The Development of Novel and Non-Invasive Germplasm Selections Native to Arkansas for Highway Re-Vegetation Projects

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MBTC DOT 3027
March 2012

Prepared for
Mack-Blackwell Rural Transportation Center
University of Arkansas
The National Transportation Security Center of Excellence:
A Department of Homeland Security
Science and Technology Center of Excellence

ACKNOWLEDGEMENT
This material is based upon work supported by the U.S. Department of Transportation under Grant Award Number DTRT07-G-0021. The work was conducted through the Mack-Blackwell Rural Transportation Center at the University of Arkansas.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*

2. REPORT DATE
Submitted to MBTC on 3/3/15/2012

3. REPORT TYPE AND DATES COVERED
Final Report – 7/1/2010 – 6/30-2011

4. TITLE AND SUBTITLE
The Development of Novel and Non-Invasive Germplasm Selections Native to Arkansas for Highway Re-Vegetation Projects

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Mack-Blackwell Rural Transportation Center
4190 Bell Engineering Center
University of Arkansas
Fayetteville, AR 72701

8. PERFORMING ORGANIZATION REPORT NUMBER

MBTC DOT 3027

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Department of Transportation
Research and Special Programs Administration
400 7th Street, S.W.
Washington, DC 20590-0001

10. SPONSORING/ MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

Supported by a grant from the U.S. Department of Transportation University Transportation Centers program

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

N/A

13. ABSTRACT (MAXIMUM 200 WORDS)

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14. SUBJECT TERMS

15. NUMBER OF PAGES
15

16. PRICE CODE
N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
none	none	none	N/A

Technical Report Documentation

1. Report Number MBTC DOT 3027	2. Government Access No.	3. Recipient's Catalog No.
4. Title and Subtitle The Development of Novel and Non-Invasive Germplasm Selections Native to Arkansas for Highway Re-Vegetation Projects		5. Report Date Submitted to MBTC on 3/3/15/2012 6. Performance Organization Code
7. Author(s) Garry V. McDonald, Ph.D.		8. Performing Organization Report No.
9. Performing Organization Name and Address Mack-Blackwell Rural Transportation Center 4190 Bell Engineering Center University of Arkansas Fayetteville, AR 72701		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address US Department of Transportation Research and Special Programs Administration 400 7th Street, S.W. Washington, DC 20590-0001		13. Type of Report and Period Covered Final Report – 7/1/2010 – 6/30-2011 14. Sponsoring Agency Code

15. Supplementary Notes

Supported by a grant from the U.S. Department of Transportation University Transportation Centers program

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17. Key Words Native plants, Environmental Quality, Vegetation.		18. Distribution Statement No restrictions. This document is available from the National Technical Information Service, Springfield, VA 22161	
19. Security Classif. (of this report) unclassified	20. Security Cassif. (of this page) unclassified	21. No. of Pages 15	22. Price N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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Problem Description

Re-vegetation strategies and programs are a crucial element in highway construction projects to prevent sheet and gully erosion and as a component of habitat and soil remediation efforts following road construction. Vegetation plays an important part in stormwater filtration and sediment mitigation to protect sensitive wetlands adjacent to highway construction projects. While roadway landscaping projects are often thought of only in terms of aesthetics, landscaping can be a functional and vital component of a transportation corridor by creating visual barriers to block light from vehicular headlights from on-coming traffic, especially on curves on median divided highways. Trees and shrubs can be used as visual and acoustic buffers where highways run in close proximity to built up populated areas. Large shrub plantings can also act as a soft physical barrier or shock absorber in medians to prevent head-on collisions. Additionally, landscaping can contribute to carbon sequestration by capturing carbon dioxide and converting this greenhouse gas to biomass. Plants can also help to mitigate auto emissions while having a positive effect on air quality along transportation corridors in congested urban areas. Beyond the practical and functional aspects of highway vegetation, the aesthetic component cannot be denied. A whole tourism industry is built around seasonal driving tours during the wildflower season and autumnal color tours along major and minor roads have a major economic impact on many rural areas in Arkansas.

In the past, criteria used to select plant material for re-vegetation projects was based on ease of establishment, rapidity of cover, and ease of propagation which normally meant some kind of seedage. Little thought was given to the ecological or cultural consequences of such plant selections. Kudzu *Pueraria lobata* (Willd.) Ohwi, although originally introduced from Japan as a forage crop for cattle, was widely planted by the U.S. Soil Conservation Service in the 1930's to control soil erosion and to re-build soils since the plant is a nitrogen fixing legume. Kudzu's invasive history is legend in the southeastern parts of the United States. Another example of particular interest to the Arkansas River Valley was the introduction of callery pear *Pyrus calleryana* 'Bradford', a native of China, as a street tree in the 1960's (Arnold, 2008). This cultivated variety was originally released as a sterile female selection. Over time, out-crossing pressure has led to trees becoming fertile and this tree is now considered an invasive species in many areas. Large areas of native vegetation along Interstate 40 in the Ft Smith area are being displaced due to this species. As callery pear is highly resistant to diseases, normal disease pressure usually present in this genera of the rose family has little effect on the emerging populations. While admittedly very showy in the spring, these invasive populations are displacing the native flora and affecting local fauna as well. The callery pear thickets appearing on highway rights of way are difficult and expensive to control. The invasive introduced kudzu and callery pear are only two of many plant species that are impacting both urban and rural highway vegetation habitat. Other lesser known examples of invasive species with significant impacts on the local flora and fauna are bermudagrass *Cynodon dactylon*, bahiagrass *Paspalum notatum*, and King Ranch bluestem *Bothriochloa ischaemum* var. *songarica* all which displace native grasses impacting many native ecosystems.

Approach

One of the key principles of sustainable landscape design and implementation in roadside re-vegetation is the use of native plants (McDonald 2010). This rationale is twofold. One is that native plants are adapted to the local geophysical and climatic conditions increasing the chance of successful establishment and long term growth. The second is that native plants preserve a local identity and regionalism which is tied in with societal issues and the preservation of local culture. While this may sound esoteric, the loss of local identity in the local landscape is apparent in the modern suburban and rural commercial retail centers where market branding of both building and landscape makes one retail location in the country look like every other retail location in the country. As a result, the regional and vernacular landscape is impacted and unsustainable over time. This is true also in highway vegetation projects as it is in commercial projects. While native plants are a component of sustainable landscape systems, not all native plants are equal. The concept of provenance is important when selecting plant material for local or regional use (Arnold 2008). Provenance is the term used to denote the source or place of origin of a particular plant genetic resource or germplasm. Same species can vary by location even though that species is native to a wide geographical area. The classic example of plant provenance is Red Maple *Acer rubrum* which is natively growing from the Florida Keys to Quebec, Canada. However, Red Maple germplasm collected in Florida would be unable to survive in Canada, while Red Maple germplasm collected in Canada would not thrive in south Florida. Red Maple has adapted over a wide geographical range of local growing conditions. The practical implications of this are that consolidation in plant production operations nationwide has reduced the genetic resources or range of provenances for most of the native plants commercially produced. For long term sustainability, local sources or at least regional sources of plant material needs to be developed for local or regional use. Previous involvement with a multistate collaborative research team selected Bald Cypress *Taxodium distichum* from provenances ranging from Mexico to Central Florida and has identified germplasm with differential response to highly saline (sodium salts) water, high soil alkalinity, and foliar diseases (Arnold et al., 2010; Denny 2007; McDonald et al., 2008). This work will expand the geographical range that Bald Cypress can be used in the landscape. Concurrent research investigating atmospheric ozone sensitivity among native perennial species has identified approximately 50 plant species with some potential for re-vegetation use (Hunter 1989; Steyermark, 1963; Vines, 1994). A review and analysis of local and regional published botanical floras has yielded other potential species.

Methodology

Twenty seven perennial plant species were identified as possible candidates for highway re-vegetation use (Table 1.). Criteria used to select the species were an identifiable source of germplasm that was native to and collected from the Ozark Plateau/Mountain geographical region. Plants had to have an aesthetic landscape appearance in addition to being adaptable to re-vegetation sites and establishment conditions, and tolerance to possible degraded air quality which might exist in more urban or suburban areas. A final criterion is that the plant species should be reasonably available in the landscape trade or easily established from seed as a common problem in re-vegetation projects is a lack of sufficient numbers of plants to complete a project. Plants were obtained from a commercial source or started by seed and planted out in replicated blocks representing a simulated re-vegetation plot at the Division of Agriculture University of Arkansas Research Farm in Fayetteville, Arkansas. Plots were drip irrigated (2 gpm emitters) once weekly, mulched with 2 inches of hardwood bark, and establishment data were collected to determine ease and success of establishment in addition to establishing germplasm blocks for future work. In addition to plant establishment, plants were also screened for tolerance to ozone (O3) gas exposure. Ozone damage in many agronomic crops or forestry species has been well documented (Krupa, Tomneijek, and Manning, 1998; Richards et al. 1958; Skelly, 2000). However, few if any of the selected plant species selected for this research have been documented as to ozone damage sensitivity. Since one of the criteria for the selection of these plant species is adaptability to urban and suburban areas, ozone screening was conducted. Plants were exposed in a closed system growth chamber to 2.0 mg· L^{-1} ozone and observed for visual symptoms. A severity index was used to indicate the level of visual foliar damage. The severity index was calculated by assigning each individual plant a severity damage factor (0= no symptoms to 5= very severe symptoms) multiplied by a percentage of the leaves injured on each plant further multiplied by a percentage of the plants affected within a specific species exposed to ozone. This final number was divided by the total number of plants treated within a given species (N=9) to generate an average severity index for each plant species.

Findings

Establishment: All 27 selected readily established in the trial plots in the spring of 2010 with minimum loss from transplant shock (< 6%). Flowering was minimum the first season as perennials take a year to establish before normal flowering commences. Plant survival from winter temperatures as cold as -27°C was greater than 90% along with summer survival when plants were not irrigated during the summer of 2011 when summer temperature reached a maximum of 42°C (17 days over 38°C) with a rainfall of 3.3 cm during June and July 2011(Table 1.).

Ozone Tolerance: Plants were exposed, in a closed system growth chamber, to an acute exposure to ozone gas to induce physical or visual damage which was documented. Out of the original 27species tested, 17 species showed no effects from a peak acute ozone exposure of 2.0 $mg \cdot L^{-1}$. These plant species are therefore highly resistant to ozone and would be candidates for use in areas with high ozone levels such as urban and suburban areas. For those plant species affected by ozone exposure, a severity index used to quantify damage (Table 2.). The higher the severity index number listed for each plant species, the greater the physical ozone damage. Of those 10 species exhibiting visual damage, only *Coreopsis tripteris* had differing levels of damage from the remaining species.

Overall findings are that all 27 selected perennial species native to the Ozark region successfully transplanted and established in a simulated re-vegetation plot. Plants had a high rate of winter survivability in a year with below average winter temperatures including a minimum of -27°C. Plants also survived un-irrigated summer temperatures of a maximum of 42°C un-irrigated.

There was a differential response of the various species to an acute exposure of ozone gas. There were even differences within plant genera as in *Coreopsis*. This would indicate that different plant species within a given genera can have varying degrees of tolerance to ozone exposure.

Table 1. Plant data for selected perennial plant germplasm native to the Ozark Plateau and Mountain physiographic area

Genus species	Common Name	Establishment Survival (%)*	Winter 2011 Survival (%)	Summer 2011 Survival (%)
Asclepias syriaca	Common Milkweed	95	99	98
Coreopsis lanceolata	Tickseed	100	100	100
Coreopsis palmata.	Stiff Tickseed	100	100	100
Coreopsis tripteris	Tall Tickseed	100	100	100
Echinacea pallida.	Pale Coneflower	98	95	100
Echinacea paradoxa	Bush’s Coneflower	95	98	99
Echinacea simulata	Wavy Coneflower	100	100	97
Liatris aspera	Blazing Star	98	95	100
Liatris pycnostachya	Blazing Star	95	95	100
Monarda bradburiana	Beebalm	100	100	100
Monarda fistula	Beebalm	100	100	100
Oligoneuron rigidum	Stiff Goldenrod	100	98	100
Penstemon cobaea	Beardtongue	98	96	100
Penstemon digitalis	Penstemon	98	95	100
Penstemon pallidus	Pale Beardtongue	100	98	100
Rudbeckia fulgida	Orange Coneflower	100	100	100
Rudbeckia missouriensis	Missouri Coneflower	100	100	100
Rudbeckia subtomentosa	Sweet Coneflower	95	100	100
Silphium integrifolia	Rosinweed	100	100	100
Solidago nemoralis	Goldenrod	100	100	100
Solidago speciosa	Goldenrod	100	100	100
Tradescantia ernestiana	Spiderwort	98	95	95
Tradescantia ohiensis	Bluejacket	95	95	98
Tradescantia subaspera	Spiderwort	100	100	98

*Percentage of plants that survived establishment, winter kill, and summer drought respectively.

Table 2. Plant Damage Severity Indices for the 10 plant species showing visual foliar damage from an acute exposure of 2.0 mg·L-1 ozone (O3).

Genus species	Severity Index [z]
Coreopsis tripteris	29522a [yx]
Coreopsis palmata	11966ab
Penstemon cobaea	8300b
Solidago nemoralis	6030b
Monarda fistulosa	4203b
Silphium integrifolium	2837b
Oligoneuron rigidum	2818b
Rudbeckia missouriensis	2710b
Penstemon pallidus	227b
Solidago speciosa	621b

[Z] Mean severity index was calculated by summing severity indexes for nine individual treatment plants and dividing by nine.
[Y] Values within columns followed by the letter “a” indicate significantly greater than the minimum using Hsu’s MCB ($\alpha = 0.05$).
[X] Values within columns followed by the letter “b” indicate significantly less than the maximum based on Hus’s MCB ($\alpha = 0.05$). Mean standard error = 272.1

Conclusions

Twenty seven perennial plant species native to the Ozark physiographic area were identified as having potential for highway re-vegetation projects. Plant species selection criteria were based on germplasm of known Ozark provenance, ease of transplant establishment, survivability, and aesthetic worth in a constructed landscape. In addition, plants were exposed to an acute dose of ozone gas to evaluate tolerance to ozone atmospheric pollution. All 27 perennial species were found to have satisfactory transplant survival rates and were found to be winter hardy and tolerant of extreme summer temperatures and moderate drought conditions. Additionally, out of the 27 perennial species tested, 17 were found to be unaffected by acute exposure to ozone gas. Out of the 10 perennial species that showed visual foliar symptoms, visual symptoms were documented and a severity index for each individual species was determined. Within the genus Coreopsis, differences in ozone damage was measured and suggest that certain species within a genera may have greater or lesser ozone tolerance. In certain agronomic or other crops differences to ozone tolerance exist even at the cultivated variety level.

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