Herbaceous responses to seasonal burning in experimental tallgrass prairie plots

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Research Project Summary:

CITATION:
Smith, Jane Kapler. 2010. Herbaceous responses to seasonal burning in experimental tallgrass prairie plots. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2010, August 19].

SOURCES:
Unless otherwise indicated, the information in this Research Project Summary comes from the following papers:

Copeland, Tanya E.; Sluis, William; Howe, Henry F. 2002. Fire season and dominance in an Illinois tallgrass prairie restoration. Restoration Ecology. 10(2): 315-323. [1].

Howe, Henry F. 1994. Response of early- and late-flowering plants to fire season in experimental prairies. Ecological Applications. 4(1): 121-133. [3].

Howe, Henry F. 1995. Succession and fire season in experimental prairie plantings. Ecology. 76(6): 1917-1925. [4].

Howe, Henry F. 1999. Response of Zizia aurea to seasonal mowing and fire in a restored prairie. The American Midland Naturalist. 141(2): 373-380. [5].

Howe, Henry F. 2000. Grass response to seasonal burns in experimental plantings. Journal of Range Management. 53(4): 437-441. [6].

INTRODUCTION:
This Research Project Summary covers 4 studies, all investigating the responses of early- and late-flowering herbaceous species to spring and summer fires in sites where tallgrass prairie species had been planted in former agricultural fields. The first study, described in 2 papers [3,4], focuses on grasses and forbs, both early- and late-flowering species. The second [6] focuses exclusively on dominant grasses. The third [5] focuses on a single perennial

forb, golden zizia, as an example of an early-flowering subdominant species. The fourth [1] focuses on early- and late-flowering subdominant herbaceous species. Two hypotheses were investigated:

Hypothesis 1, referred to below as the "flowering-season hypothesis": Fire reduces the abundance of species that are experiencing their greatest growth at the time of burning. If this hypothesis is valid, then spring fires should reduce early-flowering species (including C_3 grasses), and summer fires should reduce late-flowering species (including C_4 grasses).

Hypothesis 2, referred to below as the "subdominant species hypothesis": Summer fires favor subdominant species. The authors describe 3 ways in which summer fire could improve growing conditions for subdominants: first, by reducing shade from late-flowering dominants, which are generally taller than early-flowering species [1]; second, by removing litter and providing openings that persist through most of the subsequent growing season [1,4]; third, by producing more variation in fire behavior and direct effects, thus increasing the number of species that could meet with favorable conditions in the postfire environment [1].

Common names are used throughout this summary. For a complete list of the common and scientific names of species discussed and for links to FEIS species reviews, see the Appendix.

STUDY LOCATION:
The first 3 studies [3,4,5,6] were conducted near Viola, southwestern Wisconsin. The fourth study [1] was conducted at Goose Lake Prairie State Natural Area in Grundy County, northeastern Illinois.

SITE DESCRIPTION:
The first 3 studies [3,4,5,6] were conducted in a field on a flat bottomland floodplain classified as "wet-mesic" [6], where shallow standing water accumulates in early spring and drains from April to mid-May. The valley collects cold air, so the frost-free season is limited to mid-May through mid-September. Soils are loams with 3.4% organic matter and pH averaging 7.01 [3].

The 4th study [1] was conducted on sites with level topography, where much of the surrounding area is wet prairie or prairie marsh with poor natural drainage. Two soil types occur in the study area: a loam and a silty loam.

All studies used small treatment plots (maximum size 12 × 15 m [3,4]) in former agricultural sites that had been cleared of all vegetation, then planted with herbs native to tallgrass prairie. (However, some nonnative species may have been planted in the plots used for Study 2.) Before conversion to agriculture, the study sites probably experienced the historical fire regime described in Table 1:

Table 1. Fire regime information on the vegetation community studied in this Research Project Summary. Fire regime characteristics are taken from the LANDFIRE Rapid Assessment Vegetation Model [8]. This vegetation model was developed by local experts using available literature, local data, and/or expert opinion as documented in the PDF file linked from the Potential Natural Vegetation Group listed below. Cells are blank where information is not available in the Rapid Assessment Vegetation Model.

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Central tallgrass prairie	Replacement	75%	5	3	5
	Mixed	11%	34	1	100
	Surface or low	13%	28	1	50

*Fire Severities:
Replacement=Any fire that causes greater than 75% top removal of a vegetation-fuel type, resulting in general replacement of existing vegetation; may or may not cause a lethal effect on the plants.

Mixed=Any fire burning more than 5% of an area that does not qualify as a replacement, surface, or low-severity fire; includes mosaic and other fires that are intermediate in effects.
Surface or low=Any fire that causes less than 25% upper layer replacement and/or removal in a vegetation-fuel class but burns 5% or more of the area [2,7].

PLANT PHENOLOGY:
These studies focus specifically on relationships between phenology and burn season. Spring fires were conducted as early as March 31 and as late as May 18, when "early-flowering" species (i.e., flower and set seed before mid-July) were likely to be most sensitive. Summer fires were conducted as early as July 15 and as late as September 3, when "late-flowering" species (i.e., flower and set seed after mid-July) were likely to be most sensitive. "Mid-flowering" species (i.e., flower and set seed June through August) were also observed. (Definitions of flowering periods are from [4].)

FIRE SEASON AND SEVERITY CLASSIFICATION:
Spring/summer, mixed severity, especially in summer burns [5]

RESULTS FROM INDIVIDUAL STUDIES:
Plant responses to fire were measured the growing season after the final burn treatment in each study. Preburn conditions and results of the 4 studies are summarized individually below. The Fire Management Implications section integrates results from all studies, discusses ways in which these studies are and are not consistent with the hypotheses above, and summarizes management implications of the research.

Study 1: Responses of early- and late-flowering prairie species to burning in different seasons
Study 2: Responses of early- and late-flowering grasses to burning in different seasons
Study 3: Response of an early-flowering, subdominant forb to burning in different seasons
Study 4: Responses of dominant and subdominant prairie species to burning in different seasons

Study 1: Responses of early- and late-flowering prairie species to burning in different seasons [3,4]

Prefire plant community: After existing vegetation was removed by herbicide application, plowing, and disking, the site was planted in 1986 with seed of more than 70 prairie species. By 1990, an additional 35 species had volunteered (not planted, either native or nonnative) on the site. The 12 most common species are discussed below. Despite the overall variety of species, some study plots were virtual monocultures.

Fire description: One-third of experimental plots were burned twice in the spring (1989 and 1992); one-third were burned twice in summer of the same years; and one-third were left unburned (Table 2).

Table 2. Fire behavior for plots planted with prairie species in 1986 [4].

Burn Date	Burn time (min)*	Flame height (m)	Fireline intensity (kW/m)**	Immediate fire effects
Spring-burned plots				
3/31/1989	3-5	1.5	626	Reduced all aboveground biomass to ash
4/2/1992	10-15	0.5	57	Reduced 45% of aboveground biomass to ash, left patches of moist litter 1-5 cm deep
Summer-burned plots				
7/15/1989	15-30	0.8	161	Reduced 34% of aboveground biomass to ash, left 66% of biomass standing, with dead or top-killed stems
7/19/1992	30-60	0.1	2	Reduced all litter to ash, left some upright vegetation standing, with dead or top-killed

				stems

*Time to burn 12 × 15 m plot
**Estimated from flame height

Fire effects on plant community: Plant responses were measured the growing season after the each burn year (1990 and 1993).

The summer after the first burns (1990), 12 species occurred with ≥10% cover in at least 1 treatment, so their frequency and canopy cover were analyzed for different responses (Table 3). Several early-flowering species increased after 1 summer burn, as predicted; these include black-eyed Susan and quackgrass. However, another early-flowering species, reed canarygrass, did not respond positively to 1 summer burn. Switchgrass, a late-flowering species, decreased as predicted after 1 summer burn, but most other late-flowering species did not decrease.

Table 3. Responses of common herbaceous species 1 growing season after a single spring or summer burn in experimental tallgrass prairie plots [3]. All of these species except Canada horseweed, white heath aster, Canada wildrye, and indiangrass are followed through a second burn and recovery year in table 4.

Species	Flowering season*	Change in % frequency	Change in % canopy cover	Consistent with Hypothesis 1?
Forbs:				
black-eyed Susan	early	Increased on summer burns	Increased on summer burns	yes
Canada goldenrod	late	Increased from 1988 to 1990 for all treatments	Not affected by burns	no
Canadian horseweed	late	Decreased on spring burns and controls, increased on summer burns	Decreased on spring burns and control, unchanged on summer burns	no
eastern daisy fleabane	mid	Decreased on spring burns and unburned plots	No clear pattern	no
white heath aster	late	Not affected by year or treatment	Not affected by year or treatment	no
white panicle aster	late	Increased from 1988 to 1990 for all treatments	Not affected by year or treatment	no
Grasses:				
big bluestem	late	Increased from 1988 to 1990 on all treatments	Increased from 1988 to 1990 on all treatments	no
Canada wildrye	late	Reduced on all treatments	No clear pattern	no
indiangrass	late	Not affected by year or treatment	Not affected by year or treatment	no
quackgrass	early	Increased on summer burns	Decreased on spring burns and unburned plots	yes
reed canarygrass	early	Not affected by year or treatment	Not affected by year or treatment	no
switchgrass	late	Decreased on summer burns	Decreased on summer burns	yes

*Early=flower and seed before mid-July; mid=flower and set seed June through August; late=flower and set seed after mid-July

[4]

After the 2nd set of burns, only 8 species were abundant enough to be analyzed quantitatively (Table 4). Consistent with Hypothesis 1 (that vulnerability to fire is greatest at the time of flowering), early-flowering species were more abundant on summer-burned than spring-burned plots. Responses of late-flowering species were less consistent with the flowering-season hypothesis. Switchgrass declined after burn treatments, but the decline was less severe on spring-burned than summer-burned plots. Big bluestem dominated most plots and increased in all treatments over time. Two late-flowering forbs, Canada goldenrod and white panicle aster, increased throughout the study and were not noticeably influenced by fire. The authors note that big bluestem and these 2 forbs are "vigorous cloners", which is likely to reduce their sensitivity to fire.

Table 4. Mean (SE) cover (%) of herbs in twice-burned plots the summer after the 2nd burn [4]. For information on 1st-year responses, see table 3.

Species	Flowering season	Spring burned	Summer burned	Unburned	Consistent with Hypothesis 1?
Forbs:					
black-eyed Susan	early	0	7.5 (6.1)*	0	yes
Canada goldenrod	late	25.1 (17.2)	14.2 (12.6)	29.3 (16.0)	no
eastern daisy fleabane	mid	0.7 (0.7)	1.2 (1.4)	0.1 (0.2)	no
white panicle aster	late	4.6 (5.6)	5.1 (9.7)	8.9 (9.5)	no
Grasses:					
big bluestem	late	52.7 (19.6)	38.9 (15.1)	43.6 (22.0)	no
quackgrass	early	0.1 (0.2)	4.9 (10.3)*	0.4 (1.0)	yes
reed canarygrass	early	1.5 (3.5)	18.6 (20.2)*	3.5 (4.3)	yes
switchgrass	late	12.3 (3.5)*	2.6 (2.0)	2.9 (4.4)	yes

*Significantly different from other treatments for this species, as indicated either by statistical analysis or by inspection where statistical tests were inapplicable

When species from the same flowering season were grouped for analysis, data for % cover were consistent with the flowering-season hypothesis: Cover of early-flowering herbs was greater after summer burns (32%) than after spring burns (2%) or in unburned treatments (4%) ($P \leq 0.001$). Cover of late-flowering herbs in spring burns and unburned treatments averaged 97% and 93%, respectively, and was significantly greater than in summer burns, where they retained dominance but with lower cover (66%) ($P \leq 0.001$).

Productivity of individual species was not consistent with the flowering-season hypothesis. In the growing season after the second set of burns, monoculture plots dominated by big bluestem had significantly more biomass than monoculture plots dominated by other species, with no significant differences between treatments (Table 5) [4].

Table 5. Mean (SE) biomass in monoculture plots after 2 burn treatments [4].

Species	Biomass (g/m²)
big bluestem	1384.0 (129.6)a
Canada goldenrod	838.4 (92.8)b
switchgrass	836.8 (100.8)b
reed canarygrass	598.4 (64.0)b
quackgrass	510.4 (64.0)b

*Means followed by different letters are significantly different (*P*<0.025).

Study 2: Responses of early- and late-flowering grasses to burning in different seasons [6]

Prefire plant community: After existing vegetation was removed by herbicide application, plowing, and disking, the site was planted in 1992 with 3 early-flowering C_3 grasses (reed canarygrass, slender wheatgrass, and Virginia rye) and three late-flowering C_4 grasses (big bluestem, prairie dropseed, and switchgrass). Spring and summer burns were conducted in 1995 and 1997; postfire responses were measured in summer 1998.

Fire description: One-third of experimental plots were burned twice in the spring (1995 and 1997); one-third were burned twice in summer of the same years; and one-third were left unburned (Table 6). Burns were conducted in the afternoon of nearly windless days when precipitation had been <1 cm in the previous 2 days. Ring-center firing was used for ignition. All burns killed or top-killed nearly all aboveground vegetation. The first 3 burns consumed most aboveground biomass, but the August 1997 fire left approximately 30% of dead vegetation standing, enough to provide shade after burning. The author mentions variation in fire behavior, caused by variation in abundance of green vegetation, as an important characteristic of summer fires in prairie ecosystems.

Table 6. Fire behavior for plots planted with prairie species in 1992. Values are means (SE, when available).

Date	Green biomass (g/m^2)	Preburn litter (g/m^2)	Preburn green (%)	Burn time (min)*	Flame length (m)	Fireline intensity (kW/m)**
Spring-burned plots						
5/18/1995	72 (4)	296 (29)	20 (2)	not given	0.6	98
5/04/1997	19 (3)	299 (31)	6 (1)	not given	1.19	421
Summer-burned plots						
8/12/1995	536 (106)	198 (19)	71 (4)	2.7 (0.3)	1.29	456
8/01/1997	310 (39)	234 (19)	56 (3)	4.2 (0.4)	0.67	116

*Time to burn 7 × 7 m plot
**Estimated from flame length

Fire effects on plant community: In the growing season after the 1st burn year, unburned plots had significantly more litter than burned plots (*P*<0.025). This difference did not appear to influence productivity.

The summer after the 2nd burns, unburned plots again had more litter than burned plots, 4 times as much as summer-burned plots. Productivity of C_3 and C_4 grasses was consistent with the flowering-season hypothesis: C_3 grasses produced less biomass in spring-burned than summer-burned plots, and C_4 grasses produced less biomass in summer-burned than spring-burned plots (*P*<0.05). Overall productivity was greatest on spring-burned plots, less on summer-burned plots, and least on unburned plots (*P*<0.05).

Species-specific results were consistent with the flowering-season hypothesis only for spring burns: Cover of two C_4 species (big bluestem and switchgrass) increased in spring-burned plots while cover of reed canarygrass (a C_3 species) decreased. Summer burning produced more variable results: Cover of reed canarygrass was expected to increase and cover of the C_4 grasses to decrease, but instead, reed canarygrass codominated the summer-burned plots with the other C_3 grasses and with C_4 grasses.

Study 3: Response of an early-flowering, subdominant forb to burning in different seasons [5]

Prefire plant community: After existing vegetation was removed by herbicide, burning, plowing, and disking, a mixture of species native to tallgrass prairie was planted in 1990. The mixture included golden zizia, an early-flowering, nonrhizomatous, perennial forb. This species was used as an example of an early-flowering, subdominant, perennial forb native to tallgrass prairie. Plots were dominated by reed canarygrass from 1992 through the end of the study (1996). Plots were burned by an intense wildfire in April 1994. Experimental burns were conducted in spring and summer 1995; postfire responses were measured in summer 1996.

Fire description: One-third of experimental plots were burned in spring 1995, one-third were burned in summer of the same year, and one-third were left unburned. Each burn covered a 9 × 9 m plot and lasted 3 to 5 minutes (Table 7).

Table 7. Experimental burns on plots planted with prairie species in 1990.

Treatment	Date burned	Flame height (m)	Fireline intensity (kW/m)*	Postburn surface with >1 cm litter, 1995 (%)	Mean canopy height, 1996 (cm)**	Mean litter depth, 1996 (cm)
Spring-burned	5/18/1995	0.6-1.6	460	<20	55 (3)a	11 (1)a
Summer-burned	8/19-21/1995	0.5-3.0	742	63	66 (5)b	4 (2)b
Unburned	N/A	N/A	N/A	100	43 (3)c	15 (1)c

*Estimated from flame height
**Values in the same column followed by different letters are significantly different ($P<0.001$)

Fire effects on plant community: Results from this study are consistent with both Hypothesis 1, that plants are most vulnerable to fire when they are flowering, and Hypothesis 2, that summer fire favors subdominant species. Golden zizia occurred on more plots in summer-burned than spring-burned treatments, had more stems per plot, and produced more flowering stems. Frequency and density of golden zizia were least on unburned plots (Table 8). Observations on individual plots suggested that higher-intensity fire favored golden zizia: 64% of individuals in summer-burned plots occurred in the 2 plots with the greatest fireline intensity and little or no litter remaining after fire, and all flowering in the summer-burned plots occurred in the 2 high-intensity burn plots.

Table 8. Abundance of golden zizia 1 year after burning.

Treatment	Frequency (%)	Mean (SE) density (stems/8 × 8 m plot)*	Number of flowering stems/total stems**
Spring-burned	50	2.5 (0.8)a	0/30
Summer-burned	83	17.4 (8.0)b	35/209
Unburned	33	0.8 (0.4)a	2/9

*Means followed by different letters are significantly different ($P<0.05$).
**Chi-square test indicated that differences in number of flowering stems between spring- and summer-burned plots were not likely due to chance ($P<0.05$).

Study 4: Responses of dominant and subdominant prairie species to burning in different seasons [1]

Prefire plant community: Prairie species were planted in 1976, after existing vegetation had been removed. Between 1987 and 1996, the site was burned 5 times with spring fires. In 1996, C_4 grasses (big bluestem, indiangrass, and switchgrass) were the dominant species.

Fire description: Experimental burns were conducted in 1997 (one-third of plots in spring, one-third in summer, and one-third left unburned), and vegetation was measured again in 1998. Fire spread rates were similar in all burns, averaging 1.3 m/min to cross a 10 × 10 m plot (Table 9).

Table 9. Burning conditions and fire behavior in plots planted with prairie species in 1976.*						
Date	Temperature (°C)	Relative humidity (%)	Wind (km/hr)	Flame height (m)	Fireline intensity (kW/m)**	Litter consumption (%)
Spring-burned						
4/23/1997	8	79	16	1.9 (0.4)a	1262	100a
Summer-burned						
9/3/1997	22	63	19	0.7 (0.1)b	118	91b

*Values within a column followed by different letters are significantly different (*P*<0.025).
**Calculated from flame height

Fire effects on plant community: Contrary to both Hypothesis 1, that plants are most vulnerable to fire when they are flowering, and Hypothesis 2, that summer fire favors subdominant species, summer burning favored big bluestem over all other species, both dominant and subdominant. Increased tillering of big bluestem was observed after both spring and summer burns, with a greater increase in summer-burned than spring-burned plots (Table 10). If this species' responses to summer fire were based only on phenology, it would be expected to decline after summer fire. The authors attribute big bluestem's increase to its ability to reproduce from extensive, sod-forming rhizomes and the fact that the late-summer burn removed litter for much of the subsequent growing season. The other late-flowering dominants (switchgrass and indiangrass) did not respond positively to burning in either spring or summer. Neither of these species produces dense sod like that of big bluestem. The authors indicate that switchgrass reproduces mainly from seed and basal buds; the FEIS review of indiangrass indicates it regenerates from seed and short rhizomes.

Table 10. Responses of dominant tallgrasses to spring and late-summer burns in experimental prairie plots. Data shown are mean number of reproductive tillers/m².*

Species	Spring burn		Late-summer burn	
	Preburn	Postburn	Preburn	Postburn
big bluestem	1.10a	4.93b	1.32a	14.90c
indiangrass	45.81a	37.71ab	32.81b	30.81b
switchgrass	3.12a	1.78a	2.22a	1.38a

*Means within a row followed by different letters are significantly different (*P*<0.05).

The effects of burn season on subdominant species were addressed according to flowering time (early- and late-flowering) rather than individual species. As predicted by Hypothesis 2, that summer fire favors subdominant species, species richness of subdominants increased in summer-burned plots regardless of flowering season, but not in spring-burned plots (Table 11). The similar responses of early- and late-flowering subdominants suggest that flowering season is not an important influence on subdominant species' responses to fire. Instead, their positive response to summer fire may be due to indirect effects, specifically reduction of litter during much of the subsequent growing season and reduction of shade from dominants.

Table 11. Richness of subdominant species in response to spring and late-summer burns in restored prairie. Data are means (SE) in 10 × 10 m plot.

Flowering season*	Spring burns		Late-summer burns	
	Preburn	Postburn (1 yr)	Preburn	Postburn (1 yr)
Early	0.67 (0.33)a**	1.17 (0.31)a	0.33 (0.21)a	2.5 (0.22)b
Mid	4.00 (0.73)a	3.33 (0.71)a	4.17 (1.11)a	6.17 (1.40)b
Late	3.50 (0.56)a	3.17 (0.54)a	3.67 (0.49)a	5.50 (0.56)b

*Early=flower and set seed before mid-July; mid=flower and set seed June through August; late=flower and set seed after mid-

July [4]
**Values within a row followed by different letters are significantly different (*P*<0.05).

Planted prairie species and volunteer species responded similarly to burn treatments in terms of species richness, indicating that burn treatments did not favor volunteer (likely undesired) species.

FIRE MANAGEMENT IMPLICATIONS:
Data from the first growing season after burning provided some evidence supporting the initial hypotheses but also demonstrated that responses to fire vary within flowering guilds and are often species-specific.

Regarding Hypothesis 1, that fire reduces the abundance of species that are experiencing their greatest growth at the time of burning: Results of spring burns were consistent with this hypothesis: Spring burns tended to reduce early-flowering dominant species and favor late-flowering ones (Studies 1, 2). Results of summer burns were more species-specific and not completely consistent with this hypothesis. Some late-flowering dominants declined after summer burns, but the C_4 grasses as a group still tended to dominate, and strongly rhizomatous species (grasses and forbs) often increased (Studies 1, 2, 4).

Regarding Hypothesis 2, that summer fires favor subdominant species and increase species richness: Studies 2, 3, and 4 appeared to validate this hypothesis, although Study 3 addressed only a single species. These studies demonstrated 2 possible mechanisms for positive responses to summer burning. First, summer-burned plots tended to have less litter in the subsequent growing season than spring-burned plots, possibly offering more microsites for establishment and growth of subdominant species regardless of their flowering seasons. Second, summer burns often included patches of very low fire intensity due to green vegetation; the resulting spatial variation in biomass consumption and litter removal could favor a greater variety of species after fire. A third possible mechanism, making more light available to subdominants by reducing cover of late-flowering dominants, was not clearly demonstrated by these studies, since many dominant grasses, both early- and late-flowering species, responded positively to summer fire.

Based on historical patterns, management-imposed fire regimes may need to deliberately vary fire season and fire behavior in tallgrass prairie ecosystems. In the past, a varied array of burn seasons, burn intervals, and grazing disturbances almost certainly produced a greater variety of species assemblages with more biodiversity than any single management regime (such as repeated dormant-season fires) could now produce [3]. Spring and fall fires can suppress woody species, but burning only in these seasons may favor C_4 grasses and late-flowering, rhizomatous forbs over all early-flowering species and late-flowering subdominants, eventually reducing biodiversity [5]. Summer burns could enhance the frequency and richness of subdominant species [4] without compromising vigor of dominant late-flowering grasses. Furthermore, it may be possible to thus increase biodiversity without disproportionately encouraging species that are not native to prairie ecosystems [1].

APPENDIX: SPECIES INCLUDED IN THIS SUMMARY:
This Research Project Summary contains fire effects and/or fire response information on the following species. For further information, follow the highlighted links to the FEIS reviews of those species.

Scientific name	**Common name**
Andropogon gerardii	big bluestem
Conyza canadensis	Canadian horseweed
Elymus canadensis	Canada wildrye
Elymus repens (*Agropyron repens*)*	quackgrass
Elymus trachycaulus (*Agropyron trachycaulum*)	slender wheatgrass
Elymus virginicus	Virginia rye
Erigeron annuus	eastern daisy fleabane
Panicum virgatum	switchgrass

Phalarus arundinacea	reed canarygrass
Rudbeckia hirta	black-eyed Susan
Solidago altissima	Canada goldenrod
Sorghastrum nutans	indiangrass
Sporobolus heterolepis	prairie dropseed
Symphyotrichum ericoides (*Aster ericoides*)	white heath aster
Symphyotrichum lanceolatum (*Aster simplex*)	white panicle aster
Zizia aurea	golden zizia
*For species that have undergone scientific name changes, names in parentheses are those used in the research paper.	

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