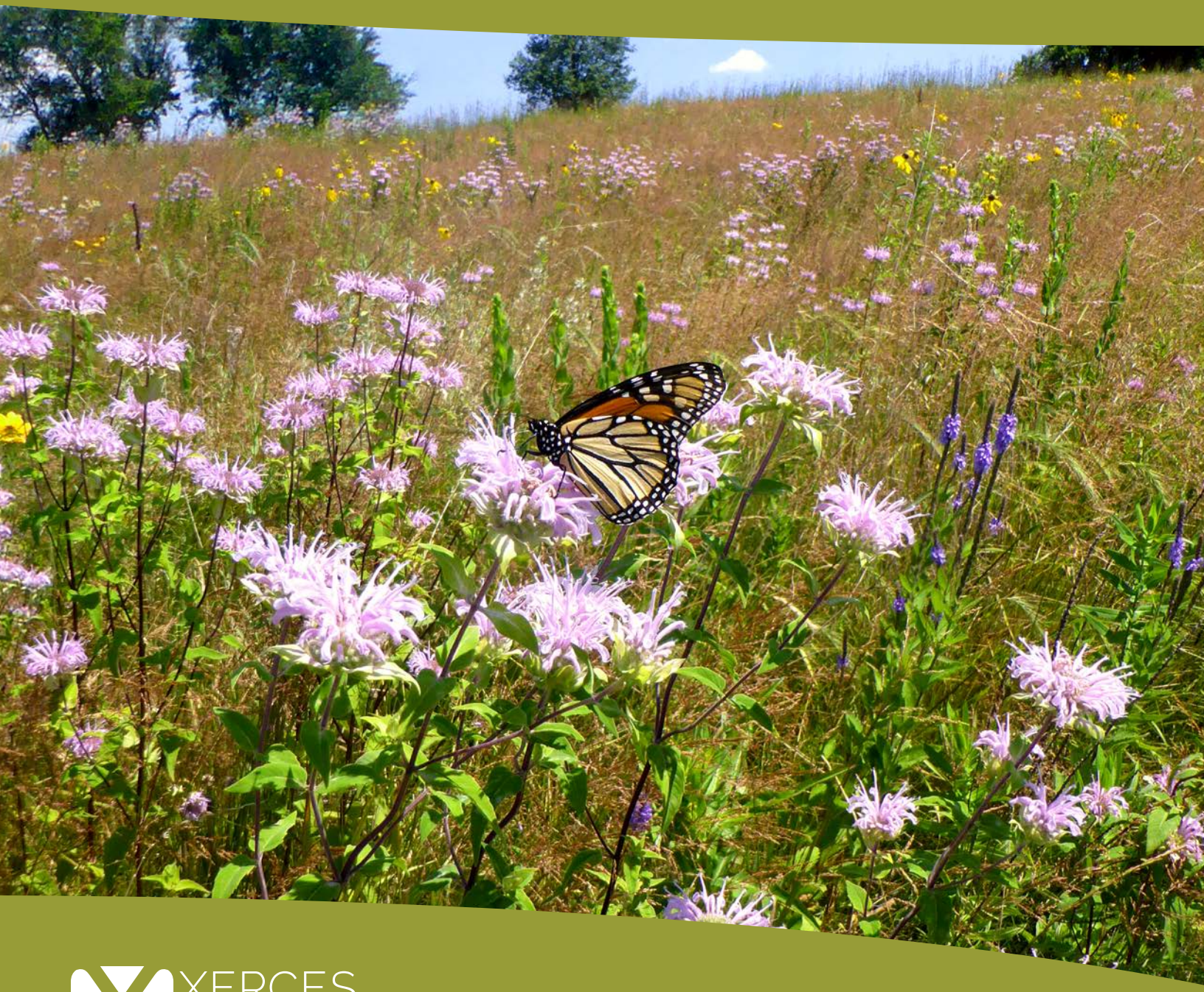
Interseeding Wildflowers to Diversify Grasslands for Pollinators

GUIDANCE FOR THE GREAT PLAINS AND MIDWEST REGIONS

Dave Williams, James Eckberg, Jennifer Hopwood, Rae Powers, Mace Vaughan,
Karin Jokela, Sarah Foltz Jordan, and Eric Lee-Mader



XERCES SOCIETY
for Invertebrate Conservation

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The Xerces Society for Invertebrate Conservation

www.xerces.org

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Covers: *front*—Interseeded prairie in Minnesota; *back*—red-belted bumble bee (*Bombus rufocinctus*) visiting purple prairie clover (*Dalea purpurea*) on an interseeded prairie in Minnesota. Photographs by The Xerces Society/ Sarah Foltz Jordan.

We are grateful to the photographers for allowing us to use their wonderful photographs (see *Additional Acknowledgments* on page 36). The copyright for all photographs is retained by the photographers. None of the photographs may be reproduced without permission from the photographer. If you wish to contact a photographer, please contact the Xerces Society at the address above.

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https://xerces.org/interseeding-grasslands-for-pollinators/

Contents

Figure 1: Wildflowers interseeded into grassy areas provide numerous resources for pollinators, including nectar to fuel the migration of the painted lady butterfly (*Vanessa cardui*), shown here.

Introduction

There are tens of millions of acres of grasslands in the United States, including grass-dominated stands enrolled in the Conservation Reserve Program (CRP) and other conservation set-aside programs. These grasslands range from diverse stands of native grasses and wildflowers to dense stands of non-native pasture grasses with few to no wildflowers. Native bees, honey bees, monarch butterflies, and other pollinators important to our ecosystems and agriculture need grassland wildflowers to survive. The recent declines of these pollinators have elevated the urgency to diversify stands dominated by grasses or weeds by incorporating wildflowers. Yet introducing wildflowers into low diversity sites with highly competitive stands of vegetation and managing stands so wildflowers can persist over time is a challenge.

Land managers and land owners can bring wildflowers back to low diversity, established grass stands through a process known as interseeding (also referred to as overseeding). Interseeding involves suppression of grasses and/or weeds using grazing, mowing, haying, prescribed burning, chemical control, disking, or a combination of these techniques prior to seeding, and again after seeding, to maximize wildflower establishment and persistence. Thoughtful selection of wildflower species that are most likely to take hold in the competitive environment of a grass-dominated planting and that are appropriate for the site is also required. Interseeding is an option for Mid-Contract Management required of CRP plantings, with cost-share assistance available. This publication provides guidelines and specific strategies for interseeding wildflowers into established grasslands and identifies species of wildflowers most likely to establish and persist in the Midwest and Great Plains.

Findings included here are the result of a review of published restoration research primarily from the Midwest and Great Plains states, and feedback obtained directly from current land managers, researchers, and land owners (hereafter referred to as practitioners) with expertise in this field who participated in an online survey and follow up conversations. Practitioners have experience interseeding in Minnesota, Iowa, North Dakota, Nebraska, Missouri, Kansas, and Illinois. The following recommendations are most relevant to Midwest and Great Plains states but may be adapted or applied in other regions as well.

Figure 2: On the left, a grass-dominated CRP site provides little value for pollinators. The CRP site on the right was interseeded with various native wildflower species that will both support pollinators and persist in grassland habitat.

Figure 3: Long-horned bee (*Melissodes* sp.) on golden tickseed (*Coreopsis tinctoria*).

1

Considerations When Interseeding Wildflowers

When and Where to Interseed

Land owners and land managers looking to diversify grasslands have several options. Some lands can be revitalized through careful ongoing management. For example, altering grazing practices or conducting prescribed burns at key times may suppress dominant vegetation or stimulate seeds in the soil seed bank to germinate. In particular, managers of unbroken prairies which may still retain a viable wildflower seed bank should prioritize management to restore diversity. If management actions do not increase wildflower diversity on unbroken prairies over time, interseeding may be appropriate. However, wildflower species and seed sources should be selected with input from a regional expert. Interseeding may be particularly important for grass-dominated plantings on previous agricultural land (such as CRP) that have little to no wildflower seed in the soil. In previously cropped grasslands, the soil seed bank has likely become depleted to such an extent that species diversity cannot return without supplementing species through seed or plug additions. Interseeding is most appropriate for enhancing established vegetation, since the process does not kill all existing vegetation.

Finally, land managers and owners have the option to start over entirely, killing existing vegetation and planting into bare soil in order to convert to a diverse native vegetation. This option may be most appropriate when a site is so heavily invaded by an aggressive non-native grass (e.g., reed canarygrass) that any existing native vegetation cannot be salvaged through management or enhanced through interseeding.

Figure 4: This planting on the University of Northern Iowa's campus was originally planted with only five species of native grasses in the mid 1970s. As part of a graduate research project by Dave Williams, parts of the site were interseeded with 23 wildflower species in 1999. Wildflowers established and have since persisted.

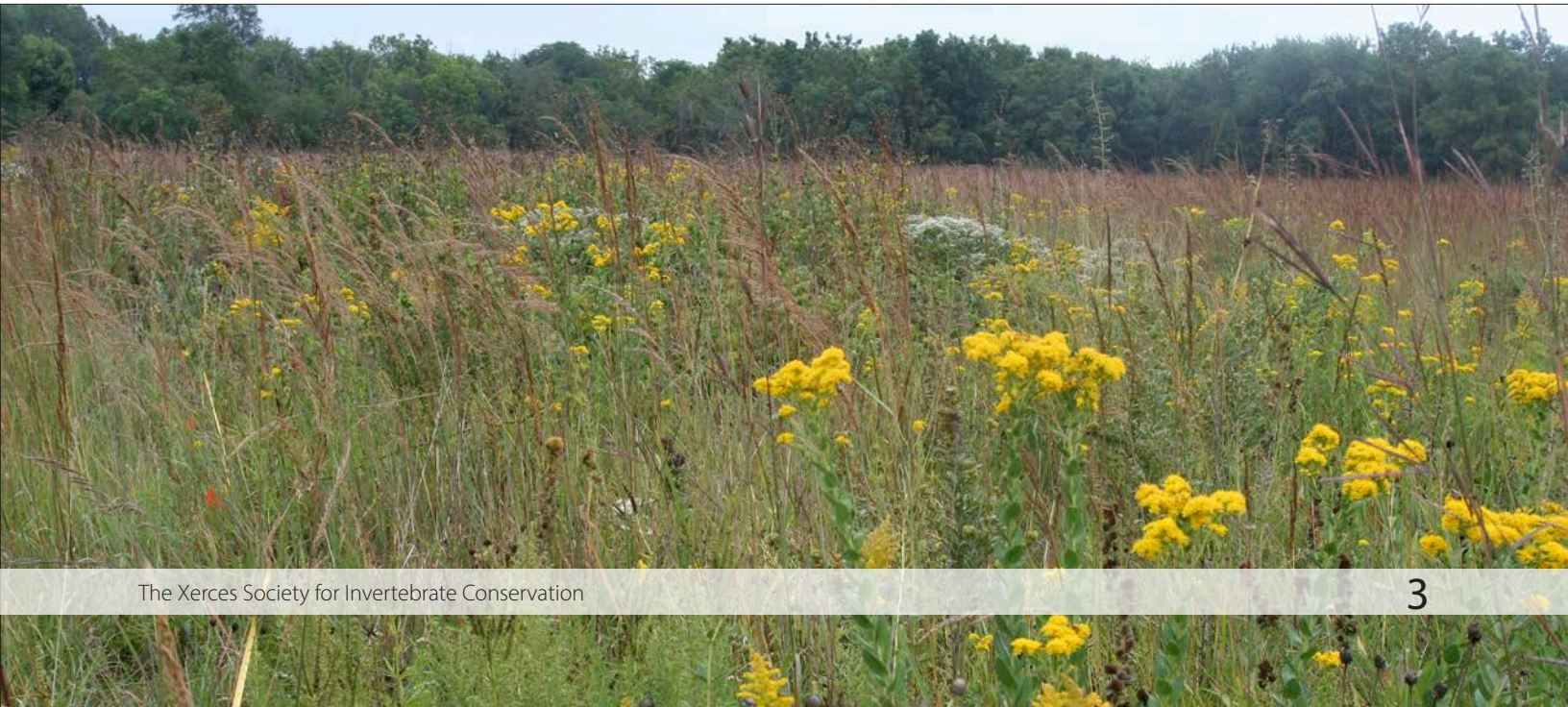



Figure 5: Wildflower establishment is most successful when interseeding into stands of short native bunch grasses, such as little bluestem (left). Plantings dominated by introduced cool season grasses like smooth brome (right) require more aggressive control prior to interseeding wildflowers.

Key Considerations for Interseeding

Many factors influence the success of interseeding wildflowers into grasslands. Grass phenology, litter management, invasive weeds, soil type and drainage class, landscape position, species selection, and precipitation in the first growing season should all be considered when planning an interseeding.

Grass Phenology

The success of an interseeding project relies upon suppression of established grasses and/or weeds in the stand both pre- and post-seeding. Established grasses should be suppressed when the most dominant species are actively growing and at, or near, flowering. For example, research has shown that a single instance of defoliation of grasses when in the boot stage can suppress growth. The boot stage of a grass is when the tiller (shoot) is elongating and the seed head is developing inside the tiller. When grasses are in the boot stage, plant energy goes into flowering and root reserves are low. Practitioners have found that disturbances in the boot stage will suppress grass growth for the rest of the growing season; however, it may require multiple disturbances to achieve longer-term suppression.

Phenology of the dominant grasses on site will guide both pre- and post-seeding management strategies. Common groups of grasses that may be dominant on site may include: cool-season non-native grasses, native warm-season grasses, and mixtures of cool and warm season grasses.

Introduced cool-season pasture grasses and turfgrass such as smooth brome (*Bromus inermis*), tall fescue (*Schedonorus arundinaceus*), Kentucky bluegrass (*Poa pratensis*), and reed canarygrass (*Phalaris arundinacea*) actively grow during the spring months and flower in late-spring. Cool-season grasses can actively grow again in fall if moisture is adequate. Suppression of cool-season grasses should target spring and fall growth periods. Practitioners noted that cool-season grasses may pose a greater competitive threat to seedling establishment compared with warm-season grasses because they are actively growing when the interseeded species are beginning to germinate. If the grass stand is dominated by sod-forming grasses (e.g., Kentucky bluegrass, reed canarygrass, or smooth brome), competition with the interseeded wildflowers can be severe. Dense grass sod can reduce seed contact with soil, which reduces germination. Additionally, the canopy of cool-season stands can decrease establishment. Sod-forming grasses should be controlled more aggressively than other grasses prior to introducing wildflowers. See Part Two for guidance on grass suppression.

Warm-season native tallgrass species such as big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*) actively grow during the summer months and flower in late-summer. Suppression of these and other dominant warm-season grasses should take place during the summer months. The dense canopy of tall warm-season grasses can virtually eliminate light to the soil surface, starving wildflower seedlings of the sunlight they need to survive. The canopy should be greatly reduced before and after interseeding.

Mixed cool- and warm-season grass stands may include the warm-season species mentioned above, as well as cool-season non-native species or cool season native species such as Canada wildrye (*Elymus canadensis*), June grass (*Koeleria macrantha*), green needlegrass (*Nassella viridula*), and western wheatgrass (*Pascopyrum smithii*). Suppression of mixed grass stands can happen throughout the growing season. These grasses can form a dense canopy that prevents sun from reaching wildflower seedlings, and that canopy must be suppressed before and after interseeding in order for seeded wildflowers to establish.

Multiple practitioners noted success when interseeding wildflowers into stands dominated by native short bunch grasses like side-oats grama (*Bouteloua curtipendula*) and little bluestem (*Schizachyrium scoparium*). Short bunch grasses may allow more sunlight penetration to the soil surface for developing wildflower seedlings and bare soil areas among short bunchgrass clumps may provide space for root development of wildflower seedlings to establish. If these grasses are dominant, litter removal may be the only pre-seeding management needed.

Litter Management

A careful evaluation of litter (detached herbaceous plant material) and subsequent litter management is a key step before interseeding. Litter build-up in grasslands can interfere with all seeding methods by reducing seed-to-soil contact critical for seed germination. An overview of seeding methods can be found in the Interseeding section in Part Two. Broadcasting or drop-seeding over the soil surface are

Wildflowers & Native Grasses

Practitioners have noted that interseeding is often more successful when wildflowers are seeded into stands dominated by native short bunch grasses. Native tall grasses and introduced cool season grasses require more intensive suppression.

Figure 6: Shorter-statured native bunchgrasses, like side-oats grama (*Bouteloua curtipendula*) and little bluestem (*Schizachyrium scoparium*), dominate this site in Minnesota, allowing wildflowers to establish with less competition.

Figure 7: Many practitioners use prescribed burns to remove excessive litter before interseeding.

FIGURE 8: On the left, excessive litter from tall fescue (*Schedonorus arundinaceusa*) invasion. The planting on the right was burned in the fall prior to seeding using a native seed drill. In places where thatch was unburned, seedling emergence was decreased.

TABLE 1—Invasive Plants of Concern

These invasive plants found in Midwest and Great Plains states should be controlled prior to interseeding.

	COMMON NAME	SCIENTIFIC NAME
GRASSES	**Cheatgrass**	*Bromus tectorum*
	Kentucky bluegrass	*Poa pratensis*
	Reed canarygrass	*Phalaris arundinacea*
	Smooth brome	*Bromus inermis*
	Tall fescue	*Schedonorus arundinaceus*
BROADLEAVES	**Bird's foot trefoil**	*Lotus corniculatus*
	Canada thistle	*Cirsium arvense*
	Common St. Johnswort	*Hypericum perforatum*
	Crown vetch	*Securigera varia*
	Field bindweed	*Convolvulus arvensis*
	Japanese knotweed	*Polygonum cuspidatum*
	Leafy spurge	*Euphorbia esula*
	Multiflora rose	*Rosa multiflora*
	Plumeless thistle	*Carduus acanthoides*
	Purple loosestrife	*Lythrum salicaria*
	Russian olive	*Elaeagnus angustifolia*
	Salt cedar	*Tamarix* spp.
	Sericea lespedeza	*Lespedeza cuneata*
	Sweet clover	*Melilotus officinalis*
	Teasel	*Dipsacus* spp.
	Whitetop	*Cardaria draba*

the seeding methods most severely impacted by litter build up. On sites with a layer of litter, it is best to use a seed drill. However, excessive litter build-up can even hinder contact of no-till drills with the seed bed and severely restrict sunlight from newly emerged seedlings. Some cover from litter however, can protect wildflower seedlings from desiccation and reduce soil erosion, especially on arid sites.

A majority of practitioners use prescribed burning to remove litter; haying and grazing are also used, though less often. Some practitioners suggest that raking cut material in preparation for baling hay is beneficial because it scratches the soil surface, actively lifts litter, and helps to increase contact of seeds with soil. Disking should not be used to remove litter because it will likely encourage weeds and promote soil erosion.

Invasive Weeds

Interseeding wildflowers into a stand that contains invasive weeds can be problematic (Table 1). Invasive weeds often out-compete native species, resulting in reduced stand vigor and additional weed invasion. If invasive weeds are present in the stand, stressing or killing the dominant grasses (a step that is needed for interseeding success), especially strategies involving grass-selective herbicides that do not affect broadleaf weeds, can promote the germination of weed seed in the soil and/or cause weed rhizomes in the soil to re-sprout. Canada thistle (*Cirsium arvense*) seed, for example, can remain viable in the soil for 20 years or more. It is essential to scout for these weeds and take appropriate control measures before and after interseeding wildflowers. If weed pressure is high, starting over may be the preferred option rather than interseeding. Additional information on controlling invasive weeds can be found in Section 2 of this guide. For a comprehensive list of invasive plant species in the Midwest and Great Plains please visit websites for state Departments of Agriculture, or visit the USDA PLANTS database page for Introduced, Invasive, and Noxious Plants (https://plants.usda.gov/java/noxiousDriver).

Soil Moisture Definitions & Drainage Characteristics

SOIL MOISTURE DEFINITIONS		DRAINAGE CHARACTERISTICS		
Soil Moisture	**NRCS Classification**	**Rate**	**Result**	**Associated Soil Classifications**
Dry (Xeric) []	Excessively Drained	Very rapidly	Dry soil for most of the year	sand, sandy clay, loamy sand
Dry–Mesic []	Somewhat Excessively Drained	Rapidly	Dry soil for periods during the year	sandy loam
Mesic (Medium) []	Well and Moderately Well Drained	Readily	Moist for most of the year	loams, sandy loam, silt loam
Mesic–Wet []	Somewhat and Poorly Drained	Slowly	Wet soil for periods during the year	clay, clay loam,loamy sediments, silty clay loam
Wet (Hydric) []	Very Poorly Drained	Very slowly	Standing water at/near the surface for most of the year	muck, aquolls, ponded, aquents, fluvaquents

Soil Type, Drainage Class, Ecological Sites, and Landscape Position

To maximize interseeding success, wildflower species should be selected to best fit the soil characteristics and moisture conditions of the planting site. It is important to determine the soil type and drainage class of the planting site in advance of interseeding. This information can be found at the NRCS Web Soil Survey (www.websoilsurvey.nrcs.usda.gov). The Web Soil Survey can also provide information about ecological sites, which includes information on appropriate plant communities.

Practitioners have found that interseeding wildflowers is generally more successful in dry, poorer soils (e.g., sandy, gravelly, rocky, or shallow loam soils, such as those often found on steep slopes and ridges) where grass stands are already sparse and weed pressure is often lower. Nutrient rich and saturated soils often support thick grass stands and potentially more robust weeds that will compete with interseeded wildflowers and grasses.

Interseeding success is also influenced by topographical position of the planting site on the landscape. Some practitioners noted that interseeding success was lowest on sites subject to soil deposition or periodic flooding. Wildflower and grass seeds buried by soil deposition or lost by soil erosion and/or increased competition from weed seed and weed propagules deposited on the site from floods may account for the poor establishment of interseedings on these sites.

Understanding Ecological Site Descriptions (ESDs)

Detailed information about Ecological Sites can be found in NRCS's Ecological Site Descriptions (ESDs). ESDs include site characteristics, plant communities, management options for sites, and supporting resources. ESDs, as well as descriptions of soil and forage plants for grazing animals (Forage Suitability Groups) can be found here: https://esis.sc.egov.usda.gov/Default.aspx.

FIGURE 9: Pale purple coneflower (*Echinacea pallida*), a wildflower attractive to pollinators, has the best chance to establish and persist when planted in dry to dry-mesic soils and likely will not establish when planted in sites with wetter soils.

Species Selection

Choosing species to interseed depends on the characteristics of the existing plant community. If a stand is dominated by non-native cool-season grasses, the seed mix should include native species from all plant guilds: warm and cool-season grasses, sedges, legumes, and non-legume wildflowers. This will increase the potential of establishing a stable, diverse, and weed resistant plant community that will attract and sustain insects and other wildlife. If the stand is largely warm-season grasses, then native wildflowers, native cool-season grasses, and sedges should be selected for the interseeding project.

It is critical that the moisture preference of selected species closely matches the soil moisture conditions of the planting site. This will offer the best opportunity for interseeded plants to establish and persist. Plant dry-adapted species on dry sites, wet-adapted species on wet sites. If a diverse remnant site with similar soils can be found nearby, species composition at the remnant site may serve as a guide for species selection for interseeding. If you are interseeding on remnant prairie or rangeland, consult with a local expert about species selection and seed sourcing.

Practitioners agree it is important to select species that are native to the region of the planting site. To determine a native range for a given species, visit the USDA–PLANTS database (https://plants.usda.gov) or Biota of North America (http://bonap.org). The native range of an individual species is searchable by its common name or scientific name on the USDA–PLANTS database. Note: it may be easier to search for an individual species by scientific name as some species have many different common names.

Seed cost must be considered when selecting species and seeding rates. The cost of seed varies greatly by species, but wildflower seed usually adds a significant cost to a seed mix. For this reason practitioners have developed precise methods for designing seed mixes. The Natural Resources Conservation Service (NRCS) typically uses seed calculators to design seed mixes based upon the number of seeds per square foot for each species. For an example of a simple seed rate calculator go to https://xerces.org/xerces-seed-mix-calculator.

Figure 10: Three years after being interseeded, this planting bordering crop fields is rich in native wildflower species suited for the area.

Figure 11: Some wildflowers are better than others at establishing into grass-dominated sites; hoary vervain (*Verbena stricta*), rosinweed (*Silphium integrifolium*), and butterfly milkweed (*Asclepias tuberosa*), shown here, are examples of species with high interseeding success rates.

Finally, the likelihood that a species will establish and persist when interseeded should be considered when choosing species. Currently, seed is commercially available for hundreds of native wildflowers. Practitioners agree that some of these wildflowers establish readily when interseeded, while others establish more slowly and may not appear in the planting for many years (or at all) after sowing seed. Based on survey responses from practitioners and review of interseeding research, we have compiled a list of 81 wildflowers in Table 2 (p. 10–12) that are most likely to establish and persist in interseeded plantings and provide abundant resources for bees and other pollinating insects. In addition, in Table 6 (see Addendum) we provide a short list of 21 wildflowers that have consistently persisted after being established in fifteen interseeding projects that were seeded between 1997 and 2010 in eastern Iowa by the Tallgrass Prairie Center. For recommendations on native grasses or sedges to include in interseeding mixes, check with your local NRCS field office.

Precipitation

Practitioners and research studies indicate that interseeding is generally more successful when rainfall in your region is at or above average in the first growing season. Adequate soil moisture is required for seed to imbibe water and initiate germination, and is essential for seedling survival. Choosing to seed or not to seed based on weather predictions is a moving target, but checking the long-range precipitation forecast to determine if there is a chance of drought conditions may help inform interseeding decisions. Long range precipitation forecasts can be found at the National Weather Service Climate Prediction Center website (www.cpc.ncep.noaa.gov).

Note: Some practitioners suggest interseeded projects that experience drought conditions the first growing season may not be failures; often seed remains dormant during droughts and germinates the following spring when there is adequate rainfall.

TABLE 2—Persistent Native Wildflowers for Interseeding

These native species are found in the Midwest and Great Plains and are likely to establish and persist when interseeded. This list was derived from practitioner input and review of scientific literature involving interseeding. Suggested interseeding rates are included when available but may vary from state to state. Selecting species that are native to the region of the planting site is important for the success of the planting. We include the following as states within the Midwest and Great Plains for this list: Kansas (KS), Missouri (MO), Iowa (IA), Illinois (IL), Indiana (IN), Minnesota (MN), Wisconsin (WI), Nebraska (NE), South Dakota (SD), North Dakota (ND), EASTERN Montana (MT), EASTERN Wyoming (WY), and EASTERN Colorado (CO). Note that distributions of species can vary within a state. Local experts or agencies can help to develop a species list appropriate for your site.

	SCIENTIFIC NAME	COMMON NAME	SOIL MOISTURE	DISTRIBUTION	SEEDS PER OUNCE	INTERSEEDING RATE	SOWING SEASON & SEEDING METHODS	SOURCE
SPRING	***Anemone canadensis***	Canadian anemone	dry-mesic–mesic	Widespread	8,000	0.25–1.5	no-till drill	research/literature, practitioners
	Astragalus crassicarpus	Groundplum milkvetch	dry-mesic–mesic	Widespread	5,200	—	—	practitioners
	Baptisia alba	White wild indigo	dry-mesic–mesic	IA, IL, IN, KS, MN, MO, NE, WI	1,700	0.01–0.1	no-till drill	practitioners
	Baptisia bracteata	Longbract wild indigo	dry-mesic–mesic	IA, IL, IN, KS, MN, MO, NE, WI	1,400	0.01	no-till drill	research/literature, practitioners
	Penstemon digitalis	Foxglove beardtongue	mesic	Widespread [CO, MT, ND, WY]	130,000	0.2–1	no-till drill	practitioners
	Penstemon grandiflorus	Large beardtongue	dry-mesic	Widespread	14,000	—	no-till drill	practitioners
	Tradescantia bracteata	Longbract spiderwort	dry-mesic–mesic	Widespread [CO]	10,000	—	no-till drill	research/literature, practitioners
	Tradescantia occidentalis	Prairie spiderwort	dry-mesic–mesic	Widespread [IL, IN, MO]	9,000	—	—	practitioners
	Tradescantia ohiensis	Bluejacket/Ohio spiderwort	dry-mesic–mesic	IA, IL, IN, KS, MN, MO, NE, WI	8,000	0.3–1	no-till drill	research/literature
	Vicia americana	American vetch	mesic	Widespread	2,000	—	—	research/literature, practitioners
	Zizia aptera	Meadow zizia/heartleaf golden Alexanders	mesic–wet-mesic	Widespread [NE]	12,000	—	broadcast seeder	research/literature, practitioners
	Zizia aurea	Golden Alexanders/zizia	mesic	Widespread [CO, MT, WY]	11,000	0.2–1.7	drop seeder, broadcast seeder, no-till drill	research/literature, practitioners
LATE SPRING–EARLY SUMMER	***Anemone cylindrica***	Candle anemone/ thimbleweed	dry-mesic–mesic	Widespread	26,000	0.1–1	drop seeder, broadcast seeder, no-till drill	research/literature, practitioners
	Anemone virginiana	Tall thimbleweed/ thimbleweed	dry-mesic–mesic	Widespread [CO, MT]	28,000	—	no-till drill	practitioners
	Astragalus canadensis	Canada milkvetch	dry-mesic–mesic	Widespread	17,000	1–2	drop seeder, no-till drill	practitioners
	Coreopsis palmata	Stiff tickseed	dry-mesic–mesic	Widespread [CO, MT, ND, WY]	10,000	0.1–1.2	broadcast seeder	practitioners
	Coreopsis tinctoria[1]	Golden tickseed	mesic–wet-mesic	Widespread	10,000	—	—	research/literature, practitioners
	Coreopsis tripteris	Tall tickseed	dry-mesic–mesic	IA, IL, IN, KS, MO, WI	14,000	0.4	no-till drill, broadcast seeder	research/literature, practitioners
	Parthenium integrifolium	Wild quinine	dry-mesic–mesic	IA, IL, IN, KS, MN, MO, WI	7,000	0.2–0.3	no-till drill, broadcast seeder	—
	Rosa arkansana	Prairie rose	dry-mesic–mesic	Widespread	2,500	—	no-till drill	practitioners
	Sphaeralcea coccinea	Scarlet globemallow	mesic	Widespread [IL, IN, MO, MI]	31,250	—	—	practitioners
	Veronicastrum virginicum[2]	Culver's root	mesic–wet-mesic	Widespread [CO, MT, WY]	800,000	1–3.8	broadcast seeder, no-till drill	—

KEY

BLOOM TIME

SOIL MOISTURE—dry [dry]; dry-mesic [dry-mesic]; mesic [mesic]; wet-mesic [wet-mesic]; wet [wet]. *(See Soil Moisture Definitions & Drainage Characteristics on page 7 for details).*

DISTRIBUTION within Midwest/Northern Great Plains—Widespread species occur across the Midwest/Northern Great Plains, except in certain states [✕].

SEEDS PER OUNCE (approximate)—sourced from USDA–PLANTS (https://plants.usda.gov).

INTERSEEDING RATE—suggested seeds per square foot.

SOWING SEASON (SPRING, FALL, SPRING & FALL) & seeding methods—drop seeder [drop seeder]; broadcast seeder [broadcast seeder]; no-till drill [no-till drill].

SOURCE (interseeding rates, sowing season, and seeding method)—research/literature [research/literature]; practitioners [practitioners].

PRACTITIONER NOTES

1. Annual/Biennial.
2. Practitioners widely plant with some examples of poor establishment.
3. Practitioners widely plant and no failed plantings.
4. Rarely interseeded with variable success.

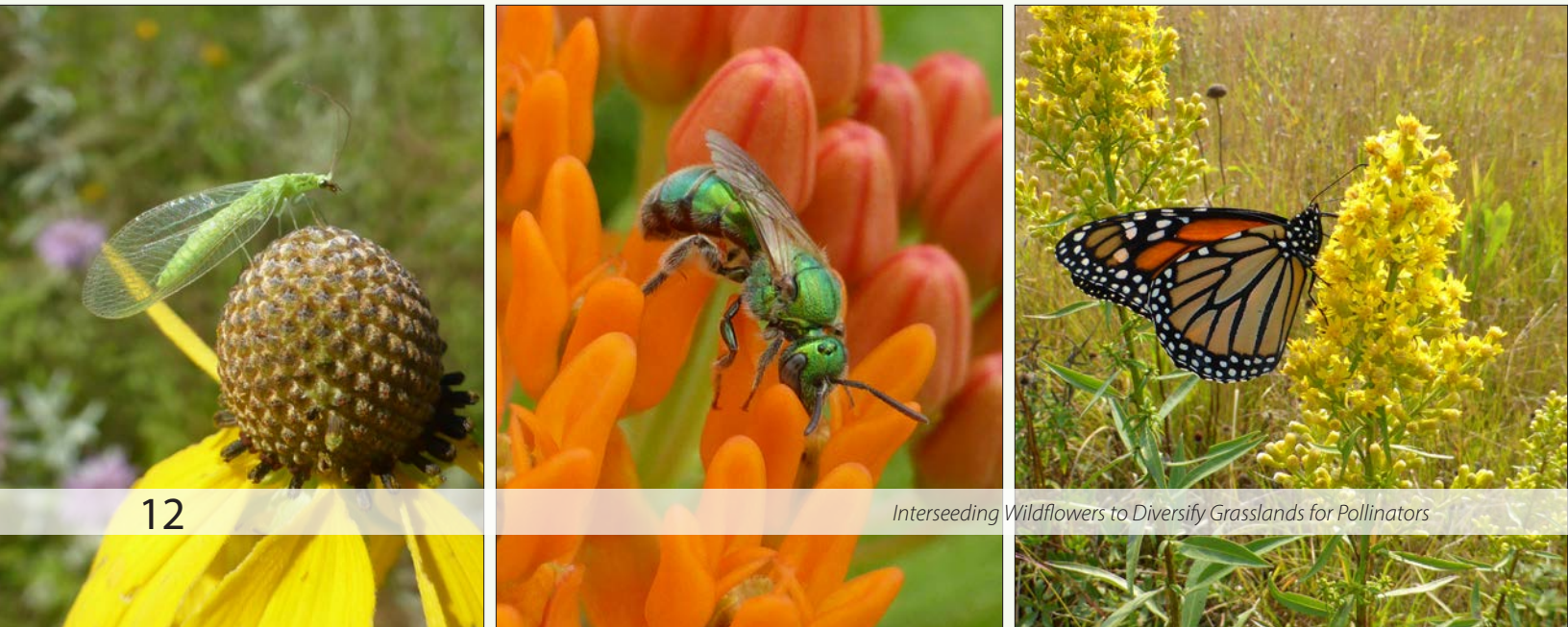
	SCIENTIFIC NAME	COMMON NAME						
SUMMER	***Achillea millefolium***	Common yarrow		Widespread	180,000	—	—	
	Agastache nepetoides	Yellow giant hyssop		Widespread [~~CO~~, ~~MT~~, ~~ND~~, ~~WY~~]	90,000	4.3		
	Amorpha canescens	Leadplant		Widespread	16,000	0.2–1		
	Arnoglossum reniforme	Great Indian plantain		IA, IL, IN, KS, MN, MO, WI	4,000	0.14		
	Asclepias incarnata[2]	Swamp milkweed		Widespread	4,800	0.15–0.25		
	Asclepias syriaca[3]	Common milkweed		Widespread [~~CO~~, ~~WY~~]	4,000	0.1		
	Asclepias tuberosa[2]	Butterfly milkweed		Widespread [~~CO~~, ~~MT~~, ~~ND~~, ~~WY~~]	4,300	0.1–0.25		
	Asclepias verticillata[4]	Whorled milkweed		Widespread [~~CO~~]	11,000	—	—	
	Brickellia eupatorioides	False boneset		Widespread	32,000	—		
	Chamaecrista fasciculata[1]	Partridge pea		Widespread [~~MT~~]	2,700	0.3		
	Cleome serrulata[1]	Rocky Mountain beeplant		Widespread	2,600	—	—	—
	Dalea candida	White prairie clover		Widespread	19,000	0.7–1		
	Dalea purpurea	Purple prairie clover		Widespread	15,000	0.5–3		
	Dalea villosa	Silky prairie clover		Widespread [~~IL~~, ~~IN~~]	14,000	—	—	
	Desmanthus illinoensis	Illinois bundleflower		Widespread [~~MT~~, ~~WY~~]	4,200	0.2–0.3	—	
	Echinacea angustifolia	Narrow-leaf purple coneflower		Widespread [~~IL~~, ~~IN~~, ~~WI~~]	8,000	—	—	
	Echinacea pallida	Pale purple coneflower		IA, IL, IN, KS, MO, NE, WI	5,200	0.1–1		
	Echinacea purpurea	Eastern purple coneflower		CO, IA, IL, IN, KS, MO, WI	6,600	1		
	Eryngium yuccifolium	Button eryngo/rattlesnake master		IA, IL, IN, KS, MN, MO, NE, WI	7,500	0.15–2		
	Gaillardia aristata	Blanketflower		CO, MT, WY, IL, MN, ND, SD, WI	13,800	—	—	
	Grindelia squarrosa	Curlycup gumweed		Widespread	25,000	—	—	
	Hasteola suaveolens	False Indian plantain		IA, IL, IN, MN, MO, WI	14,000	—		
	Heliopsis helianthoides	Smooth oxeye		Widespread [~~MN~~, ~~MT~~, ~~WY~~]	6,300	0.25–1		
	Heterotheca villosa	Hairy false goldenaster		Widespread [~~MO~~]	230,000	—	—	
	Lespedeza capitata	Roundhead lespedeza		Widespread [~~CO~~, ~~MT~~, ~~WY~~]	8,000	0.2–1		
	Machaeranthera tanacetifolia[1]	Tansyleaf tansyaster		CO, MT, WY, IL, KS, NE, SD	70,000	—	—	
	Monarda fistulosa	Wild bergamot		Widespread	70,000	0.75–3		
	Monarda pectinata[1]	Pony beebalm/plains lemon monarda		CO, WY, KS, MO, NE, SD	70,000	—	—	
	Oenothera biennis[1]	Common evening primrose		Widespread [~~CO~~, ~~WY~~]	90,000	—	—	
	Phacelia hastata	Silverleaf phacelia		CO, MT, WY, KS, NE, ND, SD	9,500	—	—	
	Potentilla arguta	Tall cinquefoil		Widespread	230,000	2.9		
	Pycnanthemum verticillatum	Whorled mountainmint		IA, IL, IN, KS, MO, NE	185,000	6.4		
	Pycnanthemum virginianum	Common mountainmint		Widespread [~~MT~~, ~~WY~~]	220,000	2–3		
	Ratibida columnifera	Upright prairie coneflower		Widespread	37,500	—		
	Ratibida pinnata	Pinnate prairie/gray-headed coneflower		Widespread [~~CO~~, ~~MT~~, ~~ND~~, ~~WY~~]	30,000	0.9–3		

(Continued on next page.)

TABLE 2—Persistent Native Wildflowers for Interseeding *continued*

	SCIENTIFIC NAME	COMMON NAME						
SUMMER (continued)	***Rudbeckia hirta***[1]	Black-eyed Susan		Widespread	92,000	2–5.3		
	Rudbeckia triloba[1]	Brown-eyed Susan		Widespread [MT, ND, NE, SD, WY]	34,000	1.6		
	Silphium integrifolium	Wholeleaf rosinweed		Widespread [MN, MT, ND]	1,200	0.01		
	Silphium laciniatum	Compassplant		Widespread [MT, ND, WY]	660	0.01–0.1		
	Silphium perfoliatum	Cup plant		Widespread [SD, MT, WY]	1,400	—		
	Silphium terebinthinaceum	Prairie rosinweed		IA, IL, IN, MO, WI	1,000	—		
	Verbena hastata	Swamp verbena		Widespread	93,000	—		
	Verbena stricta	Hoary verbena		Widespread	28,000	0.25		
FALL	***Euthamia gymnospermoides***	Texas goldentop		Widespread	350,000	—	—	
	Helenium autumnale	Common sneezeweed		Widespread	130,000	—		
	Helianthus grosseserratus	Sawtooth sunflower		Widespread [SD, MT, WY]	15,000	0.25		
	Helianthus maximiliani	Maximilian sunflower		Widespread	13,000	—	—	
	Helianthus occidentalis	Fewleaf sunflower		IA, IL, IN, KS, MN, MO, WI	14,000	0.25		
	Helianthus pauciflorus	Stiff sunflower		Widespread	4,000	—		
	Liatris punctata	Dotted blazingstar		Widespread	8,000	—	—	
	Lobelia siphilitica	Great blue lobelia		Widespread [MT]	500,000	1–2		
	Oligoneuron rigida	Stiff goldenrod		Widespread	41,000	0.25–3		
	Solidago gigantea	Giant goldenrod		Widespread	250,000	—	—	
	Solidago nemoralis	Gray goldenrod		Widespread	300,000	—		
	Solidago speciosa	Showy goldenrod		Widespread [SD, MT, WY]	95,000	2–4		
	Symphyotrichum ericoides	White health aster		Widespread	200,000	—	—	
	Symphyotrichum laeve	Smooth blue aster		Widespread	55,000	1–3		
	Symphyotrichum novae-angliae	New England aster		Widespread	66,000	0.35–1		
	Symphyotrichum oolentangiense	Skyblue aster		Widespread [SD, MT, ND, WY]	80,000	—		

FIGURE 12: Diverse native wildflower species interseeded into this Minnesota natural area support beneficial insects and pollinators. From left to right: green lacewings (*Chrysoperla* sp.) on gray-headed coneflower (*Ratibida pinnata*), pure green sweat bee (*Augochlora pura*) on butterfly milkweed (*Asclepias tuberosa*), monarch (*Danaus plexippus*) on showy goldenrod (*Solidago speciosa*).



2

The Interseeding Process

The interseeding process has three stages:

1. Pre-seeding management to suppress highly competitive vegetation and manage litter;
2. Interseeding the site; and,
3. Post-seeding management to the existing grass stand to support seedling establishment.

Prepare for Interseeding: Suppressing Highly Competitive Vegetation and Litter Management

There are many management options available to suppress dominant and established grasses and reduce litter, including herbicide applications, haying, mowing, grazing, burning, or tillage. We cover each of these treatments below.

Grazing for Grass Suppression and Litter Removal

Grazing can be an effective technique to manage dominant grasses prior to interseeding wildflowers. It can also be used for litter management. Appropriate grazing intensity and timing are critical to achieve maximum grass suppression. Practitioners agree that grass suppression is highest when grazing occurs during the active growth stage of the dominant grasses. For cool-season grasses, graze in the spring and early fall. For warm-season grasses, graze during the summer months. Grazing for grass suppression may be a multi-year process. Grazing an aggressive grass, like smooth brome, over one growing season will only weaken it; it will quickly recover if not suppressed by grazing in the following year.

There are three basic grazing levels: intensive (heavy), moderate, and light. Under intensive grazing,

FIGURE 13: Grazing a site intensively for the entire growing season (top) to prepare for interseeding can be effective (bottom).

the goal is to apply maximum suppression to the grasses; down to 2–4" of stubble. Under moderate grazing, the goal is to maintain grass vigor to support high quality long-term forage. This approach operates under the premise of 'take half and leave half'. Under light grazing, the goal is to have little to no impact on grass growth. Light grazing results in a stand with a grass canopy and some patchy holes in the vegetation. Practitioners suggest that season-long intensive grazing for at least one growing season prior to interseeding is a good practice for suppressing grasses. Contact a grazing specialist or other qualified professional for assistance in developing a management plan if grazing is part of your long term management strategy.

Burning, Haying, or Mowing for Grass Suppression and Litter Removal

Burning, haying, or mowing can be used for grass suppression or litter management, whether in conjunction with other practices or as a standalone practice. Mowing can be used to suppress grass by preventing seed development. However, unless clippings are removed, mowing does not manage litter and the addition of clippings must be addressed through another litter removal option prior to interseeding. If you are haying or burning primarily to remove litter, plan to interseed shortly after a burn or hay to maximize the amount of bare soil for seed contact.

Figure 14: Burning is an effective technique to remove litter before interseeding.

Timing is critical to suppress grass using burning, haying, or mowing. As with other grass suppression disturbances, time the disturbance to coincide with the active growth stage (boot stage) of the grass; burning, haying, or mowing in spring and/or fall to knock back cool season grasses and mid to late summer to target warm season grasses. Practitioners have found that burning, haying, or mowing grasses in the boot stage will suppress growth for the rest of the growing season; however, it may require multiple disturbances of this kind to achieve longer-term suppression. Research on March interseeding in an eastern Nebraska prairie restoration dominated by big bluestem found that few milkweed or other wildflower species establish in the absence of disturbance.

Herbicides for Grass Suppression

The majority of practitioners surveyed have successfully used a non-selective herbicide with the active ingredient glyphosate (i.e., Roundup®), or a grass-selective herbicide containing clethodim to suppress established grasses (Table 3). Non-selective and grass-selective herbicides can be used on either cool-season, warm-season, or mixed cool and warm season grass stands. A grass-selective herbicide should be used if the stand has desirable wildflowers. A non-selective herbicide can be used if there are no desirable species in the stand. Mowing,

haying, grazing, or burning a site prior to herbicide application may increase herbicide contact with new growth of the grass, improving grass control.

Cool-season grasses should be sprayed in the spring or in the fall shortly before dormancy. Some practitioners believe that control of cool-season grasses is improved with a fall chemical application (as compared to a spring application) because the plant moves more energy into its roots to overwinter during the fall and the chemical moves into the roots more efficiently. To adequately suppress aggressive cool-season grasses such as smooth brome and tall fescue, two consecutive seasons of applications may be needed. A stand initially sprayed in spring should be sprayed again that fall prior to seeding. Likewise, a stand initially sprayed in fall should be sprayed again the following spring before seeding. Of all introduced grassland species, reed canarygrass is

FIGURE 15: Although warm-season grasses and wildflowers persisted in much of this prairie planting, reed canarygrass took over the lower portion of the planting following a flood. The invaded area will be spring-sprayed with glyphosate and reseeded with wetland natives.

TABLE 3—Practitioner-Used Herbicides for Control of Established Grasses

Many factors are responsible for the efficacy of an herbicide including growth stage, application timing and application rates. This information reflects reported efficacy by practitioners.

HERBICIDE A.I.ⓘ	TRADE NAMES		GRASSES REPORTED TO BE CONTROLLED†	NOTES FROM PRACTITIONERS
Glyphosate⁂	Round-up	⚠	Big bluestem, fescue, Indiangrass, Kentucky bluegrass, quackgrass, reed canarygrass, smooth brome, switchgrass	With proper application timing, effectively suppresses cool-season grasses while not destroying warm-season grasses.
Clethodim⁂	Select, Envoy		Big bluestem, fescue, Indiangrass, Kentucky bluegrass, reed canarygrass, smooth brome, switchgrass	A "wildflower-safe" option. May eradicate native grasses.
Imazapic⁑	Plateau		Smooth brome, fescue, reed canarygrass	Some wildflowers show tolerance.
Sethoxydim⁑	Poast		Tall fescue	Effectively suppresses grasses without eradicating them.
Fluazifop-P-butyl*	Fusilade		Reed canarygrass	

ⓘ **HERBICIDE A.I.—Active Ingredient** & reported use by practitioners:

⁂ Many practitioners report using this herbicide

⁑ More than one practitioner reported using this herbicide

* One practitioner reported using this herbicide

SELECTIVITY—None (⚠), grass-selective ( ), some wildflowers tolerant ( ). **NOTE:** *Consult herbicide labels for potential toxicity toward non-grasses.*

† Information does not represent comprehensive lists of the grasses suppressed by each herbicide. While practitioners typically reported that the herbicide effectively suppressed all grasses, some practitioners specifically reported the grasses suppressed by each herbicide (presented in this column). Exclusion of grasses from this list is not meant to indicate an herbicide is ineffective at suppressing a particular grass species. Rather, practitioners did not report on those combinations of herbicides-grasses. Many factors are responsible for the efficacy of an herbicide including growth stage and herbicide rates. This information reflects reported efficacy by practitioners. Follow herbicide labels to ensure effective herbicide treatments. It is a violation of Federal law to use herbicides and other pesticides in a manner inconsistent with the labeling.

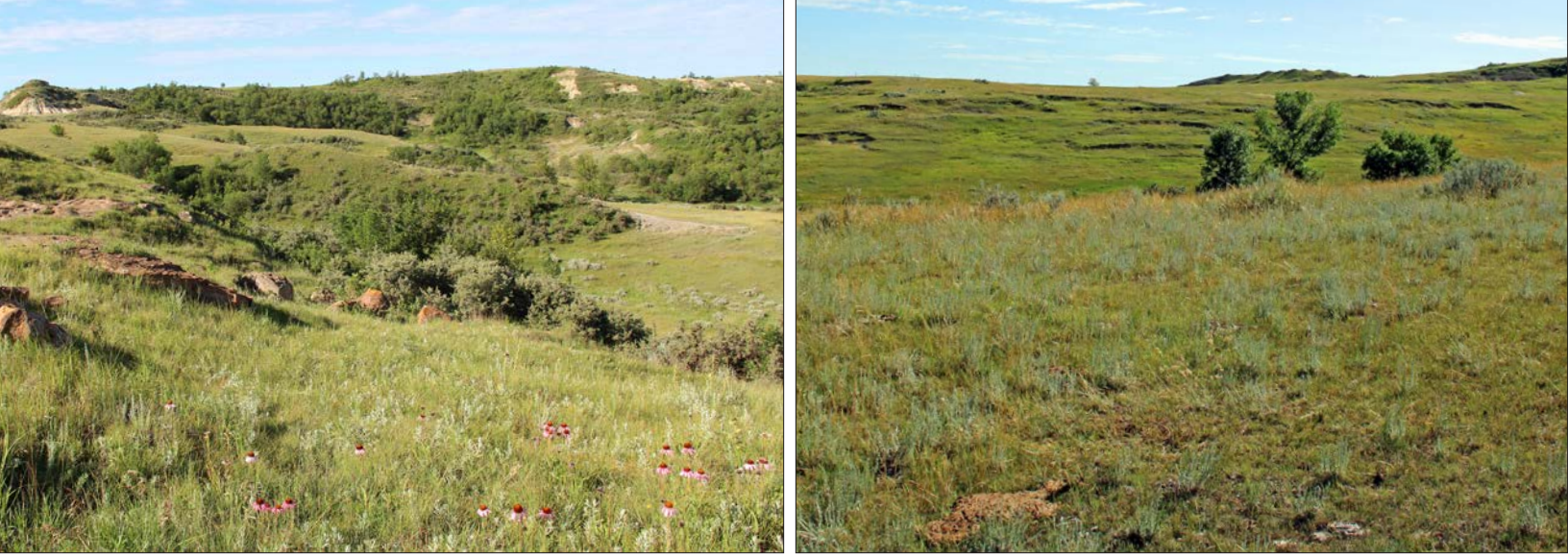


Figure 16: Disking should never be used on rangeland or prairie (left). If management cannot return plant diversity on degraded rangeland (right), interseeding following a non-disking method of grass suppression is an option.

reported by practitioners to be the most aggressive and difficult to treat. Interseeding wildflowers into reed canarygrass may require multiple herbicide treatments over multiple consecutive growing seasons before interseeding.

If few to no cool-season grasses are present, many practitioners choose to only suppress warm-season grasses when interseeding wildflowers. This can be achieved with a single herbicide application to a warm-season grass stand in mid-summer prior to interseeding wildflowers the following fall or spring. This approach creates a window for wildflower seedling establishment followed by the recovery of warm-season grasses, resulting in a more diverse plant community.

Herbicides and Pollinators

There is limited information on toxicity of herbicides to pollinators. Caterpillars (larval stage) of butterflies and moths may be most impacted by herbicides because they have the greatest risk of exposure through direct contact and ingestion of treated plants. Research has shown that sethoxydim and fluazifopp-butyl (found in some grass-selective herbicide products) can reduce survivorship of some species by 21–32%. These herbicides should be avoided if rare or imperiled butterfly species are present in the caterpillar stage.

Figure 17: While caterpillars (and their host plants) are not the intended targets of grass-selective herbicides, some species can still be harmed by exposure.

Disking for Grass Suppression

Mechanical disruption of the established grasses can be a successful technique to suppress dominant grasses. If warm-season grasses are dominant, some practitioners use light, shallow disking (run over field lightly several times) as a method to temporarily stress the native warm-season grasses and repeat in mid- to late-summer when the stand is actively growing at or near boot stage. Interseeding should follow soon after. If cool-season grasses are dominant, disking should take place in late spring to apply maximum suppression to the cool-season grass stand, and interseeding should occur shortly after. Some practitioners do not use disking, noting that it promotes soil erosion, weed growth, and disturbs the soil biology. Disking may be appropriate under some circumstances on previously cropped land, but should never be undertaken on native rangeland or prairie remnants.

Invasive Species Control

Many invasive or weedy non-native species will require additional steps to control. Keep in mind that the presence of invasive weeds in the stand suggests there are also viable seeds for those species in the soil. Suppressing the dominant grasses in the stand may promote germination of invasive weed seeds, and further weed control may be needed.

Many practitioners spot-spray broadleaf invasive weeds with a broadleaf herbicide prior to spraying the grass stand with a grass herbicide or non-selective herbicide (e.g., glyphosate). Mowing, haying, grazing, and burning can also be used to manage weedy or invasive vegetation. If invasive weeds are clustered in one or a few areas, mowing haying, or burning the weedy areas when weeds are vulnerable and prior to weed seed set can reduce weed seeds and weed populations. If weeds are not toxic to livestock, grazing animals into an area of weedy vegetation and intensely grazing the weeds to knock back vegetation and prevent seed set may be an effective control method. If weeds are scattered throughout the site, carefully timing haying, mowing, spot-spraying and/or grazing to manage weeds over multiple seasons may be necessary.

It is important to be familiar with the characteristics of target weeds. Some weed species will set seed lower to the ground when mowed or hayed and may need additional control through spot-spraying or hand-weeding. Other weed species are stimulated by mowing, haying, or grazing and it is not advisable to use these control methods.

The Weed Seed Bank

The presence of invasive weeds also means there are viable seeds for those species in the soil.

Figure 18: Invasive weeds like Canada thistle (*Cirsium arvense*), shown here invading a CRP planting in North Dakota, can crowd out desirable species and reduce plant diversity quickly.

Interseeding

Seeding Rates

Research has shown that native plant recruitment from seed is very low when interseeded into existing vegetation. It is important therefore, to select species for interseeding that are most likely to establish and persist (Table 2). In addition, higher seeding rates are needed when interseeding wildflowers into suppressed grasses as compared to conventional seeding into bare soil; practitioners suggest increasing rates by 25%. See Table 2 for suggested seeding rates for interseeding recommended species.

Site-Specific Wildflower Seeding Rates

Higher seeding rates are needed when interseeding into suppressed grasses compared to bare soil. Practitioners suggest increasing rates by 25%.

Figure 19: Interseeding requires higher rates of wildflower seed and should focus on species that will persist against established grasses.

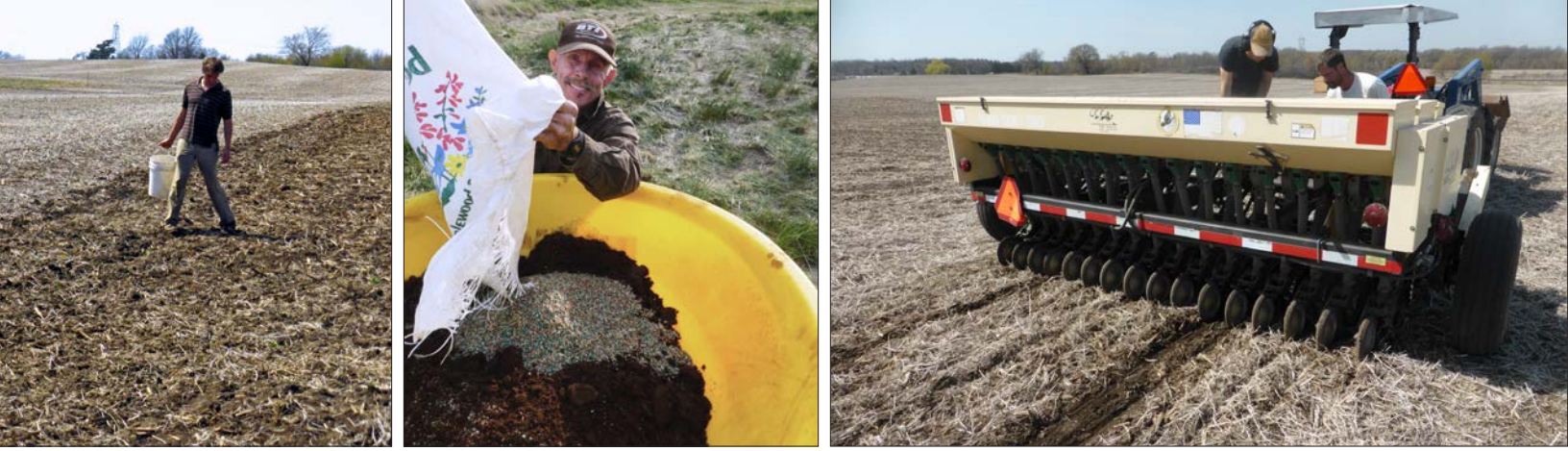


Figure 20: Interseeding a site can be done by hand (left) or mechanically, by using a broadcast seeder (middle) or seed drill (right).

Figure 21: Snow seeding is an option for interseeding during the dormant season in cold climates. Because seed is broadcast on top of snow, it easy to see seed coverage and achieve even distribution of seed across the site. Snow seeding can be done by hand (top), with a belly crank, or a drop seeder (bottom).

Seeding Methods

There are several seeding methods that can be used to effectively interseed wildflowers into grasslands including no-till drills, broadcast seeders, and drop-seeders, and they each may have different site preparation requirements. In general, broadcasting or drop seeding requires pre-seeding management that removes litter and exposes bare ground, while seed drilling may be successful with a small amount of litter remaining. If broadcasting seed, it also advisable to follow up with a cultipacker to press the seed lightly into the soil to increase germination. Seed-to-soil contact is critical for germination and establishment as a consequence. Table 4 (below) outlines some additional considerations for selecting a seeding method.

Seeding Times

Most practitioners recommend a dormant season seeding if wildflowers are the main component of the seed mix. Dormant seeding mimics the natural process of fall/winter seed ripening and dispersal of many prairie wildflower species. In addition, dormant seeding benefits most wildflowers by exposing the seed to cold-moist stratification, which improves germination for many wildflower species. Practitioners recommend planting shortly before the ground freezes in the fall or in early spring when soils still freeze overnight. Some practitioners have also successfully broadcast seed onto light snow. Broadcasting seed onto ice or heavy snow pack, however, may expose seed to wind erosion and seed loss (or seed drift to lower areas of the site) may result. If your land is enrolled in a USDA program, check your contract specifications for guidance on seeding timing.

Figure 22: Broadcast seeding (Truax Seed Slinger) native plants. The site was cultipacked (Figure 24) after seeding to improve seed-to-soil contact.

Figure 23: Preparing to interseed a 10 acre site previously dominated by cool-season pasture grasses (smooth brome, Kentucky bluegrass, orchardgrass, and tall fescue) with a Truax no-till drill.

TABLE 4—Seeding Methods Overview

Consult with your local NRCS field office or see the restoration and planting guidance documents included in the Additional Resources section for more information about the process of seeding.

METHOD	ADVANTAGES	DISADVANTAGES
Broadcast seeders, fertilizer spreaders, or hand broadcasting	⊕ Inexpensive ⊕ Easy to use ⊕ Poorly cleaned seed is not an issue ⊕ Variety of models available: e.g., hand cranks, tractor mounts, hand powered turf grass seeders ⊕ Can be used for both large and small areas ⊕ Can accommodate large and small seed	⊖ Requires a seed bed without much litter for seed to soil contact ⊖ Seed should be pressed into the soil after planting (e.g., cultipacking) ⊖ Some models of broadcast seeders cannot accommodate large seeds ⊖ If interseeding through CRP mid-contract management, check with NRCS; doubling of seeding rates is often required ⊖ Hand-powered models and hand broadcasting are time consuming for large areas
Drop seeders	⊕ Inexpensive ⊕ Easy to use ⊕ Can accommodate large and small seed ⊕ Many models and sizes available ⊕ Convenient for large areas	⊖ Requires a smooth seed bed without much litter for seed to soil contact ⊖ Calibration requires trial and error ⊖ Seed should be pressed into the soil after planting (although some models have a roller attached behind the seeder, which takes care of this step) ⊖ If interseeding through CRP mid-contract management, check with NRCS; often require doubling of seeding rates
Native seed drills (including airseeders)	⊕ Convenient for large areas ⊕ Seed box agitators and depth controls are designed for planting small or fluffy native seeds at optimal rate and depth ⊕ Can plant into a light stubble layer ⊕ Does not require seed to be pressed into soil surface after planting	⊖ Can be expensive, not readily available in some areas ⊖ Difficult to calibrate for small areas (less than 1 acre) ⊖ Requires a tractor and an experienced operator to set planting controls ⊖ Seed with a lot of chaff can clog delivery tubes ⊖ Can be difficult to ensure a planting depth at or less than 1/4", which is important for germination

Figure 24: After broadcasting seed on a site, following up with a cultipacker or roller is important to ensure adequate seed-to-soil contact.

Figure 25: Annual weeds (e.g., foxtail) were creating excessive shade on Illinois bundleflower (*Desmanthus illinoensis*) seedlings in a first year prairie planting (left). Establishment mowing in the first year of the new planting removed the shade canopy created by annual weeds and increased sunlight to the slower-growing perennial wildflower seedlings (right).

Seedling Establishment Management

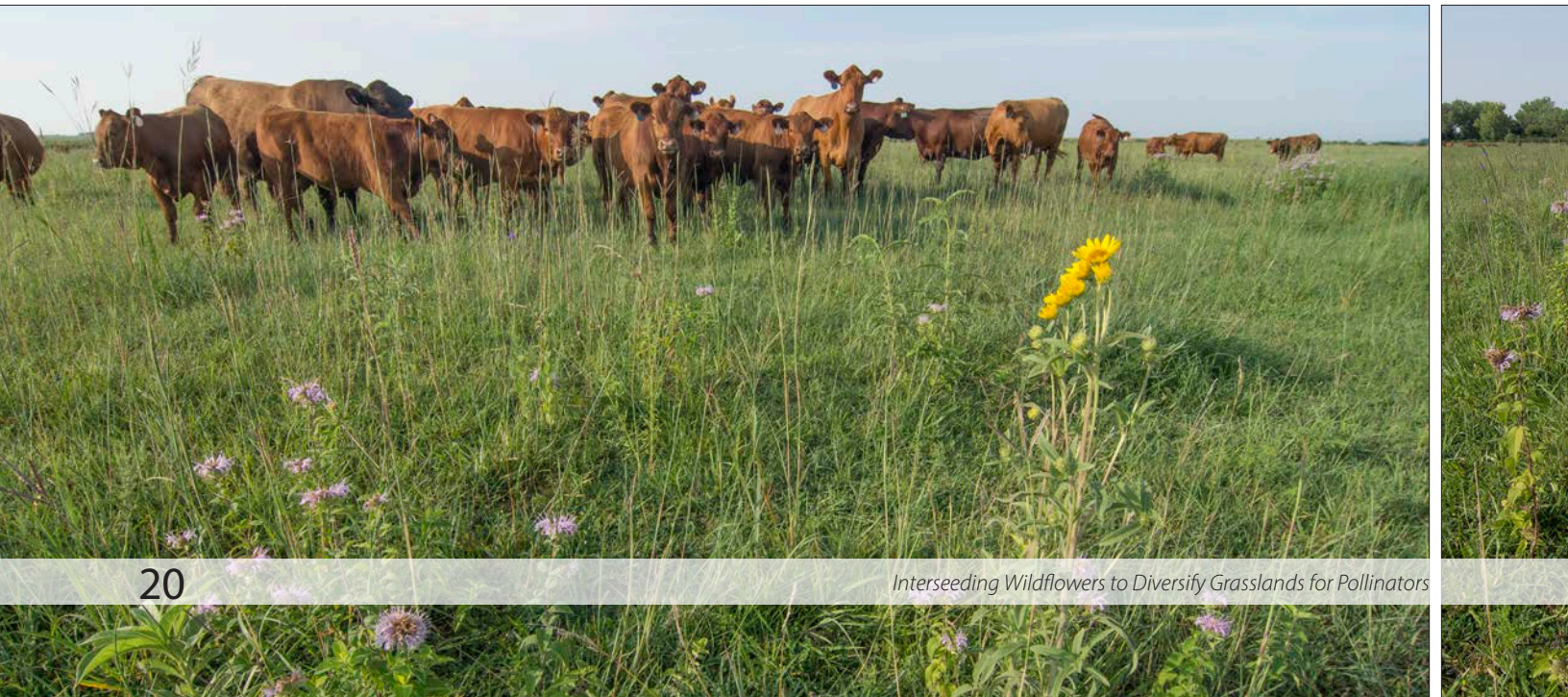
In the first year of establishment, new seedlings require light, adequate soil moisture, and space above and below ground to survive. Wildflower seeds and seedlings are greatly affected by grass canopies and dense sod. Seedlings under a grass canopy are often light starved, resulting in reduced seed germination, less seedling growth, and increased seedling mortality. Dense grass sod also eliminates space for seedlings to grow below ground, decreasing seedling establishment. For these reasons, initial post-seeding management should include continued disturbance of grasses, such as grass selective herbicide, mowing, grazing, or haying. The duration of these disturbances should be based on field checks to determine if the dominant grasses need continued suppression and to assess if wildflowers are responding positively. If the wildflower seedlings have widespread damage due to disturbance, the disturbance should be discontinued. Seedlings in their first year of growth are very fragile.

If your land is enrolled in an USDA program, be sure to check with NRCS to ensure that any post-seeding practices used on an interseeded planting are in compliance with CRP contractual terms.

Grazing

Some practitioners have observed improved wildflower establishment under intensive grazing with short duration aimed at knocking back the grasses during the first year after interseeding. They note that carefully timed and planned grazing during establishment suppresses the grasses, allowing increased

Figure 26a: Cattle grazing in a patch burn grazing system on this Nebraska prairie (left) that was previously interseeded in 2011, using fire and grazing to suppress grasses and remove litter.



sunlight and open areas below ground for seedling roots to grow. Carefully monitoring and adapting grazing during the first growing season after interseeding is critical; remove or lessen stocking rate if there is damage to new wildflower seedlings. An NRCS grazing specialist can help prescribe appropriate stocking rates and grazing timing and duration for establishment management.

Rotational grazing has been used by practitioners using interseeding. Rotational grazing utilizes multiple fields/paddocks which cattle are rotated through for grazing. There are many variations of rotational grazing. Rotational grazing can be effective for establishment management because cattle are able to be moved to a different field/paddock once there is sufficient grass suppression or they begin to graze on young wildflowers. Varying the season and order of grazing in fields/paddocks can help maintain wildflower diversity in a rotational grazing system. Patch burn grazing systems are used by some practitioners. Patch burn grazing is the application of prescribed fire to focus livestock grazing on a portion of a single grazing unit, increasing the diversity and structure of the vegetation to benefit wildlife and maintain livestock production. Cattle prefer grazing in the recently burned unit although they have access to all portions of the grazing unit and will occasionally graze in unburned sections. This leads to selective grazing on preferred grasses and promotes wildflower establishment and persistence. Different portions of the unit should be burned in subsequent years. Burning is not recommended in the first year after seeding. Using a light stocking rate or rotational grazing followed by a patch burn grazing system may help maintain wildflowers on site. For more information on patch burn grazing go to: www.prairienebraska.files.wordpress.com/2011/05/patch-burning-for-diversity.pdf.

Mowing or Haying

Mowing grasses helps sunlight reach emerging wildflowers and can be especially important in the first season following interseeding. Practitioners who use mowing as a management tool agree that recently interseeded grasslands should be mowed multiple times (2–4 times) in the first, and possibly second, year to allow dappled-to-full sunlight to reach wildflower seedlings. Mowing may not be necessary, however, on dry sites where grasses do not excessively shade wildflower seedlings. Interseeded dry sites should be visited multiple times in the first year of establishment to assess canopy shade and be mowed to 8" high if grasses shade the soil surface. Consider including annual and biennial wildflower species on dry sites that will likely not need establishment mowing.

Figure 26b: More than six years later, the wildflowers (left) are surviving well and providing important resources to prairie specialists, like the regal fritillary butterfly (*Speyeria idalia*, right), that can thrive in patch burn systems if rotating portions of the land are left unburned as a refuge.

Figure 27: Cutting prairie hay (top) in fall for baling. Fall (dormant) haying can be used to remove litter prior to interseeding wildflowers or as a long-term management strategy to reduce volunteer trees and shrubs, and promote native plant growth (bottom).

Mow before grasses begin to form a canopy that casts shade over the wildflower seedlings. A good rule of thumb is to mow when grasses are knee-high, reducing their height to 8". Research from a Plant Materials Center indicates that first mowing when grasses are shorter may better promote wildflower establishment than waiting for grasses to grow to knee-high. Mowing should coincide with the active growth periods of the grasses being controlled: early spring to early summer for cool-season grasses and late spring through summer for warm-season grasses. To minimize damage to the seedlings, mow no lower than 4" and increase the height of the mower as the first growing season progresses and the wildflower seedlings grow. Grass clippings can build in the wheel tracks of some mowers and kill seedlings; to avoid this, alternate directions each time you mow so the mower does not go over the same tracks repeatedly.

If mowing is needed to control grasses in the second growing season, mow no lower than 12" high to minimize damage to the interseeded wildflowers. Haying may be used in lieu of mowing with a few caveats: 1) Haying must be done well before grasses develop a closed canopy, which, if allowed to develop, will increase seedling mortality. 2) Clippings should be baled and removed from the site as soon as possible. 3) Cutting, raking, baling, and removal should be done when the soil is firm so soil disturbance from equipment is minimized. If you cannot adjust the height on your haying equipment, consider another seedling establishment management.

Herbicides for Grass Suppression

Grass-selective herbicides may also be used to suppress grasses during the initial establishment of wildflowers (Table 3). Although grasses are most effectively suppressed during or immediately before flowering, to prevent any grass competition or shading of wildflower seedlings, an earlier application is recommended during seedling establishment management. Grass selective herbicides should be applied early in the annual growth and development of the target grass, before the grass goes to flower and also before the grass is actively competing with the new wildflowers. Clethodim and sethoxydim are two of the most widely used grass-selective herbicides. Although neither herbicide should completely eradicate native grasses, if there is any concern about inadvertently eradicating native grasses, use sethoxydim (not clethodim), or utilize another method of grass suppression.

Figure 28: Careful spot-spray herbicide application of aminopyralid to Canada thistle in a two-year-old interseeded planting shown in photos above. An after market spray wand extension (left) was added to the backpack sprayer (right) to minimize overspray on adjacent wildflowers.

Invasive Species Control

If invasive weeds are present on the site, follow-up management will be needed while interseeded wildflowers establish. It is best to address invasive weeds before and soon after interseeding. If invasives spread throughout the planting site, control becomes much more difficult and damage to the interseeded plants is more likely. Areas of dense weed invasions that are treated using any method should be monitored for ongoing weed problems and to measure the status of wildflower success in that area after treatment. It may be necessary to sow additional seed to intensely treated areas after the weed population is under control.

Spot-mowing or haying areas of invasive weeds after interseeding can be used to control weed seed set. When mowing or haying to control a perennial weed species, mow events may need to occur multiple times during critical plant development stages to reduce seed set and plant vigor. Mowing and haying for weed control is easy to implement when weedy species have grown taller than wildflowers and can be cut above the height of the young wildflowers. Grazing can help manage widespread weeds in the early years of a planting but must be carefully monitored and adapted if wildflower seedlings are damaged. If dense areas of weeds are present, fencing grazing animals into an area for weed control is an option but may damage wildflower seedlings in that area.

Spot-spraying with a backpack sprayer can be a very effective method for controlling weeds after interseeding. Use the most appropriate herbicide for the targeted invasive weed. Some broadleaf herbicides are better at controlling certain invasive weeds like Canada thistle than other herbicide products. A subset of wildflowers will tolerate certain selective herbicides (e.g., aminopyralid) that target broadleaf weeds like Canada thistle. If feeding or marketing forage, always check the labels to ensure the herbicides will not restrict these activities. Herbicides for specific invasive weeds can be found in the Midwest Invasive Plant Network's invasive plant control database at www.mipn.org/control.

Figure 29: Female long-horned bee collecting nectar and pollen from a brown-eyed Susan (*Rudbeckia triloba*).

3

Putting It All Together: Interseeding Strategies

The timing and implementation of interseeding strategies should be tailored to the grass species in the existing stand and conditions of the site. The following are successful examples of pre- and post-interseeding strategies, derived from both research and practitioners. Choose the option that best matches the equipment and resources you have available.

Management Timelines:

- Pre-interseeding activities
- Interseeding
- Post-interseeding activities

Options for Interseeding Cool-Season Grass Stands

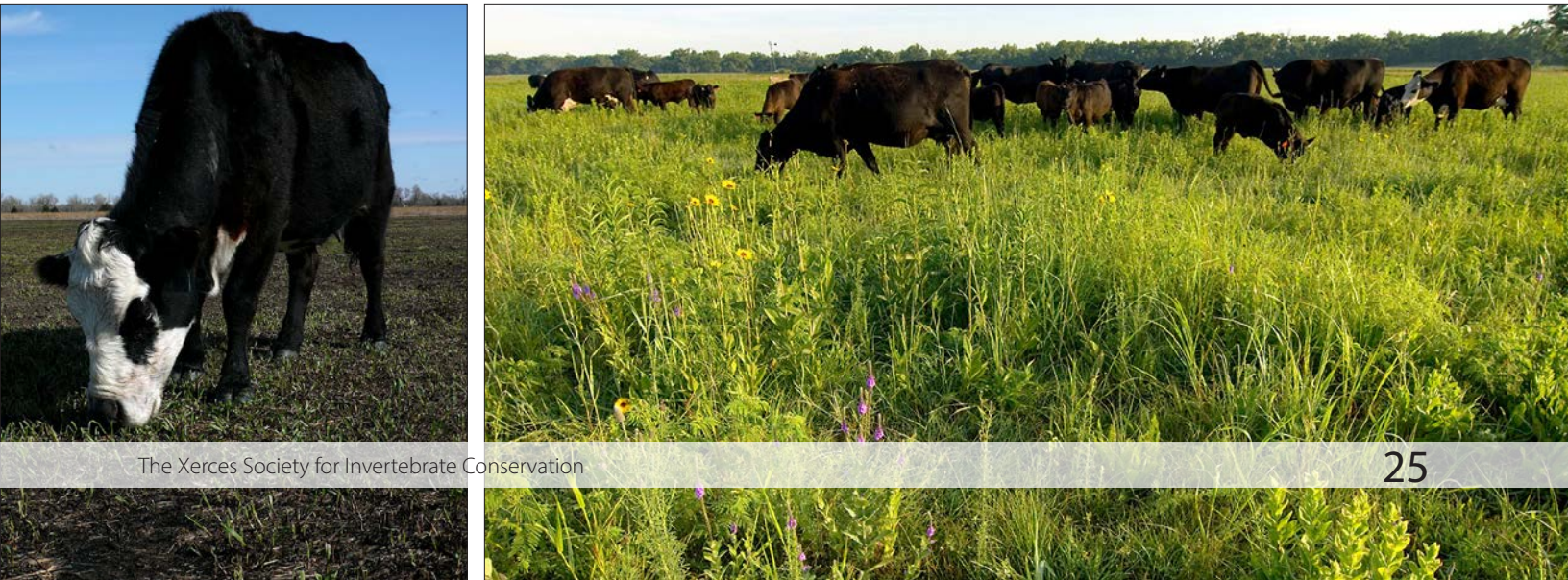
The following techniques can be used in grasslands dominated by cool-season grasses. Some customization will be required to account for different growing times as noted. Wildflowers as well as native grasses should be included in the seed mix.

1 Fall Graze → Fall Spray → Spring Interseed → Late Spring Graze* → Early Fall Graze

Intensively graze cool-season grasses in late summer to suppress grasses and remove litter. Spray cool-season grass regrowth with glyphosate in fall. Interseed the following spring. In the first year and second of establishment, intensively graze in late-May to early-June and again in late-September to early-October. In year two, intensively graze the site in late-May to early-June and again in late-September to early-October. If there is enough fuel load, spring burn the site in year three. Graze the site in late-August through September in year three.

* *Check herbicide to ensure there are no restrictions that would prevent marketing of any cattle or forage exposed to herbicide.*

Figure 30: Cow grazing on smooth brome in recently burned patch in restored prairie managed with patch-burn grazing system (left). Following establishment, the site is managed with patch burn grazing (right).



2 Fall Burn → Dormant Interseed → Spring Spray

Burn the site in fall to remove litter and suppress grasses, and interseed grasses and wildflowers during the dormant season. Apply a grass-selective herbicide the following spring when cool-season grasses reach 8" tall and respray grasses in the following fall after the native grasses have become dormant to minimize herbicide damage. Read and follow herbicide label directions carefully.

3 Late Summer Mow → Fall Spray → Dormant Interseed → Summer Mow

Mow the stand in early August. Spray grass regrowth in fall with glyphosate before a killing frost. Interseed grasses and wildflowers in the dormant season using a seed drill. Mow (8" high), 3–4 times in the first year of establishment. Mow (12" high) in late-spring in year two. Note: Ongoing management to suppress cool-season grasses will likely be needed in subsequent years. This approach is best suited for sites with less dominant nonnative cool-season grasses or native cool-season grasses.

4 Late Spring Multiple Disturbances → Late Spring Interseed → Late Spring Multiple Disturbances

Native wildflowers and grasses can be successfully interseeded into smooth brome with only the use of fire, grazing, or mowing alone. For example, smooth brome must be burned in the boot stage for at least four consecutive years before interseeding. Wildflowers and grasses may need to be interseeded multiple times to fully establish. Annual spring burning may be required for an additional six consecutive years after interseeding.

Figure 31: This prairie in Cedar Falls, Iowa, was interseeded with 85 species of warm and cool-season grasses, sedges, and wildflowers. Prior to interseeding the site had only a few relic native species as well as non-native cool-season grasses. The site was burned in the spring, then interseeded soon after, and was spring burned annually for three growing seasons in years 3-5 after sowing the seed.

Options for Interseeding Warm-Season Grass Stands

The following techniques can be used in grasslands dominated by warm-season grasses. Some customization will be required to account for different growing times as noted. Wildflowers should be the primary focus of interseeding seed mixes.

Management Timelines:

- Pre-interseeding activities
- Interseeding
- Post-interseeding activities

1 Late Summer *OR* Fall Burn → Dormant Interseed → Summer Graze

Burn in the late summer or fall and interseed shortly after burning. Moderately graze throughout the summer or intensively graze for short periods in the first growing season after interseeding.

2 Fall Burn → Fall Interseed → Summer Mow *OR* Hay

This technique has been used for interseeding wildflowers into native warm-season bunch grasses like big bluestem and Indiangrass. Fall burn and interseed shortly after burning. Mow or hay (4–6" high) whenever vegetation reaches 12–18" in height from late-May to late-August in the first growing season. This technique is very effective against warm-season grasses, but has low success on cool-season grass stands.

FIGURE 32: Cattle grazing around various native wildflowers, including boneset (*Eupatorium* spp.) and blue lobelia (*Lobelia siphilitica*), in Wisconsin.

3 Late Summer Mow *OR* Hay → Dormant Interseed → Summer Spray → Summer Mow

Mow or hay the site in August to stress the warm-season grass stand. If litter remains, hay again or burn the site in fall. Interseed wildflowers during the dormant season and spray a grass selective herbicide (e.g., sethoxydim) the following summer. Mow (6–8" high) two times in the first year of establishment if grass remains vigorous. Because the timing of the spray event occurs after seeding, some seedlings may be susceptible to herbicide damage. Read and follow herbicide label directions carefully.

4 Late Spring Burn → Late Spring Disk *OR* Rototill → Late Spring Interseed → Summer Mow *OR* Hay

On sites with low or no weed pressure, burn the site in mid-spring to remove litter. Disk or rototill 2" deep to expose bare soil in late-spring. Interseed wildflowers soon after. Cultipack to improve seed contact with the soil. Mow 8" high when grasses reach knee high in the first year of establishment.

Management Timelines:

- Pre-interseeding activities
- Interseeding
- Post-interseeding activities

Options for Interseeding Mixed Grass Stands

The following techniques can be used in grasslands where both cool and warm-season grasses are prevalent. Some customization will be required to target grass suppression when grasses are most vulnerable in your region. Wildflowers should dominate the seed mix.

1 First Year Graze → Dormant Interseed → Second Year Graze *OR* Hay

Graze the grass stand intensively throughout the growing season prior to interseeding. The site can be interseeded in the fall or dormant season of the same year or in the following spring. The site should be intensively grazed for two weeks or hayed when cool-season grasses reach boot stage in the first spring after seeding. To target warm-season grasses, hay or intensively graze for two weeks when warm-season grasses reach boot stage in the first summer after seeding.

2 Spring Burn → Spring Interseed → Graze *OR* Hay

Burn in the spring and interseed natives shortly after burning. Intensively graze or hay as described in the first mixed-season option the summer following interseeding in the spring.

3 Fall Burn → Dormant Interseed → Mow, Hay, *OR* Graze

Burn in the fall and interseed shortly after burning. Mow or hay multiple times in the first growing season after seeding or intensively graze as in the first mixed-season option.

4 Late Summer *OR* Fall Burn → Fall Spray → Dormant Interseed → Spray *OR* Hay

Burn in late summer or early fall. Spray grass regrowth in fall with glyphosate. Interseed in the dormant season. Spray with clethodim in the first growing season or hay once per season for multiple years following seeding. Vary the timing of disturbance to suppress the most dominant grasses or alternate disturbance timing between warm and cool seasons.

5 Late Spring Spray → Late Summer Mow, Spray, Disk, *OR* Rototill → Dormant *OR* Spring Interseed → Spring Graze → Summer Mow

Inspect the field for broadleaf invasive species such as introduced species of thistles in late-spring, and if disturbing the site with mowing or disking, spot-spray thistles with an appropriate broadleaf herbicide prior to disturbing the grasses. Mow, spray glyphosate, or disk the grass stand in late-summer. Interseed natives during the dormant season or in the following spring. Intensively graze during the spring months; remove cattle in late-spring when seedlings emerge. Mow 8" high when grasses reach knee high in the first year of establishment. Additional mowing may be needed in year two if weed pressure is high. Spot-spray with a broadleaf herbicide if thistles are detected in year two.

4

Managing Interseeded Grasslands Beyond Establishment

Practitioners generally follow four best practices in long term management of interseeded grasslands. They:

1. Assess the conditions on the ground;
2. Implement practices to maintain wildflower diversity;
3. Evaluate the effects of those management activities; and,
4. Adapt and modify future activities using site-based experience.

Since wildflower species often respond differently to each management activity, it is important to vary the management activity type, timing, and location to ensure a refuge for wildlife and promote the entire wildflower community. If burning, grazing, haying, or mowing is used as a management tool, remember to leave at least ⅓ of the site undisturbed as a refuge for pollinators and other wildlife. When thinking about timing of management, also consider the primary nesting season for grassland birds or flight periods for listed pollinator species.

Within this framework, a combination of periodic fires, haying, mowing, grass-selective herbicides, and/or grazing can all be implemented to maintain wildflower diversity. Practitioners agree that varying the management activities is critical to wildflower diversity, but there is little agreement on how to vary practices. Some managers suggest light to moderate season-long grazing with rest periods or burning every 2–3 years, while others suggest limiting grazing to specific times of year and longer intervals between prescribed burns (4–7 years). This discordance underscores the value of adaptive management

TABLE 5—Common Long-term Management Issues of interseeded Sites

ISSUES/CONCERNS	MANAGEMENT OPTIONS
Cool-season grasses persist in planting	Prescribed burn, grass-selective herbicide, grazing, or haying at vulnerable grass growth stage (boot stage).
Warm-season grasses dominate over wildflowers	Mid- to late-summer haying, burning, grazing, or grass selective herbicides at vulnerable grass growth stage (boot stage).
Woody encroachment	Use prescribed fire alone to eliminate brush or spot mow or cut brush in spring or fall, apply an appropriate herbicide to the cut stump, follow-up with prescribed fire if woody plants re-sprout or sucker.
Maintaining wildflower abundance and diversity	Periodically burn, graze, hay, mow, or use grass-selective herbicides. Target the active growth period of the dominant grasses.
Invasive weed management	Use grazing, mowing, burning, haying, or herbicides to control invasives, timing management for when target species are most vulnerable.

FIGURE 33: Spot mowing (gray dogwood) with a gas powered weed whip (fitted with a brush blade) can be used for brush control for smaller patches in planted prairies. Cut stems should be treated with a cut stump herbicide to prevent re-sprouting.

FIGURE 34: Spot mowing with a small rotary mower can be used to control larger brush or weed patches in planted prairies with minimal disturbance to adjacent prairie plants.

approaches tailored to address the conditions of the specific interseeding project. Table 5 provides an overview of specific concerns related to wildflower persistence or plant community management in interseeded plantings, along with management options that can be used to address these concerns. (Note that one or more of these options can be applied to a given site.)

FIGURE 35: This interseeded grassland in Minnesota now provides valuable resources for pollinators.

5

Conclusion

Pollinators are in decline and now is the time to embrace opportunities to enhance habitat to support pollinators. Interseeding is one strategy to consider to increase plant diversity in species-poor grasslands, and offers an opportunity to diversify the millions of acres of CRP and conservation lands in the United States and provide pollinators with much-needed resources. Interseeding can be tailored to best fit the soil and climate conditions, experience of the producer or practitioner, and equipment available. Practitioners have been successfully interseeding wildflowers into species-poor grasslands for many years. It is our hope that by bringing together current best practices of interseeding in the Midwest and Great Plains states, this document will enable additional practitioners and land managers to increase diversity in their grasslands through interseeding.

FIGURE 36: This planting on a college campus was interseeded with 50 species of prairie grasses and wildflowers, using a no-till drill in the fall.

Addendum

TABLE 6—Wildflower Species Persistent In Interseeded Plots

These native species that have persisted in 7–20-year-old interseeded plantings. The results were derived from 15 interseeded plantings in Eastern Iowa.

SCIENTIFIC NAME	COMMON NAME	
Baptisia alba	White wild indigo	0.01–0.1
Desmodium canadense	Showy tick trefoil	0.25–1
Echinacea pallida	Pale purple coneflower	0.1–1
Eryngium yuccifolium	Rattlesnake master	0.15–2
Helianthus grosseserratus	Sawtooth sunflower	0.25
Heliopsis helianthoides	Ox-eye sunflower	0.25–1
Lespedeza capitata	Round-headed bush clover	0.2–1
Monarda fistulosa	Wild bergamot	0.75–3
Parthenium integrifolium	Wild quinine	0.2–0.3
Penstemon digitalis	Foxglove beardtongue	0.2–1
Ratibida pinnata	Gray-headed coneflower	0.9–3
Rudbeckia subtomentosa	Sweet black-eyed Susan	0.2–2
Silphium integrifolium	Rosinweed	0.01
Silphium laciniatum	Compass plant	0.01–0.1
Solidago rigida	Rigid goldenrod	0.25–3
Solidago speciosa	Showy goldenrod	2–4
Symphyotrichum laeve	Smooth blue aster	1–3
Symphyotrichum novae-angliae	New England aster	0.35–1
Verbena stricta	Hoary vervain	0.25
Vernonia fasciculata	Ironweed	0.25
Zizia aurea	Golden Alexanders	0.2–1.7

INTERSEEDING RATE—suggested seeds per square foot

The Tallgrass Prairie Center at the University of Northern Iowa has a documented record of more than 50 interseeding projects in Iowa, planned and managed by TPC staff between 1997 and 2010. Many of these plantings were interseeded into established grasses that included mowed and unmowed turfgrass (Kentucky bluegrass), old smooth brome-clover-alfalfa pastures, and brome and fescue roadsides. Detailed records for these projects exist, including site preparation prior to interseeding, planting method and time, seed mixes, and post seeding management.

These plantings included a variety of interseeding methods: fall, frost and spring seeding; fall and spring spraying, haying, disking; broadcast seeding, broadcast + drag, broadcast + cultipack, Truax no-till drill, Brillion drop seeder, and hydroseeding. Plantings were seeded at a rate of 40 seeds/ft² (20 grass, 20 wildflower) and were based on pure live seed. Seed mixes included 30–70 species and all plant guilds were represented. Post seeding management included mowing 3–5 times in the first growing season. Long-term management included fall haying, fall and spring burning every 2–3 years, and mowing (in fall or early spring annually or every 2–3 years).

Fifteen of these interseeded plantings were sampled in October 2017 to determine which plant species have persisted. To assess vegetation establishment, a random walking transect was conducted across each planting and every wildflower that came in contact was recorded. From the original seed mixes, 21 species were detected in nearly 100% of the plantings sampled. Seeding rates for those species are included for reference (Table 6). These species are recommended for inclusion in interseeding projects if the species ranges and soil moisture preferences fit the location and soil moisture conditions of the planting site.

Additional Resources

Restoring, Planting, and Managing Grasslands

Sardiñas, H., J. Hopwood, J. K. Cruz, J. Eckberg, K. Gill, S. Foltz Jordan, M. Vaughan, N. Lee Adamson, A. Stine, and E. Lee-Mäder. 2018. *Maintaining Diverse Stands of Wildflowers Planted for Pollinators*. 60 pp. Portland, Oregon: The Xerces Society. Available soon at: www.xerces.org/pollinator-conservation/natural-areas/

Upper Midwest Pollinator Meadow Habitat Installation Guide & Checklist. 2015. 20 pp. Portland, Oregon: The Xerces Society. Available at: www.xerces.org/pollinator-conservation/pollinator-habitat-installation-guides/

Helzer, C.. 2010. *The Ecology and Management of Prairies in the Central United States*. 232 pp. Iowa City: University of Iowa Press.

Kurtz, C.. 2001. *A Practical Guide to Prairie Reconstruction*. 80 pp. Iowa City: University of Iowa Press.

Packard, S., and C. Mutel. 1997. *The Tallgrass Restoration Handbook: For Prairies, Savannas, and Woodlands*. 504 pp. Washington, D. C.: Island Press.

Ecology and Conservation of Pollinators

Mader, E., M. Shepherd, M. Vaughan, S. H. Black, and G. LeBuhn. 2011. *Attracting Native Pollinators. Protecting North America's Bees and Butterflies*. 371 pp. North Adams, MA: Storey Publishing.

Hatfield, R., S. Jepsen, E. Mader, S. H. Black, and M. Shepherd. 2012. *Conserving Bumble Bees: Guidelines for Creating and Managing Habitat for America's Declining Pollinators*. 32 pp. Portland, OR: The Xerces Society for Invertebrate Conservation. Available at: www.xerces.org/wp-content/uploads/2012/06/conserving_bb.pdf

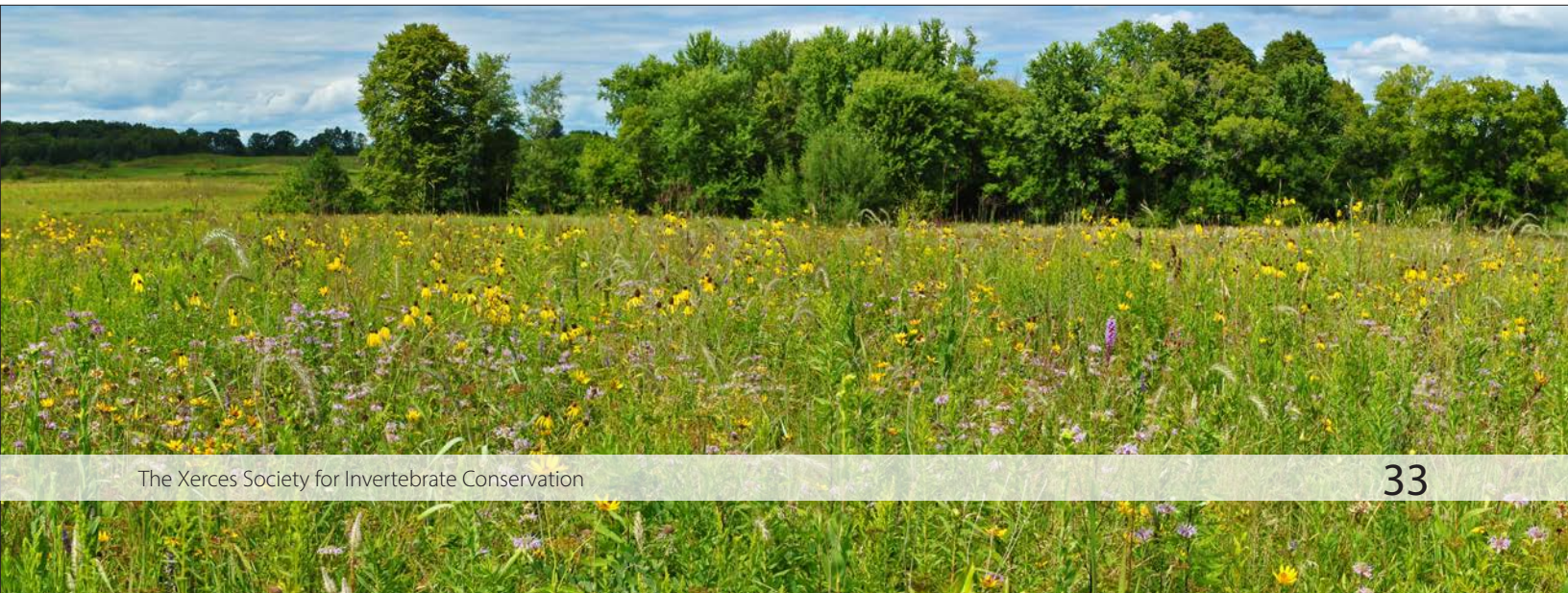
Vaughan, M., J. Hopwood, E. Lee-Mader, M. Shepherd, C. Kremen, A. Stine, and S. H. Black. 2015. *Farming for Bees: Guidelines for Providing Native Bee Habitat on Farms*. 76 pp. Portland, OR: The Xerces Society for Invertebrate Conservation. Available at: www.xerces.org/wp-content/uploads/2008/11/farming_for_bees_guidelines_xerces_society.pdf

Additional Interseeding Guidance

Guidelines for inter-seeding to restore or enhance native species diversity (Minnesota Board of Soil and Water Resources) www.bwsr.state.mn.us/native_vegetation/inter-seeding.pdf

U.S. Department of Agriculture–Natural Resources Conservation Service (USDA–NRCS). 2007. *Interseeding. Iowa fact sheet*. Available online at: www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid...ext=pdf

Figure 37: Diverse wildflowers blooming in Wisconsin prairie after successful restoration from degraded grassland.



References

Adkins, J. K., and T. G. Barnes. 2013. Herbicide Treatment and Timing for Controlling Kentucky Bluegrass (*Poa pratensis*) and Tall Fescue (*Festuca arundinacea*) in Cool Season Grasslands of Central Kentucky, USA. *Natural Areas Journal* 33:31–38.

Ashworth, A. J., F. L. Allen, P. D. Keyser, D. D. Tyler, A. M. Saxton, and A. M. Taylor. 2015. Switchgrass yield and stand dynamics from legume intercropping based on seeding rate and harvest management. *Journal of Soil and Water Conservation* 70:374–384.

Bahm, M. A., T. G. Barnes, and K. C. Jensen. 2011. Herbicide and Fire Effects on Smooth Brome (*Bromus inermis*) and Kentucky Bluegrass (*Poa pratensis*) in Invaded Prairie Remnants. *Invasive Plant Science and Management* 4:189–197.

Balogianni, V. G., S. D. Wilson, B. M. Vaness, A. S. MacDougall, and B. D. Pinno. 2014. Different Root and Shoot Responses to Mowing and Fertility in Native and Invaded Grassland. *Rangeland Ecology & Management* 67:39–45.

Brandt, A. J., and E. W. Seabloom. 2012. Seed and establishment limitation contribute to long-term native grass wildflower declines in California grasslands. *Ecology* 93(6): 1451-1462.

Christiansen, P. A. 1994. Establishment of prairie species by overseeding into burned roadside vegetation. In Hartnett, D. (ed.). *Proceedings of the 14th Annual North American Prairie Conference*. 167-169.

Cull, M. I. 1976. Establishing prairie vegetation along highways in the Peoria area. In Glenn-Lewin, D. C. and R. Q. Landers, Jr. (eds.). *Fifth Midwest Prairie Conference Proceedings*. 172-177.

Dickson, T. L., B. Hayes, and T. Bragg. In Press. Effects of 34 years of experimentally manipulated burn seasons and frequencies on prairie plant composition. *Rangeland Ecology & Management*.

DiVittorio, C. T., J. D. Corbin, and C. M. D'Antonio. 2007. Spatial and temporal patterns of seed dispersal: An important determinant of grassland invasion. *Ecological Applications* 17(2): 311-316.

Fansler, V. A., and J. M. Mangold. 2011. Restoring Native Plants to Crested Wheatgrass Stands. *Restoration Ecology* 19:16–23.

Foster, B. L. 2001. Constraints on colonization and species richness along a grassland productivity gradient: The role of propagule availability. *Ecology Letters* 4:530–535.

Foster, B. L., C. A. Murphy, K. R. Keller, T. A. Aschenbach, E. J. Questad, and K. Kindscher. 2007. Restoration of prairie community structure and ecosystem function in an abandoned hayfield: A sowing experiment. *Restoration Ecology* 15:652–661.

Frances, A. L., C. Reinhardt Adams, and J. G. Norcini. 2010. Importance of seed and microsite limitation: Native wildflower establishment in non-native pasture. *Restoration Ecology* 18(6): 944-953.

Kennedy, T. A., S. Naeem, K. M. Howe, Johannes M. H. Knops, D. Tilman, and P. Reich. 2002. Biodiversity as a barrier to ecological invasion. *Nature* 417: 636-638.

LaBar, C. C. and C. B. Schultz. 2012. Investigating the role of herbicides in controlling invasive grasses in prairie habitats: Effects on non-target butterflies. *Natural Areas Journal* 32(2): 177-189.

Long, Q., B. L. Foster, and K. Kindscher. 2014. Seed and microsite limitations mediate stochastic recruitment in a low-diversity prairie restoration. *Plant Ecology* 215:1287–1298.

Madison, L. A., T. G. Barnes, and J. D. Sole. 2001. Effectiveness of Fire , Disking , and Herbicide to Renovate Tall Fescue Fields to Northern Bobwhite Habitat. *Wildlife Society Bulletin* 29:706–712.

Martin, L. M., and B. J. Wilsey. 2006. Assessing grassland restoration success: Relative roles of seed additions and native ungulate activities. *Journal of Applied Ecology* 43:1098–1109.

Martin, L. M., and B. J. Wilsey. 2014. Native-species seed additions do not shift restored prairie plant communities from exotic to native states. *Basic and Applied Ecology* 15:297–304.

Meissen, J. 2017. *Prairie enhancement of non-native cool-season grass stands. Final Research Report*. Tallgrass Prairie Center-University of Northern Iowa. 13 pp. Cedar Falls, Iowa.

Murphy, R. K., and T. a Grant. 2005. Land management history and floristics in mixed-grass prairie, North Dakota, USA. *Natural Areas Journal* 25:351–358.

Rosburg, T. R. 2001. Effects of late spring fires on the survival, growth, and reproduction of prairie wildflowers. In Bernstein N. P. and L. F. Ostrander (eds.). *Proceedings of the 17th North American Prairie Conference*. 48-58.

Russell, C. and C. Schultz. 2010. Effects of grass-specific herbicides on butterflies: an experimental investigation

to advance conservation efforts. *Journal of Insect Conservation* 14(1): 53-63.

Rowe, H. I. 2010. Tricks of the Trade: Techniques and Opinions from 38 Experts in Tallgrass Prairie Restoration. *Restoration Ecology* 18:253–262.

Roy, B. A., K. Hudson, M. Visser, and B. R. Johnson. 2014. Grassland fires may favor native over introduced plants by reducing pathogen loads. *Ecology* 95:1897–1906.

Ruffner, M. E., and T. G. Barnes. 2010. Natural Grassland Response to Herbicides and Application Timing for Selective Control of Tall Fescue, an Invasive Cool-Season Grass. *Invasive Plant Science and Management* 3:219–228.

Salesman, J. B., and M. Thomsen. 2011. Smooth brome (*Bromus inermis*) in tallgrass prairies: A review of control methods and future research directions. *Ecological Restoration* 29:374–381.

Seabloom, E. W. 2001. Spatial and temporal variability in propagule limitation of California native grasses. *Oikos* 210: 291-201.

Seabloom, E. W., W. S. Harpole, O. J. Reichman, and D. Tilman. 2003. Invasion, competitive dominance, and resource use by exotic and native California grassland species. *PNAS* 100(23):13384-13389.

Smith, D., D. Williams, G. Houseal, and K. Henderson. 2010. *The Tallgrass Prairie Center guide to prairie restoration in the upper Midwest*. 301 pp. Iowa City, Iowa. University of Iowa Press. 301 pp.

Snyder, L. J., P. E. Rothrock, R. T. Reber, and N. D. Simmons. 2008. *Interseeding wildflowers in a tallgrass prairie restoration: effects of three disturbance regimes - first growing season. Thesis*. Taylor University, Upland, IN.

Suding, K. N. and K. L. Gross. 2006. Modifying native and exotic species richness correlations: The influence of fire and seed addition. *Ecological Applications*, 16(4): 1319-1326.

Tilman, D. 1997. Community Invasibility, Recruitment Limitation, and Grassland Biodiversity. *Ecology* 78:81–92.

Tranel, M. 2010. Preliminary findings of interseeded prairie wildflowers into native grass stands. In Williams D., B. Butler, and D. Smith (eds.). *Proceedings of the 22nd North American Prairie Conference*. 65-69.

Turnbull, L. A., Crawley, M. J. and Rees, M. 2000. Are plant populations seed limited? A review of seed sowing experiments. *Oikos*, 88: 225-238.

U. S. Department of Agriculture-Farm Service Agency. 2016. Conservation reserve enrollment March 31. Available online at: https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/Conservation/PDF/CRPEnrollmentMar2016.pdf

U. S. Department of Agriculture-Farm Service Agency. 1017. Planning policy for transitioning cover seedings. *Iowa Conservation Memo 17-52*. State of Iowa FSA office.

Warkins, T. E. and E. A. Howell. 1983. Introduction of selected prairie wildflowers into an established tallgrass prairie restoration. In Brewer R. (ed.). *Proceedings of the 8th North American Prairie Conference*. 147–151.

Williams, D. W., L. L. Jackson, and D. D. Smith. 2007. Effects of frequent mowing on survival and persistence of wildflowers seeded into a species-poor grassland. *Restoration Ecology* 15(1): 24-33.

Williams, D., D. Smith, R. Lensing, and K Schultz. 2010. Effects of mowing on abundance and persistence of tallgrass prairie wildflowers seeded into an established stand of prairie grasses: ten years after sowing. In Williams D., B. Butler, and D. Smith (eds.). *Proceedings of the 22nd North American Prairie Conference*. 40-44.

Willson, G. D. 1992. Morphological characteristics of smooth brome used to determine a prescribed burn date. In Smith D. D. and C. A. Jacobs (eds.). *Proceedings of the 12th North American Prairie Conference*. 113-116.

Willson, G. D. and J. Stubbendieck. 2000. A provisional model for smooth brome management in degraded tallgrass prairie. *Ecological Restoration* 18(1): 34-38.

Wilsey, B. J., and H. W. Polley. 2003. Effects of Seed Additions and Grazing History on Diversity and Productivity of Subhumid Grasslands. *Ecology* 84:920–931.

Wilson, S. D., and M. Pärtel. 2003. Extirpation or coexistence? Management of a persistent introduced grass in a prairie restoration. *Restoration Ecology* 11:410–416.

Xu, L., J. Young, A. Boe, J. R. Hendrickson, and N. H. Jr. Troelstrup. 2016. Impacts of Mowing Treatments on smooth bromegrass (*Bromus inermis*) belowground bud bank. *Natural Resource Management Faculty Publications. 214.* http://openprairie.sdstate.edu/nrm_pubs/214. Accessed 11/15/17.

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Chris Helzer: Figures 7, 21 (*top*), 26, 30

Matt Lavin [flickr.com/plant_diversity]: Figure 6

Justin Meissen [flickr.com/40855483@N00]: Figure 19

David O'Shields: Figures 23, 25 (*right*), 28, 33, 34

USDA–NRCS [photogallery.nrcs.usda.gov]: Figure 13

The Xerces Society/Sarah Foltz Jordan: Cover (*front*, *back*); Figures 1, 12, 17, 20, 24, 32, 35

The Xerces Society/Jennifer Hopwood: Figures 2 (*right*), 3, 9, 16, 18

The Xerces Society/Karin Jokela: Figures 5 (*left*), 8 (*left*)

The Xerces Society/Rae Powers: Figure 2 (*left*)

The Xerces Society/Dave Williams: Figures 4, 5 (*right*), 8 (*right*), 10, 11, 15, 23, 25 (*left*), 27, 31, 36

Practitioners

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Red-belted bumble bee (*Bombus rufocinctus*) visiting purple prairie clover (*Dalea purpurea*) on an interseeded prairie in Minnesota.

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