JOURNAL OF THE TENNESSEE ACADEMY OF SCIENCE 79(1):13–17 JANUARY 2004

ASSESSMENT OF SPECIES FOR LANDSCAPE MANAGEMENT OF ARCHAEOLOGICAL SITES IN MIDDLE TENNESSEE

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ABSTRACT—The establishment of grasslands or wildflower meadows using native grasses and forbs is a possible management option on archaeological sites that are dominated by fescue. The goal of the present study was to evaluate the effectiveness of several species of grasses and forbs as replacements at archaeological sites. The investigation was set up in an old field containing lithic material (Gossette Tract, Cheatham County, Tennessee). Approximately 1.3 ha of ground was plowed during the winter 1999–2000, seeds of five forbs and four grasses were sown in 8 to 24 0.04-ha plots during winter 2000, and growth and reproduction of the planted species were evaluated during the 2000 and 2001 growing seasons. Growth of native and nonnative species (volunteers) associated with the planted ones was recorded during both growing seasons as well. The grasses *Schizachyrium scoparium* and *Tridens flavus* and the forbs *Rudbeckia amplexicaulis, R. hirta,* and *Vernonia gigantea* established well during the first year of planting. The number of *Echinacea purpurea* plants increased between 2000 and 2001, but none flowered until 2002. *Asclepias tuberosa* was not recorded in 2000, but two plants flowered in the study plots and several were noted outside the study plots during 2001. The grasses *Tripsacum dactyloides* and *Elymus virginicus* were unsuccessful for establishment. Neither the planted species nor the volunteer species responded positively to fertilizer addition. Limited use of herbicides and fertilizer is recommended for the restoration of archaeological sites.

Throughout Tennessee, the state owns and manages many prehistoric archaeological sites that are kept in a natural condition. Visitor impact is relatively low at these sites since some are open only to the public for occasional tours. Examples of such sites in Tennessee are Mound Bottom (ca. A.D. 700–1325) in Cheatham County and Sellar's Mound (ca. A.D. 900–1250) in Wilson County. Maintaining sites as open areas that are pleasing to the public's eyes while being cost effective for management purposes is challenging. A problematic feature of some archaeological sites is controlling the encroachment of woody plants and exotic plants, particularly fescue [*Lolium arundinaceum* (Schreb.) S. J. Darbyshire or *L. pratense* (Huds.) S. J. Darbyshire]. The most common management protocol at sites is mowing, which is done once or twice a year. On the other hand, the use of other management tools, such as fire, is inappropriate since alteration of the archaeological record might occur.

One option for managing archaeological sites would be to restore them to grassland (prairie)-like habitats or wildflower meadows using native grasses and forbs. This tactic would be ecologically appropriate since grassy openings were present in the forested landscape when the first European settlers arrived in Tennessee (DeSelm, 1989). A long-term goal of establishing a native grassland/meadow on archaeological sites would be replacement of fescue with native grasses and showy forbs. Reduced frequency in mowing would be a second goal. The one obstacle in converting a meadow consisting chiefly of fescue to one of native grasses and forbs is information regarding species that might be appropriate substitutes (N. Fielder, pers. comm.).

The focus of the present study was to evaluate the effectiveness of four grasses and five forbs as replacements in archaeological sites dominated by fescue. Grass and forb seeds were sown in winter 2000, and growth and reproduction of plants were evaluated in autumns 2000 and 2001. The application of fertilizer was tested during the 2000 growing season. Growth of other native and nonnative species associated with the planted species was evaluated in both years as well.

MATERIALS AND METHODS

The study site was established on a terrace above the Harpeth River in Cheatham County, Tennessee. This state-owned property is called the Gossette Tract and lies across the river from the state archaeological site Mound Bottom. The tract was previously farmland, most recently producing corn and a mixed fescue-type grass hay. Since state ownership in the 1970's, most of the 20.2 ha site was cut for hay biannually. The study site was located several hundred meters from the flood plain. A preliminary plant inventory conducted during the 1999 growing season found that the most common plants in the field were *Andropogon virginicus* L., *Cirsium vulgare* (Savi) Tenore, *Lolium arundinacea,* and *Trifolium repens* L. An initial soil test showed that the field had relatively high levels of P available to plants; low levels of K; sufficient amounts of Ca, Mg, Zn, Fe, and Mn; and a pH of 5.2. An archaeological survey found much lithic material from the Archaic Period was exposed after plowing (Welch, 2002).

Approximately 1.3 ha of ground was plowed between 31 December 1999 and 6 February 2000 using a standard eight-foot disk, and then two railroad crossties were placed on top of the disk to provide additional weight to break-up clods of soil and grass. Cross-disking was necessary to smooth the ground and assure that most of the soil was well broken. Completion of disking included dragging the ground with the crossties. Twenty-four

TABLE 1. Species planted, the recommended and actual amount of seeds sown, and the number of plots sown.

	Recommended (per 0.4 ha)	Actually used (per 0.04 ha)	Number of plots sown
Grasses			
Elymus virginicus	4.5–8.0 kg	2.0 kg	12
Schizachyrium scoparius	3.0–13.5 kg	1.5 kg	24
Tripsacum dactyloides	3.5–5.5 kg	0.6 kg	12
Tridens flavus	9.0–18.0 kg	2.0 kg	20
Forbs			
Asclepias tuberosa	1.0 kg	99.5 g	8
Echinacea purpurea	5.5 kg	597.2 g	24
Rudbeckia amplexicaulis	2.5–3.5 kg	398.1 g	20
Rudbeckia hirta	1.5–2.0 kg	199.1 g	12
Vernonia gigantea	0.5–1.0 kg	99.5 g	12

0.04 ha square plots were established. Metal posts marked the corners of each plot, and the site was surveyed and a plat drawn for a permanent record (Welch, 2002). The remaining plowed ground was not included in this study.

Five species of forbs and four species of grasses were chosen according to site compatibility, prevalence in Tennessee or southeastern United States, price, and minimum time required for germination (Table 1). Eight of the nine planted species are native to middle Tennessee (Chester et al., 1993, 1997), and several of them are recommended plants for landscape use in Tennessee (Harper-Lore and Wilson, 2000; Hunter, 2002). *Rudbeckia amplexicaulis* Vahl is not native to Tennessee but is widely planted in the state (Tennessee Department of Transportation, 2003); it is native to southeastern United States (Kartesz and Meacham, 1999). Seeds of *Asclepias tuberosa* L., *Schizachyrium scoparius* (Michx.) Nash, and *Vernonia gigantea* (Walt.) Trel. were collected from fields in Tennessee, while those of all other species came from stock grown in Iowa, Kansas, or elsewhere in the southeastern United States. Planting recommendations (Table 1) came from representatives of the seed vendors (Welch, 2002). Seeds were dispersed by various means. A hand-held dispenser was used to sow *Echinacea purpurea* (L.) Moench, *R. amplexicaulis, R. hirta* L., *Tridens flavus* (L.) A. Hitchc., and *Elymus virginicus* L. *Schizachyrium scoparius, Tripsacum dactyloides* (L.) L., and *Asclepias tuberosa* were spread by hand from a bucket. Due to the extreme lightness of *Vernonia altissima* seeds, they were sown by hand in a 1:1 mixture of seeds and sawdust. Seeds were sown in January and February (mostly) 2000 into 8 to 24 randomly-chosen plots, depending on the quantity of seeds available (Table 1).

The effects of fertilizer addition were tested in eight randomly selected plots, and the control was eight other plots in which fertilizer was not added. A 6-12-12 NPK fertilizer was applied by hand; each plot receiving 39.1 kg. The first application was on 15 March 2000 and the second on 2 November 2000. Four treatment and control plots contained four of the planted species (*Tridens flavus, Schizachyrium scoparius, Echinacea purpurea, Rudbeckia amplexicaulis*), while four other plots contained all nine planted species.

A 1-m^2 frame was placed at the center of each plot to reduce the influence of adjacent plots. Native and nonnative species that emerged but were not intentionally planted were called volunteers. Within the frame, the cover and density of all planted species and of the common nonnative and native volunteers were determined. Forbs were counted individually, but for grasses, tillers were counted as one individual. Height of the tallest stem and reproduction were recorded for all planted species. Even though *Andropogon virginicus* was already present at the site, the species was sown in eight plots and became established in six of them. However, *A. virginicus* was considered a native volunteer in the data analyses.

Rain gauges and a thermometer located at the site recorded daily precipitation and temperature from January to December in 2000 and 2001. Mean daily maximum and minimum temperatures were 17.7 and 7.3°C, respectively, for 2000 and 18.3 and 9.3°C, respectively, during 2001. Mean monthly precipitation totaled 89.3 mm and 105.2 mm for 2000 and 2001, respectively. Values for these variables did not differ appreciably from long-term data (1961–1990) recorded in Nashville, Tennessee, approximately 30 km from the study site. The 30-year normal daily maximum and minimum temperatures were 21.0 and 9.1°C, respectively, and monthly precipitation was 100.1 mm (National Climatic Data Center, 2000).

Two-way analysis of variance (ANOVA) examined the effects and interaction of year and fertilizer addition on the growth of volunteer (native and nonnative) species and of planted species (SPSS, 2000). Means of the various growth parameters were determined to be significantly different between years based on t-tests.

RESULTS

Density of native volunteers and cover and density of nonnative volunteers were unaffected by fertilizer addition (treatment factor, year by treatment interaction, $F \leq 3.981$, $P \geq 0.056$). On the other hand, cover of native volunteers was significantly higher in the unfertilized plots (mean $\pm$ SE = 7512.5 $\pm$ 927.0 cm^2) than in the fertilized plots (3750.0 $\pm$ 895.6 cm^2) in 2000 (t = 2.919, P = 0.001), but it did not differ between the two sets of plots in 2001 (t = 0.569, P = 0.578). Approximately 26 native and six nonnative volunteer species were present in the plots in 2000, and 33 native and eight nonnative volunteer species in 2001 (Welch, 2002).

The addition of fertilizer to the study plots did not significantly affect the cover, density, or height of *Tridens flavus, Schizachyrium scoparium, Rudbeckia hirta, R. amplexicaule,* or *Vernonia gigantea* (treatment factor, year by treatment interaction, $F \leq 3.675$, $P \geq 0.065$). Sample size was not large enough to adequately test for a treatment effect in *Echinacea purpurea.* Data on the planted species were pooled over the fertilizer treatments for all subsequent analyses.

Percentage of plots in which species became established varied from eight for *Echinacea purpurea* to 67 for *Rudbeckia hirta* during the 2000 growing season (Table 2). Establishment increased in 2001 for all planted species that became established in 2000, except *Tridens flavus* that slightly decreased. *Schizachyrium scoparium* and *Echinacea purpurea* showed the most dramatic increases. *Asclepias tuberosa* did not establish in 2000,

TABLE 2. Establishment and mean ± *SE* values for cover, density, and height of the study species.

	2000	2001
Establishment (% of plots sown)		
Elymus virginicus	0	0
Schizachyrium scoparius	21	79
Tripsacum dactyloides	0	0
Tridens flavus	50	45
Asclepias tuberosa	0	12
Echinacea purpurea	8	50
Rudbeckia amplexicaulis	40	65
Rudbeckia hirta	67	83
Vernonia gigantea	25	50
Cover (cm^2)		
Schizachyrium scoparius	166.7 ± 101.9	975.0 ± 202.6*
Tridens flavus	300.0 ± 86.4	200.0 ± 54.3
Asclepias tuberosa	0.0	800.0[a]
Echinacea purpurea	66.7 ± 52.0	295.8 ± 102.8
Rudbeckia amplexicaulis	355.0 ± 155.7	355.0 ± 76.2
Rudbeckia hirta	1433.3 ± 404.4	983.3 ± 219.1
Vernonia gigantea	83.3 ± 45.8	300.0 ± 111.5
Density (number per plot)		
Schizachyrium scoparius	1.0 ± 0.6	4.2 ± 0.9*
Tridens flavus	1.2 ± 0.4	0.9 ± 0.3
Asclepias tuberosa	0.0	2.0[a]
Echinacea purpurea	0.3 ± 0.2	1.3 ± 0.5
Rudbeckia amplexicaulis	5.4 ± 2.3	3.4 ± 0.8
Rudbeckia hirta	20.8 ± 6.5	11.2 ± 2.4
Vernonia gigantea	0.3 ± 0.2	1.4 ± 0.6
Height (cm)		
Schizachyrium scoparius	6.8 ± 2.9	42.1 ± 5.8*
Tridens flavus	36.5 ± 9.4	36.2 ± 9.8
Asclepias tuberosa	0.0	46.5[a]
Echinacea purpurea	1.2 ± 0.9	8.1 ± 1.7*
Rudbeckia amplexicaulis	7.2 ± 2.4	17.2 ± 3.1*
Rudbeckia hirta	23.2 ± 5.4	33.9 ± 5.9
Vernonia gigantea	4.9 ± 2.9	16.1 ± 5.4

* Value is significantly different from the 2000 value ($P \leq 0.013$; $t \geq 2.592$).

[a] Represents the mean of two plants in one plot.

but did so the following year. *Elymus virginicus* and *Tripsacum dactyloides* did not appear in 2000 or 2001.

The cover, density, and height of *Tridens flavus, Rudbeckia hirta,* and *Vernonia gigantea* did not differ significantly between the 2000 and 2001 growing seasons ($P \geq 0.088$) (Table 2). On the other hand, all three parameters for *Schizachyrium scoparium* significantly increased from 2000 to 2001 ($P \leq 0.006$). Although cover and density did not differ between years for *Echinacea purpurea* and *Rudbeckia amplexicaulis* ($P \geq 0.053$), plants of both species were significantly taller in 2001 than in 2000 ($P \leq 0.013$).

Plants of *Rudbeckia amplexicaulis, R. hirta* and *Vernonia gigantea* flowered in 2000 and 2001, whereas those of *Asclepias tuberosa* flowered only in 2001. None of the *Echinacea purpurea* flowered during the study. *Schizachyrium scoparium* and *Tridens flavus* flowered in 2000 and 2001.

DISCUSSION

The growth and reproductive assessments made over the two-year period of the study showed that the grasses *Schizachyrium scoparium* and *Tridens flavus* and the forbs *Rudbeckia amplexicaulis, R. hirta,* and *Vernonia gigantea* established well during the first year of planting. The number of *Echinacea purpurea* plants increased (11 in 2000 to 36 in 2001), even though none of them flowered during the study. *Asclepias tuberosa* was not recorded in 2000, but two plants flowered in 2001 and ten other plants were noted growing in plots outside of the study site. *Tridens flavus* did not perform as well as some of the other species, but this species is a visually appealing plant for archaeological sites due to its purplish inflorescence. On the other hand, two species of grasses, *Tripsacum dactyloides* and *Elymus virginicus,* were unsuccessful for establishment.

Although *Echinacea purpurea* produced basal leaves during both growing seasons, no flowers were observed until 2002. A couple of small individuals of this species first flowered in 2002, but as many as 10–15 flowered in various plots in 2003. This species often requires several years of growth before reproduction occurs. Observation of flowerbeds containing *E. purpurea* at local natural areas in Nashville and Dickson, Tennessee indicated that the plant often begins to produce flowers during the third year after being sown. Other species of *Echinacea,* such as *E. angustifolia, E. pallida,* and *E. tennesseensis,* first flower during their second or third year of growth (Baskin et al., 1997). *Echinacea purpurea* is very successful when grown with other species, particularly invasive ones (Rothenberger, 1992), and we expect an increase in abundance in future years.

Asclepias tuberosa produced no flowers during the first growing season, but did so during the second year. This plant produces a large, thick root, that probably needs substantial growth before flowering occurs. Specimens propagated from seed in the greenhouse at Radnor Lake State Natural Area (Nashville, Tennessee) required a year of growth before producing any substantial vegetation (M. Carlton, pers. comm.). Shirley (1994) also noted that 2–3 years of growth were required before plants would bloom.

Two grasses, *Elymus virginicus* and *Tripsacum dactyloides,* were never observed growing inside or outside the study plots over the two-year study. Adverse conditions during collection, handling, or shipping may have affected the viability of the seeds of these two species. However, unsuitable soil conditions in the habitat and/or seed herbivory by wild turkeys (*Meleagris gallopavo*) are other possible reasons for the absence of these two species from our plots. Both prefer wetter soil than that provided in the study site (Gleason and Cronguist, 1991; B. Hogan, pers. comm.). Although located along the Harpeth River, the study site was established on a terrace in a relatively dry, open area with limited soil moisture. Wild turkeys were observed on numerous occasions foraging and/or dusting near the study site and within some of the same plots in which seeds of *E. virginicus* and *T. dactyloides* were sown. The turkeys may have foraged on seeds of these two species since they are known to eat seeds of other grasses (Martin et al., 1951). *Tripsacum dactyloides* seeds might have been particularly appealing since they are much larger than those of the other sown species.

Plants in our experimental plots did not respond dramatically to fertilizer addition. Other experiments performed in old fields have found that plants responded positively to fertilizer application (Mellinger and McNaughton, 1975; Bakelaar and Odum, 1978). However, Tilman (1987) found that plants growing in old fields did not respond to the addition of P, K, Ca, Mg, S, and trace metals but did so to N. Two possible explanations might account for the lack of a positive response of plants to fertilizer addition in our plots: the fertilizer should have contained a higher percentage of N, P, and K and/or a higher amount of fertilizer should have been applied. A lack of statistical power to adequately detect a fertilizer effect also might have compounded the problem. A power analysis ($\alpha = 0.05$; SPSS, 2000) suggested that the power of our test was low (about 0.05–0.50), and an increase in sample size would have improved our chances of detecting a real effect if it existed. Considering that the managers of archaeological sites do not want an additional expense of fertilizers, and that some native plants grow fine in low-fertility soil, fertilization should not be necessary in most cases.

Among the grasses, *Schizachyrium scoparium* was a very successful species. This is a warm-season bunch grass that thrives in relatively poor soils. In competition studies conducted on low-N soils, *S. scoparium* and *Andropogon gerardii* Vitman completely displaced three cool-season grasses [*Poa pratensis* L., *Agropyron repens* (L.) Beauv., *Agrostis scabra* Willd.] within three years. However, displacement did not occur on high-N soils (Wedin and Tilman, 1992). An adverse outcome of using fertilizers during the establishment of meadows could be the displacement of *S. scoparium* by fescue. Fescue generally responds positively to fertilizer application, particularly N (Gibson and Newman, 2001). A sward of fescue could develop inadvertently making the establishment of a native species meadow difficult.

Herbicides could be administered prior to planting to prohibit the growth of unwanted species. Jackson (1999) found that pretreating sod with glyphosate to establish prairie grasses and forbs in Iowa succeeded in temporally reducing the vegetation cover. On the other hand, Bugg et al. (1997) cautioned about using some herbicides for establishing perennial grasses along California roadsides since they might kill the planted species. Hand application of herbicides on individual plants after the establishment of desired species may be an effective use of the chemicals. For the present project, however, the goal was to create a native meadow that was cost effective and did not require excessive mowing or purchasing of chemicals.

While many areas had much open ground in our study site, other areas contained sprouts of trees including several *Quercus* spp., *Acer saccharinum* L., *A. negundo* L., *Ulmus* spp., *Diospyros virginiana* L., and *Prunus serotina* Ehrh. The native shrub *Symphoricarpos orbiculatus* Moench grew in several plots as well. The presence of woody species that obtained growths of over 0.5 m during an early stage of succession following plowing suggests that maintaining a meadow appearance may require manually removing trees as they sprout. Once meadow grasses and forbs are well established, competition from them may suppress the growth of established tree seedlings (Burton and Bazzaz, 1995).

In order to establish a meadow consisting primarily of native plants, the present study suggests that the following approach should be attempted. In areas where possible, the land should be plowed or disked thoroughly and any persistent clumps of fescue be removed by hand. For earthen mounds, hand removal or herbicide application in place of the disk would have to suffice to prohibit harm to the archaeological record. Sowing (or planting) of native grasses and forbs should follow. After a season of growth, any unwanted saplings should be removed by hand (or by tiller) as well as any aggressive patches of fescue or other exotics. Rothenberger (1992) found that mowing trouble spots to a height of 0.2 m assisted the desired native species to gradually become dominant. After removal of unwanted species, reseed (or replant) with the desired species. Saplings can be controlled by mowing during winter. Extensive management should decrease over time, but annual monitoring for unwanted species and hand removal or spot-herbicide application will probably be necessary for a few years after the meadow is established.

ACKNOWLEDGMENTS

Special gratitude is extended to M. Carlton and N. Fielder for assistance and support.

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