2004

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D. W. Williams
University of Northern Iowa

G. A. Houseal
NRVC-UNI

D. D. Smith
NRVC-UNI

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by D. W. Williams[1], G. A. Houseal[2] and D. D. Smith [3]*

[1]*Native Roadside Vegetation Center-University of Northern Iowa, Cedar Falls, Iowa 50614–0294; 319/273–7957, dave.williams@uni.edu*
[2]*NRVC-UNI, 319/273–3005, gregory.houseal@uni.edu*
[3]*NRVC-UNI, 319/273–2238, daryl.smith@uni.edu*

Abstract

Many practitioners prefer to plant seed from multiple remnant sources within the same region of the planting site. It is believed that this seed has improved fitness (survivorship, growth, and viability) over seed from outside the region. We tested this assumption by establishing two common gardens in northern and southern Iowa. Four varieties of switchgrass (*Panicum virgatum*) from prairie remnants in northern and southern Iowa and two cultivated varieties from Nebraska and South Dakota), and stiff tickseed (*Coreopsis palmata*) from prairie remnants in northern and southern Iowa, were established in a greenhouse and transplanted into each common garden in May 2002. We hypothesized that plants grown near their origin would have improved fitness over those from distant origin. Stiff tickseed showed a trend of more shoots in regional populations vs. distant populations, though no significant differences in any of the measures of fitness between Northern and Southern Iowa populations were found. Iowa remnant populations of switchgrass had significantly ($P < 0.05$) more shoots per plant compared to at least one cultivar in both common garden sites in 2002 and 2003. Nebraska 28 cultivar of switchgrass experienced greater mortality than Iowa remnant populations. However, seed viability was not significantly ($P < 0.05$) different for the cultivated varieties of switchgrass and Northern populations; but was significantly lower for Southern Iowa populations in 2002. A decrease in fitness was measured when switchgrass seed from distant sources was planted in Iowa. The results suggest that switchgrass from various Iowa prairie remnants can be planted throughout the state without a loss of fitness.

Keywords: common gardens, *Coreopsis palmata*, cultivars, local ecotype, *Panicum virgatum*, prairie remnants, prairie restoration, regional ecotype

Introduction

Seed source is a growing concern to resource managers in prairie reconstructions and restorations. Many biologists believe that planting seed collected or derived from local prairie remnants may have improved survivorship, growth, and seed viability as compared to remnant seed from outside the region or cultivated variety seed from outside the state.

Presently in Iowa, the source of prairie seed available commercially varies. Iowa 'yellow tag' is seed is derived from identified native prairie remnant sources throughout the state. Over 150 yellow tag species are available commercially in the state (Iowa Crop Improvement 2003). Another source-identified yellow tag seed is 'Natural Selections' seed from the Iowa Ecotype Project, developed at the Native Roadside Vegetation Center at the University of Northern Iowa. Natural Selections seed is collected from Iowa prairie remnants within each of three regions (northern, central and southern). Seed from ten to thirty populations within a region is pooled. Seed from cultivated varieties of native prairie grasses are also commercially available in Iowa. Historically, cultivated varieties were developed by Plant Materials Centers through selective breeding from a few or single wild populations of native grasses. With one exception, *Andropogon gerardii* 'Roundtree' (big bluestem), all of these cultivated varieties were developed from wild populations outside of Iowa. Plants were selected for characteristics like vigorous growth for forage production, large seeds, and uniform germination (Boe and Ross 1998).

Researchers have found that remnant populations of the same species growing in different locations and different habitats exhibit local adaptations (Turresson 1922, Stebbins 1950). Some of these adaptations may be site specific. Knapp and Rice (1997) found that survivorship and seed viability were negatively affected when a native California grass, purple needlegrass (*Nassella pulchra*), was grown in regions away from their remnant populations.

In Iowa, there has been only limited research measuring fitness, defined as growth, survivorship, and seed viability, to determine the importance of seed source in the establishment or reconstruction of native plantings within the state.

Most of the prairie plantings in Iowa are being conducted by the Iowa Department of Transportation (IDOT) and Natural Resources Conservation Service (NRCS). Their recommendations for prairie reconstruction seed mixes include both cultivated varieties and yellow tag seed (Iowa Dept. of Transportation 2001, Natural Resources Conservation Service

2003). The purpose of this study is to measure the performance of two native tallgrass prairie species: a grass, switchgrass (*Panicum virgatum*), and a forb, stiff tickseed (*Coreopsis palmata*), to determine if seed origin affects growth, survivorship and seed viability when grown in common gardens. We selected switchgrass and stiff tickseed because adequate remnant populations exist throughout the state. This research will address potential differences in characteristics between populations of switchgrass and stiff tickseed native to northern and southern Iowa in addition to cultivated varieties of switchgrass (Nebraska 28 and Sunburst) developed from native populations in Nebraska and South Dakota and grown commercially. We hypothesize that seed planted close to its remnant source will have improved fitness over seed from outside the region.

Methods

Two common gardens were established in north central Iowa at the North Iowa Area Community College (NIACC) in Cerro Gordo County, Florence Park in Winnebago County, and two in south central Iowa at Pioneer Ridge Park in Wapello County and Mt. Ayr Wildlife Area in Ringgold County. Approximately 260 kilometers separated the northern and the southern common gardens. Soil types of the common gardens include; well-drained Kenyon Loam at NIACC, poorly drained Arispe Silty Clay Loam at Mt. Ayr Wildlife Area, and poorly drained Beckwith Silty Clay Loam at Pioneer Ridge Park (Dewitt 1981, Seaholm 1981, Boeckman 1992). The existing vegetation at all the common gardens sites consisted of non-native cool-season grasses. The Florence Park common garden was removed from the study because of vandalism that occurred in the summer of 2002.

A commercial grade woven polypropylene ground cloth was stapled to the ground in the fall of 2001 in all the plots. The ground cloth was used to suppress the established vegetation and eliminate weed competition. It remained in place throughout the duration of the study.

Experimental Design

Both switchgrass and stiff tickseed have a range extending throughout the entire tallgrass prairie region of the Midwest (including Iowa). Seed was collected from eight Iowa remnant populations (four northern and four southern) of each species in the fall of 2001 (Table 1). In addition, certified seed from three separate production fields of two cultivated varieties (Sunburst and Nebraska 28) of switchgrass from South Dakota and Nebraska were used for the experiment. Nebraska 28 originated from a single population in Holt County Nebraska (Alderson and Sharp 1993). Sunburst originated from native prairies in Union County South Dakota (Boe and Ross 1998).

Each common garden plot was 9 m x 15 m. Thirty plants of each population were planted into a square grid of six by five rows. There was a 20-cm separation between plants and a 2-m separation between each population. The outermost row of plants in each population grid was considered to be border plants and was not used in the statistical analysis.

Greenhouse Propagation and Transplanting

Seed of each population of switchgrass and stiff tickseed were sown in individual flats in the greenhouse in January 2002. As seedlings emerged, each seedling was transplanted from the flat to an individual conetainer with steam-sterilized soil. This was to ensure that there was only one plant in each conetainer. Conetainers measure 2.5 cm diameter by 15 cm deep. The plants were fertilized every other week. Plants were transplanted into the four common garden plots in mid–May 2002. Conetainer plants were selected at random for transplant into the common garden plots. *Panicum virgatum* plants ranged from 25–30

Table 1. Origin of *Panicum virgatum* and *Coreopsis palmata* seed used for the experiment and common garden locations (http:www.lat-long.com).

Species	Site	County
Northern Iowa		
Copa*, Pavi*	Hoffman Prairie State Preserve	Cerro Gordo
Copa, Pavi	Smith Prairie State Preserve	Kossuth
Copa, Pavi	Stinson Prairie State Preserve	Kossuth
Copa	Hayden Prairie State Preserve	Howard
Pavi	Wilkinson Prairie	Cerro Gordo
Southern Iowa		
Copa, Pavi	Medora Prairie	Warren
Copa	Mud Road	Union
Copa	Sand Creek Wildlife Area	Ringgold
Copa	railroad right-of-way	Madison
Pavi	Flaherty Prairie	Clarke
Pavi	Mt. Ayr Wildlife Area	Ringgold
Cultivars		
Pavi (Neb28)*	Broken Bow	Custer
Pavi (Neb28)	Lincoln	Lancaster
Pavi (Neb28)	Bristol	Day
Pavi (Sunburst)*	Brookings	Brookings
Pavi (Sunburst)	Bristol	Day
Pavi (Sunburst)	Colome	Tripp
Common Garden Sites in Iowa		
North Iowa Area Community College (NIACC)		Cerro Gordo
Mt. Ayr Wildlife Area		Ringgold
Pioneer Ridge Park		Wapello

Pavi - *Panicum virgatum*
Copa - *Coreopsis palmata*
Neb28 - 'Nebraska 28' cultivated variety of *Panicum virgatum*
Sunburst - 'Sunburst' cultivated variety of *Panicum virgatum*

cm tall and stiff tickseed plants ranged from 10–12 cm when transplanted at the common gardens.

Plant Measurements

Mortality, shoot, and seed viability of switchgrass and stiff tickseed were measured. Live and dead plants were assessed for calculating mortality in August 2002 and re-surveyed in June of 2003 and 2004. Shoots from five switchgrass and stiff tickseed plants chosen at random were counted from each population in August 2002 and 2003. Seed from the tallest panicle of five randomly chosen switchgrass plants of each population (not border plants) were collected and used for seed viability measurements in 2002 and 2003. Seed heads were clipped from five randomly chosen stiff tickseed plants from each population (not border plants) for seed viability measurements in 2003. Most stiff tickseed plants did not flower or set seed the first year of the experiment. The seed was hand cleaned through a series of soil sieves and sent to Iowa State Seed Testing Lab in Ames for viability testing. Standard seed testing protocols for viability were used for the seed tests (Associations of Official Seed Analyst 2003).

Statistical Analysis

For the statistical analysis, switchgrass and stiff tickseed populations were grouped by species and seed origin (northern Iowa remnants—Northern, southern Iowa remnants—Southern, Nebraska 28, and Sunburst). Data for switchgrass and stiff tickseed were analyzed separately by species within each common garden plot. A one-way ANOVA was used to analyze the data (Wilkinson 1989). Tukey's protected test for pairwise comparisons was used to determine mean differences (Wilkinson 1989). All comparisons were made at an alpha level of 0.05. Skewness (g1) and kurtosis (g2) were calculated for all data sets. A Student's t-Test (alpha = 0.05, with infinite degrees of freedom) was conducted to determine if the data had significant skew or kurtosis from zero (Wilkinson 1989). To normalize the data distribution, all non-normal data sets were transformed to conduct the ANOVA. Means were back-transformed to report the data.

Results

Mortality

There were no significant ($P > 0.05$) differences in mortality among any groups of switchgrass in 2002 and 2003. In 2004, switchgrass mortality ranged from 9.0% to 41.0% (Figure 1). Nebraska 28 had significantly ($P < 0.049$) greater mortality than the other switchgrass groups at Pioneer Ridge Park in 2004. Although not statistically significant ($P > 0.05$), Nebraska 28 had the greatest numbers of plant deaths at the other common garden locations as well. There was a trend of lower mortality of Southern switchgrass populations over Northern populations at all common garden locations in 2004 (Figure 1).

Stiff tickseed mortality ranged from 6.0% to 21.0% in 2004 and was not significantly ($P > 0.05$) different between Northern and Southern populations.

Vegetative Growth

Northern and Southern populations of switchgrass had significantly ($P < 0.05$) more shoots per plant than Nebraska 28 and Sunburst in 2002 and 2003 (Figure 2, Figure 3). Shoot numbers between Northern and Southern populations of switchgrass were not significantly ($P > 0.05$) different in 2002 and 2003.

Shoot numbers were not significantly ($P > 0.05$) different between Northern and Southern populations of stiff tickseed in 2003 (Figure 4). However, shoot numbers were highest for Southern populations of stiff tickseed grown in southern Iowa and for the Northern populations grown in northern Iowa.

Seed Viability

Switchgrass populations of Nebraska 28 (85.0%) and Sunburst (87.0%) had significantly ($P = 0.027$) greater seed viability than Southern populations (61.3%) at Pioneer Ridge Park in 2002. In 2003, there were no significant differences in seed viability among the switchgrass populations. However there was a large decrease in seed viability of all switchgrass populations in 2003 from 2002. In one southern Iowa

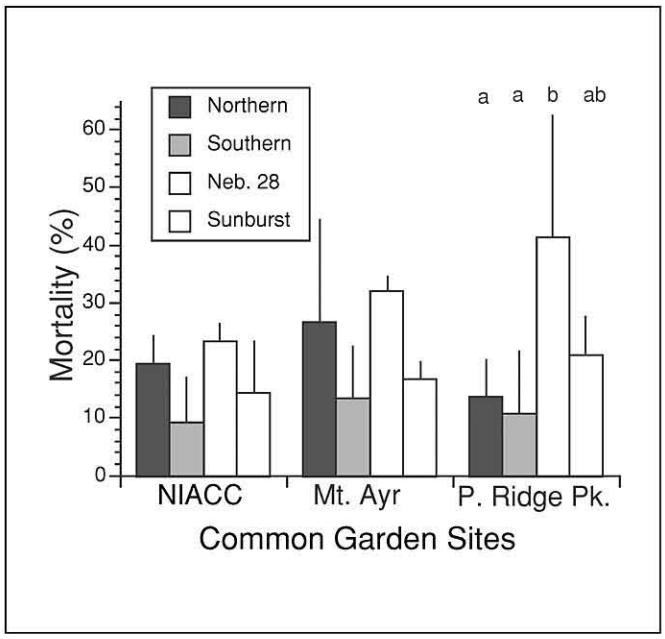

Figure 1. Mean mortality of *Panicum virgatum* populations grown in common gardens in Iowa and sampled in 2004. The cultivar Nebraska 28 had the highest mortality over Sunburst (cultivar) and the Iowa remnant populations (Northern and Southern) when grown in Iowa. Mortality data from each common garden was analyzed separately with a one-way ANOVA. Different letters denote significant ($P < 0.05$) different means with Tukey pairwise comparisons tests. Common gardens were located at NIACC (northern Iowa), Mt. Ayr Wildlife Area (southern Iowa), and Pioneer Ridge Park (southern Iowa).

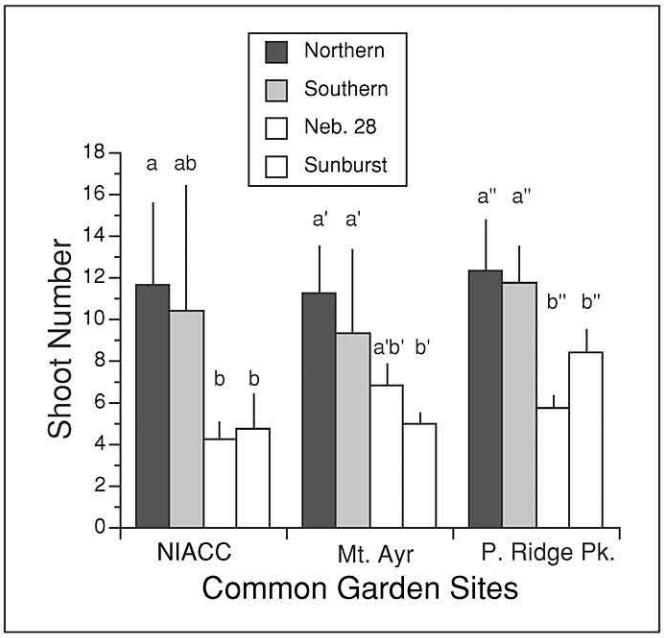

Figure 2. Mean number of shoots per plant and standard deviations of *Panicum virgatum* populations grown in common gardens in Iowa and sampled in 2002. Iowa remnant populations (Northern and Southern) had significantly more shoots over the cultivated varieties (Neb. 28 and Sunburst) when grown in Iowa. Shoot data from each common garden was analyzed separately with a one-way ANOVA. Letters denote significantly ($P < 0.05$) different means with Tukey pairwise comparisons tests. Common gardens were located at NIACC (northern Iowa), Mt. Ayr Wildlife Area (southern Iowa), and Pioneer Ridge Park (southern Iowa).

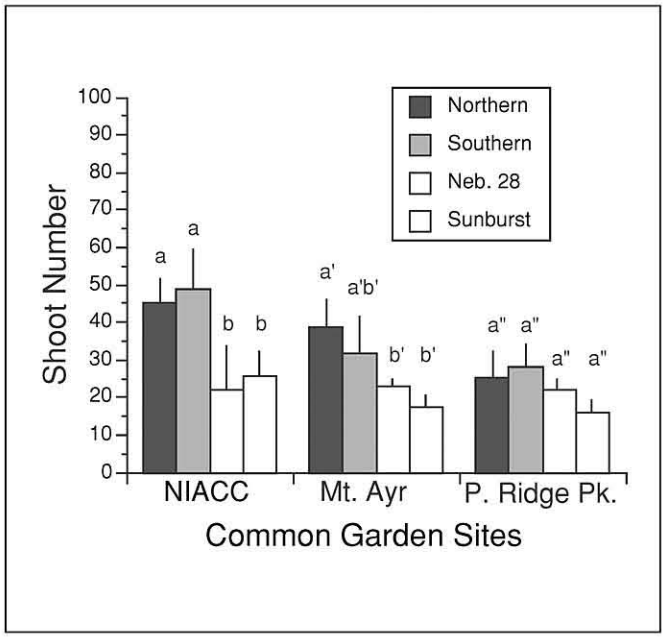

Figure 3. Mean number of shoots per plant and standard deviations of *Panicum virgatum* populations grown in Iowa and sampled in 2003.Iowa remnant populations (Northern and Southern) had significantly more shoots than the cultivars (Neb. 28 and Sunburst) when grown in Iowa. Shoot data from each common garden was analyzed separately with a one-way ANOVA. Different letters denotes significant ($P < 0.05$) different means with Tukey pairwise comparisons test. Common gardens were located at NIACC (northern Iowa), Mt. Ayr Wildlife Area (southern Iowa), and Pioneer Ridge Park (southern Iowa).

common garden, Southern populations of switchgrass produced no viable seed and could not be included in the statistical analysis in 2003.

Seed viability was not significantly ($P > 0.05$) different between Northern and Southern populations of stiff tickseed at all three common gardens in 2003 (Table 2). Seed viability was slightly improved for both Northern and Southern populations of stiff tickseed when grown in northern Iowa.

Discussion

Seed origin was a factor affecting plant fitness for switchgrass cultivars. Nebraska 28 had reduced growth and increased mortality compared to Iowa remnant populations. Nebraska 28 had the highest mortality and least growth of all switchgrass populations. Extreme habitat differences between the common garden sites and the Nebraska 28 remnant site may have contributed to its poor performance. Nebraska 28 was developed from a remnant population in the Sandhills of north-central Nebraska (Alderson and Sharp 1993). Average annual precipitation in the Sandhill region where Nebraska 28 originated is 58 cm compared to 88 cm in north and south central Iowa (NOAA 2004). In addition, soil types of the common gardens differ from the Nebraska Sandhills. Nebraska Sandhills soils consist of deep, well-drained sand with very little organic content (Moran and others 1983). In contrast, northern Iowa common garden soil consist of well-drained Kenyon loam soil high in organic content, and southern Iowa common garden soils have various poorly drained clay loam soil types (Dewitt 1981, Seaholm 1981, Boeckman 1992). Nebraska 28 may not be well suited to grow in Iowa's distinctly different climate and soils.

Sunburst had significantly fewer shoots compared to Iowa remnant populations (Figure 2, Figure 3). Forage production was a selected trait during the development of Sunburst (Boe and Ross 1998). Iowa remnant populations with no trait selection produced more shoots than Sunburst in both years of the experiment may be indicative of the problems associated with using distant cultivars in lieu of seed collected from local and regional remnants.

It appeared that weather was a significant factor affecting anthesis and subsequent seed viability in Year Two. In 2002 (Year One) rainfall was at or above the 30-year average (NOAA 2002). Rainfall did not appear to effect flowering of switchgrass in that year. However, anthesis for switchgrass populations occurred at different times during August. It was observed that the Northern, Nebraska 28, and Sunburst populations flowered in early August and the Southern populations flowered in late August. Precipitation in northern and southern Iowa in 2003 (Year Two) was far below the 30-year average (NOAA 2003). August was the driest month with less than 25% of normal rainfall in both regions of the state

(NOAA 2003). At Pioneer Ridge Park in southern Iowa, the above ground parts of many switchgrass plants had withered by late August when the flowering of southern Iowa populations had just begun. As a result, seed development on Southern populations of switchgrass at Pioneer Ridge Park was arrested and no viable seed was produced. In addition, drought conditions Year Two also affected the Southern populations of switchgrass at the other two common gardens. Mean seed viability of the Southern populations of switchgrass was 2.5 times lower in Year Two than the previous year. It is clear that water stress during anthesis may have been a major factor reducing seed viability in all switchgrass populations and had the greatest impact on the later-flowering southern Iowa populations in Year Two.

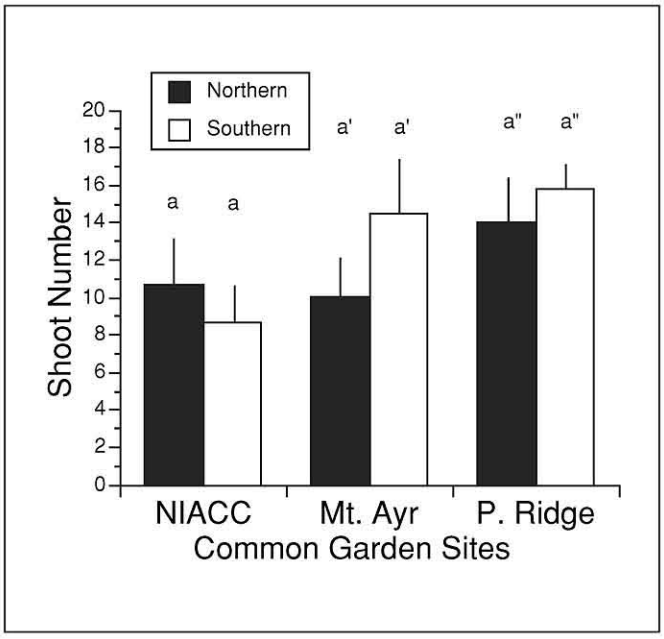

Figure 4. Mean number of shoots per plant and standard deviations of *Coreopsis palmata* populations sampled in 2003. There were no significant differences in shoot numbers between Northern and Southern populations when grown away from their remnant origins. Shoot data from each common garden was analyzed separately with a one-way ANOVA. Different letters denote significant ($P < 0.05$) means with Tukey pairwise comparisons test. Common gardens were located at NIACC (northern Iowa), Mt. Ayr Wildlife Area (southern Iowa), and Pioneer Ridge Park (southern Iowa).

There is some evidence that fitness of switchgrass seed can vary greatly among Iowa prairie remnants. Relatively equal numbers of seed were greenhouse planted for each switchgrass remnant. It was observed that few seedlings resulted from the small (fewer than 20 plants) remnants and no seedlings grew from two remnants that had less than 10 plants, whereas, seed from the largest (greater than 100 plants) remnants resulted in high seedling numbers. Small switchgrass remnants may be self-pollinating producing little or no viable seed (Talbert and others 1983, Taliaferro and Hopkins 1996). This would suggest that seed derived from larger remnant populations of switchgrass may be essential to reconstructing new stands or restoring existing stands of switchgrass in Iowa.

Fitness characteristics measured for stiff tickseed did not yield significant differences as did those found for switchgrass, although two trends were observed. Northern populations of stiff tickseed had increased shoots over southern populations in the northern common garden, and increased shoots for Southern populations over Northern populations in the southern common gardens (Figure 4). It appears that stiff tickseed should be planted close to its remnant source to maximize growth.

Conclusion

Based upon the data from this experiment, the origin of seed should be considered when reconstructing a prairie. Extreme habitat differences between where the seed originated from and where it's to be planted can affect plant fitness. This was clearly shown by the switchgrass cultivated variety Nebraska 28. Nebraska 28 grew poorly in all common garden locations. Seed that originated in the Sandhills of Nebraska should not be planted in Iowa's loamy soils. The advantages of planting regionally collected remnant seed may vary by species. Growth increased when remnant seed of stiff tickseed was planted within the same region it was collected. There was no conclusive evidence however that any plant fitness measures were improved for switchgrass.

This study was designed to look at the adaptability of remnant populations in Iowa. The species used in this experiment extend well beyond Iowa's borders, and grow in much different habitats. Future research with common garden experiments

Table 2. Seed viability and standard errors of remnant northern and southern *Coreopsis palmata* populations grown in common gardens in Iowa in 2003.

Common Seed Origin	Garden Location	Seed Viability (s.e.)	P-value (%)
NIACC (northern Iowa)	Northern	32.8 (3.71)	0.928
	Southern	33.1 (3.89)	
Mt. Ayr (southern Iowa)	Northern	23.9 (5.48)	0.903
	Southern	24.3 (3.94)	
Pioneer Ridge Park (southern Iowa)	Northern	26.2 (6.95)	0.949
	Southern	26.6 (9.25)	

There were no significant ($P > 0.05$) differences in germination of stiff tickseed populations when grown away from their remnant sources in Iowa. Seed viability tests were conducted by the Iowa State Seed Testing Laboratory in Ames, Iowa. Seed viability data from each common garden site were analyzed separately with a one-way ANOVA. Different letters denote significantly ($P < 0.05$) different means with a Tukey pairwise comparisons test.

should include plant species with narrower habitat ranges and distribution.

Acknowledgments

Thanks to the University of Northern Iowa undergraduate students Ben Stark, Andy Reeder, and Amy Carolan for their help with sampling and transplanting. A special thank you to Ed White, Iowa Department of Natural Resources; Kirk Baker, Wapello County Conservation; Robert Schwartz, Winnebago County Conservation; and Carol Schutte, North Iowa Area Community College for the use of their lawns and parks for the common gardens. The University of Northern Iowa Native Roadside Vegetation Center conducted this research with funding from the Federal Highway Administration.

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