana* 'Jefferson' and *U. americana* 'Valley Forge' which both had 0% survival rates, *U.* 'Morton Plainsman', *U.* 'Morton Glossy', and *U. propinqua* 'JFS-Bieberich' were the poorest performers at the Auburn elm trial. *U.* 'Morton Plainsman' had a survival rate of 38%, was the shortest, had one of the smallest crown widths and had the smallest trunk diameter. It was also a poor performer at the trial at Rutgers University, where it had a

survival rate of 100%, but was very susceptible to Japanese Beetle damage with a 42% incidence and 46% severity (Jacobi, 2015). By contrast, *U.* 'Morton Plainsman' was a top performer at the trial at Iowa State University and University of Vermont. At the Iowa State University trial, it was top rated based on its survival rate, which was 100%, arrangement and angles of branches, and overall growth and appearance. At the University of Vermont trial, it had 100% survival and no insects or diseases. *U.* 'Morton Glossy' had a 50% survival rate, was the second shortest and had the third smallest crown width in the Auburn trial. It was not a poor performer at any other trial locations. Although it was a poor performer at the Auburn elm trial, it was a top performer at many of the other trial sites, which includes UC Davis, Colorado State University, Iowa State University, Perdue University, State University of New York, University of Vermont, and Washington State University. It was considered to have great form, nice leaves, and tall, upright growth at these locations.

U. propinqua 'JFS-Bieberich' had the smallest crown width and had a 43% survival rate. It was also a poor performer at the following trial locations: UC Davis, Colorado State University, Iowa State University and the University of Vermont (Jacobi, 2015). At UC Davis, it was also one of the slowest growing across all three growth variables. At Colorado State University's trial, it was unacceptable due damage that was either from scale or cold temperatures. At the Iowa State trial, it had a 40% survival rate. At the University of Vermont trial it had 100% survival, but had weak, stunted, thin canopies with 20%-50% of the crowns dead.

CONCLUSION

All *U. americana* ‘Jefferson’ and *U. americana* ‘Valley Forge’ died in our trial. Both of these cultivars are common in the nursery trade, but our results indicate other cultivars are more suited for the deep South. When taking into account overall growth, performance, and insect, disease and stress tolerance, *U.* ‘Morton Red Tip’ was the best performer at the Auburn elm trial. Not only was it one of the largest, but it was mostly unaffected by insects, diseases and was able to withstand the stress of not being irrigated, mulched, and pruned. It is also has a desirable aesthetic with a tall upright habit and vase shape. It most closely embodies the quintessential American elm tree shape, and has performed very well in the deep South.

LITERATURE CITED

Batzer, J.C., and M.L. Gleason. 2013. National elm trial. Iowa State Research Farm Progress Reports. Paper 1901. 27 May 2015. <http://lib.dr.iastate.edu/farms_reports/1901>.

Campanella, T.J. 2003. Republic of Shade: New England and the American Elm. Yale University, New Haven, Conn.

Gibbs, J.N. 1981. In North America, p. 7-8. In: J. Stipes and J. Campana (eds.). Compendium of Elm Disease. Am. Phytopathological Society. St. Paul, MN.

Heybroek, H.M. 1993. Why bother about the elm? p. 1-8. In: M. Stricklen and J. Sherald (eds.). Dutch Elm Disease Research: Cellular and Molecular Approaches. Springer-Verlag, New York, NY.

Jacobi, William. "National Elm Trial." Colorado State University, 2015. Accessed May 4, 2015. <http://bspm.agsci.colostate.edu/people-button/faculty-new/william-jacobi/national-elm-trial>.

McPherson, G., L. Costello, J. Harding, M.L. Flint, and S. Mezger. 2009. National elm trial: Initial report from Northern California. Western Arborist. Fall 2009. 32-36.

Schreiber, L.R. 1993. An old problem; A new approach, p. 51-59. In: M. Stricklen and J. Sherald (eds.). Dutch Elm Disease Research. Cellular and Molecular Approaches. Springer-Verlag, New York, NY.

Table 1. Survival of elm cultivars between 2007 and 2015 in the National Elm Trial at Auburn University, Auburn, AL.

Cultivar	2007 planting	2008 planting	Survived as of 2015	Survival rate %
U . 'Morton Red Tip' Danada Charm™	5[Z]	2[Y]	6[X]	86
U . 'Morton Stalwart' Commendation™	5	2	6	86
U. 'Morton' Accolade™	5	1	5	83
U. *parvifolia* 'BSNUPF' Everclear®	5	1	4	67
U. 'Frontier'	5	3	5	63
U. *americana* 'Lewis & Clark' Prairie Expedition®	5	0	3	60
U. 'Homestead'	5	2	4	57
U. *parvifolia* 'Emer I' Athena®	5	1	3	50
U. 'Morton Glossy' Triumph™	5	3	4	50
U. 'Patriot'	5	4	4	44
U. *propinqua* 'JFS-Bieberich' Emerald Sunshine®	5	2	3	43
U. *americana* 'Princeton'	5	5	4	40
U . 'New Horizon'	5	5	4	40
U. 'Morton Plainsman' Vanguard™	5	3	3	38
U. *wilsoniana* 'Prospector'	5	4	3	33
U. 'Pioneer'	5	3	2	25
U. *parvifolia* 'Emer II' Allee®	5	6	1	9
U. *americana* 'Jefferson'	10	2	0	0
U. *americana* 'Valley Forge'	5	0	0	0

[Z] Number of replications initially planted in 2007.

[Y] Number of replications planted in 2008 to replace dead trees from 2007 planting.

[X] Number of replications alive as of summer 2015.

Table 2. Tree height of elm culitvars averaged across 2013, 2014, and 2015 in the National Elm Trial at Auburn University in Auburn, AL.

Cultivar	Height	
U. 'Morton Red Tip' Danada Charm™	6.5[Z]	a[Y]
U. parvifolia 'BSNUPF' Everclear®	6.2	ab
U. americana 'Lewis & Clark' Prairie Expedition®	6.0	abc
U. 'Patriot'	5.9	abc
U. 'New Horizon'	5.9	abc
U. parvifolia 'Emer II' Allee®	5.5	abcd
U. 'Morton Stalwart' Commendation™	5.4	abcd
U. americana 'Princeton'	5.3	abcd
U. 'Homestead'	5.2	abcd
U. 'Pioneer'	5.0	abcd
U. 'Frontier'	4.9	bcd
U. propinqua 'JFS-Bieberich' Emerald Sunshine®	4.3	bcd
U. 'Morton' Accolade ™	4.1	cd
U. wilsoniana 'Prospector'	4.1	cd
U. parvifolia 'Emer I' Athena®	4.0	d
U. 'Morton Glossy' Triumph™	3.6	d
U. 'Morton Plainsman' Vanguard™	3.2	d

[Z] Least square means of tree height in meters.

[Y] Means separated within a column using Shaffer Simulated method. Means with same letter are not significantly different.

Table 3. Actual mean height measurements by cultivar for 2013, 2014, and 2015 in the National Elm Trial at Auburn University in Auburn, AL.

Cultivar	2013	2014	2015
U. 'Morton Red Tip' Danada Charm™	5.8[Z]	6.5	6.8
U. parvifolia 'BSNUPF' Everclear®	5.6	6.2	6.5
U. 'New Horizon'	5.7	6.1	6.4
U. americana 'Lewis & Clark' Prairie Expedition®	5.5	5.7	6.1
U. 'Patriot'	5.7	5.6	6.1
U. parvifolia 'Emer II' Allee®	5.6	5.5	6.0
U. americana 'Princeton'	5.1	5.4	5.8
U. 'Pioneer'	4.5	5.4	5.6
U. 'Morton Stalwart' Commendation™	5.0	5.4	5.6
U. 'Homestead'	4.9	5.3	5.6
U. 'Frontier'	4.5	5.0	5.1
U. wilsoniana 'Prospector'	3.7	4.0	4.6
U. 'Morton Glossy' Triumph™	2.9	3.8	4.4
U. propinqua 'JFS-Bieberich' Emerald Sunshine®	4.0	4.7	4.2
U. 'Morton' Accolade ™	3.7	4.0	4.1
U. parvifolia 'Emer I' Athena®	3.6	3.7	4.0
U. 'Morton Plainsman' Vanguard™	3.0	3.4	3.5

[Z] Height measurment in meters.

Table 4. Trunk diameter at 30.5 centimeters of elm cultivars averaged across 2013, 2014, and 2015 in the National Elm Trial at Auburn University in Auburn, AL.

Cultivar	Trunk diameter	
U. americana 'Lewis & Clark' Prairie Expedition®	13.0[Z]	a[Y]
U. 'Morton Red Tip' Danada Charm™	12.7	a
U. 'New Horizon'	12.7	a
U. 'Homestead'	11.2	a
U. parvifolia 'Emer II' Allee®	10.9	ab
U. 'Pioneer'	10.7	ab
U. 'Morton Stalwart' Commendation™	10.2	ab
U. parvifolia 'Emer I' Athena®	10.2	ab
U. parvifolia 'BSNUPF' Everclear®	9.1	ab
U. 'Frontier'	8.9	ab
U. 'Patriot'	8.9	ab
U. wilsoniana 'Prospector'	7.9	ab
U. americana 'Princeton'	7.4	ab
U. 'Morton' Accolade™	7.4	ab
U. propinqua 'JFS-Bieberich' Emerald Sunshine®	6.9	ab
U. 'Morton Glossy' Triumph™	6.6	ab
U. 'Morton Plainsman' Vanguard ™	4.8	b

[Z] Least square means of trunk caliper in centimeters measured 30.5 centimeters above grade.

[Y] Means separated within a column using Shaffer Simulated method. Means with same letter are not significantly different.

Table 5. Actual mean trunk diameter measurements of elm cultivars for 2013, 2014, 2015 in the National Elm Trial at Auburn University in Auburn, AL.

Cultivar	2013	2014	2015
U. 'New Horizon'	11.1[Z]	12.9	14.2
U. 'Morton Red Tip' Danada Charm™	11.6	12.6	13.9
U. americana 'Lewis & Clark' Prairie Expedition®	11.7	13.6	13.6
U. 'Pioneer'	9.4	10.2	12.7
U. 'Homestead'	10.0	11.5	12.0
U. parvifolia 'Emer II' Allee®	9.1	11.7	11.9
U. 'Morton Stalwart' Commendation™	9.1	10.2	11.3
U. parvifolia 'Emer I' Athena®	9.2	10.1	11.1
U. 'Patriot'	7.3	8.5	10.7
U. parvifolia 'BSNUPF' Everclear®	8.3	9.1	10.2
U. 'Frontier'	8.1	9.2	9.7
U. wilsoniana 'Prospector'	6.6	7.8	9.5
U. americana 'Princeton'	5.8	7.1	8.9
U. 'Morton' Accolade ™	6.6	7.4	8.0
U. propinqua 'JFS-Bieberich' Emerald Sunshine®	6.5	6.2	7.7
U. 'Morton Glossy' Triumph™	6.0	6.2	7.7
U. 'Morton Plainsman' Vanguard™	4.1	5.0	5.2

[Z] Trunk diameter measured in cemtimeters North to South at 30.5 cm.

Table 6. Crown width of elm cultivars averaged across 2014 and 2015 in the National Elm Trial at Auburn University in Auburn, AL.

Cultivar	Crown Width	
U. americana 'Lewis & Clark' Prairie Expedition®	6.2[Z]	a[Y]
U. parvifolia 'Emer II' Allee®	5.2	ab
U. 'Homestead'	4.5	ab
U. 'Morton Stalwart' Commendation™	4.0	ab
U. 'Morton Red Tip' Danada Charm™	3.9	ab
U. 'Pioneer'	3.7	ab
U. 'New Horizon'	3.5	ab
U. parvifolia 'Emer I' Athena®	3.5	ab
U. 'Frontier'	3.4	ab
U. wilsoniana 'Prospector'	3.4	ab
U. 'Patriot'	3.3	ab
U. parvifolia 'BSNUPF' Everclear®	2.9	b
U. 'Morton Plainsman' Vanguard™	2.5	b
U. 'Morton' Accolade™	2.4	b
U. 'Morton Glossy' Triumph™	2.3	b
U. americana 'Princeton'	2.0	b
U. propinqua 'JFS-Bieberich' Emerald Sunshine®	1.3	b

[Z] Least square means of crown width in meters.

[Y] Means separated within a column using Shaffer Simulatied method. Means with same letter are not significantly different.

Table 7. Actual crown width measurements for 2014 and 2015 of elm cultivars in the National Elm Trial at Auburn University in Auburn, AL.

Cultivar	2014	2015
U. americana ‘Lewis & Clark’ Prairie Expedition®	6.2[Z]	6.1
U. parvifolia 'Emer II' Allee®	5.5	4.9
U. 'Homestead'	4.7	4.3
U. 'Morton Stalwart' Commendation™	4.0	3.8
U. 'Morton Red Tip' Danada Charm™	4.1	3.7
U. 'Pioneer'	3.9	3.6
U. parvifolia 'Emer I' Athena®	3.4	3.4
U. 'New Horizon'	3.9	3.3
U. wilsoniana 'Prospector'	3.6	3.2
U. 'Patriot'	3.5	3.1
U. 'Frontier'	3.6	3.1
U. parvifolia 'BSNUPF' Everclear®	3.3	2.4
U. 'Morton' Accolade ™	2.5	2.4
U. 'Morton Plainsman' Vanguard™	2.8	2.3
U. 'Morton Glossy' Triumph™	2.5	2.1
U. americana 'Princeton'	2.2	1.9
U. propinqua 'JFS-Bieberich' Emerald Sunshine®	1.4	1.2

[Z] Crown width measured in meters from West to East.

Table 8. Date of onset fall color by cultivar in 2013 in the National Elm Trial at Auburn University in Auburn, AL.

Cultivar	Date	Day of Onset	
U. 'Morton Glossy' Triumph™	10/2/2013[Z]	275[Y]	c[X]
U. 'Morton Stalwart' Commendation™	10/5/13	278	c
U. 'New Horizon'	10/17/13	290	b
U. parvifolia 'Emer II' Allee®	10/17/13	290	b
U. wilsoniana 'Prospector'	10/18/13	291	b
U. 'Morton Plainsman' Vanguard™	10/18/13	291	b
U. 'Patriot'	10/18/13	291	b
U. propinqua 'JFS-Bieberich' Emerald Sunshine®	10/18/13	291	b
U. 'Frontier'	10/18/13	291	b
U. parvifolia 'BSNUPF' Everclear®	10/18/13	291	b
U. 'Morton' Accolade™	10/19/13	292	b
U. 'Morton Red Tip' Danada Charm™	10/19/13	292	b
U. parvifolia 'Emer I' Athena®	10/19/13	292	b
U. americana ‘Lewis & Clark’ Prairie Expedition®	10/19/13	292	b
U. americana 'Princeton'	10/20/13	293	b
U. 'Pioneer'	10/28/13	301	ab
U. 'Homestead'	10/29/13	302	a

[Z]Date of first visible onset of fall color.

[Y]Date was converted to Julian Day Number for analysis.

[X]Means separated within a column using Shaffer Simulatied method. Means with same letter are not significantly different.