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Seed of many native species are now commercially available for prairie reconstructions, large or small. Yet many people have a interest in collecting and growing native species for butterfly gardens, backyard and schoolyard wildlife habitat, and prairie restorations. Seed collecting is satisfying and rewarding, a great volunteer activity for introducing people to prairies, and a good way to collect seed for local prairie restorations.

Which species?
Any species can be collected by hand, but hand collecting is particularly useful in collecting seed of native species which:
- occur on specific sites that may be inaccessible to machine harvest.
- are very low- or high-growing species or early- or late-ripening species.
- occur as uncommon or patchy species in native prairie.
- have explosive seed dispersal mechanisms (phiox, viola)

Equipment Needed
- Leather work gloves
- Good quality pruning shears or heavy-duty scissors
- Durable, lightweight bags of various sizes
- Appropriate clothing: sturdy footwear, long pants, hat, extra water
- Binoculars for counting
- Willing companions!

Optimal Collection Period
Polygala nemoralis

Seed Ripening Period
- July August May June
- May June September July August

How to Collect?

Seed can be stripped by hand from many species (blazingstars, asters, grasses). Efficiency can be improved by keeping both hands free by fastening collection bags and containers around the waist. In species with seed in “salt-shaker” pods, try tipping the pod into an open container to collect (shooting star, giant St. John’s wort, larkspur, wild columbine). This will minimize the need to clean seed later. If seed is held tightly in the seedhead, simply clip a portion of the seedhead for later cleaning. Prickly seedheads like rattlesnake master (Eryngium yuccifolium) or pale purple coneflower (Echinacea pallida) will require gloves and shears for efficient collecting. Plastic combs aid efficient stripping of seed from grasses as illustrated in the photo below. Species with explosive pods can be bagged with nylon hosiery just prior to seed dispersal.

Collecting from Remnant Prairies

Remnants are small remaining patches of the original prairie landscape that have not been cropped, overgrazed, or otherwise destroyed. Very few remnant prairies exist in the mid-west today, and most are in need of careful management if they are to be conserved. A commonly expressed rule is “take half, leave half” when harvesting seed from remnants. Be mindful of legal and ethical considerations when collecting. While remnants are important local genetic sources of seed stock for restorations or seed nurseries, they should not be directly exploited for commercial production of seed. Federal and state endangered species cannot be collected without proper permits (go to www.iowadnr.com/other/threatened/habitat.htm to view a list of Iowa’s threatened and endangered species).

Where to Collect?

Obtain permission from the landowner or proper land management agency prior to collecting.

Collecting Seed for Genetic Diversity

An important restoration goal should be to capture genetic diversity from remnant populations. Here are some rules of thumb to guide your efforts. First, of course, be reasonably sure the site is a remnant (never plowed, not planted).

Collect seed from at least 20 to 30 well-dispersed individual plants within a population, if possible. Randomize the selection to avoid intentionally selecting plants based on size, color, vigor or any other trait. The point is to capture genetic diversity, not novelty. To sample large, sprawling populations, walk to project sites and collect seed perhaps every 10 paces. Collect roughly equal amounts of material (seed or seedhead) from each plant you encounter. If collecting from multiple sites, attempt to equalize the contribution of seed from each site, particularly if collecting seed as foundation stock for nursery production to generate seed for other reconstructions.

Federal and state endangered species cannot be collected without proper permits, and should only be done as part of a recovery effort by qualified professionals.

Are There Negative Impacts to Collecting from Remnants?

Most prairie species are perennial, meaning their roots survive over winter to regrow shoots the next spring, so an annual seed crop is not essential to the perpetuation of the population. Exceptions are annual, biennial, and short-lived perennial species; rare and uncommon species; or common species poorly represented in a remnant. Avoid intense, repeated, annual harvesting of the same remnant area. The negative impacts of over-collecting include trampling of vegetation and introduction of exotic or invasive plants brought in on clothing or equipment. Manipulation of a remnant prairie to maximize seed production - such as whole-site, repeated annual burns; herbicide treatments; or fertilizing – is inappropriate and damaging to remnant biodiversity. Finally, any mechanical harvesting occurring in remnant sites should include a careful inspection and cleaning of equipment prior to use, including vehicles, to avoid introducing exotic/invasive species that may contaminate the equipment and lead to the degradation of the remnant or create long-term management issues.

Be mindful that removal of any plant or plant part from preserves, sanctuaries, or protected areas is illegal. Thinning, fragmentation, or equipment. Manipulation of a remnant prairie to maximize seed production - such as whole-site, repeated annual burns; herbicide treatments; or fertilizing – is inappropriate and damaging to remnant biodiversity. Finally, any mechanical harvesting occurring in remnant sites should include a careful inspection and cleaning of equipment prior to use, including vehicles, to avoid introducing exotic/invasive species that may contaminate the equipment and lead to the degradation of the remnant or create long-term management issues.

Remnant prairies provide genetically adapted seed for restoring prairies for future generations of iowans!

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When to Collect?

Seed ripening and timing of harvest varies by species, environmental conditions, and regional adaptation of plants. Most species ripen gradually, so not all seed will be at the same stage of maturity at any given time. Seed maturity usually progresses from top to bottom of the seed head in grasses and many forbs species. However some ripen from the bottom up, as in the blazingstars. Mature seeds are usually quickly dispersed either by gravity, wind, water, or animals, so it’s important not to delay collecting.

The tables illustrate approximate seed maturity times for some commonly collected native species in Iowa. Cold, moist conditions will delay seed maturity; while hot, dry conditions hasten it. Latitude affects ripening since many plants flower and set seed in response to photoperiod. Seed maturity occurs earlier in populations adapted to northern Iowa, and later in populations adapted to southern Iowa. Optimal Collection Periods when more species are likely to be in fruit are indicated.

When to Collect?

Harvest grasses at the hard-dough stage, when firm, thumbnail pressure slightly dents the caryopsis. Many grasses do not hold seed long after maturity. Test ripeness by firmly striking the seed head against palm; if some shattering occurs, the seed is ready to harvested.

In forb species, the seedhead or stalk immediately below will appear dry or discolored as seed matures. A notable exception are the spiderworts (Tradescantia), members of the day-flower family, which drop mature seed while bracts remain green and other flowers in the same cluster are in bud or blooming. Species with dispersal apparatus, i.e. ‘parachutes’ (blazingstars, asters, goldfinches, milkweeds) will appear dry and at maturity and should be picked immediately at this stage. Some species forcefully eject seed at maturity (phlox and violets, for example), and must be checked daily or bagged loosely with a mesh bag so seed is captured upon dispersal.

Keeping Records

Keeping records of where and when you collect provides important information about a prairie restoration. Basic information to include is location (county, township, section, quarter section), soil type (sandy, clayey, loamy and moisture (wet, medium, dry), slope and aspect (direction/slope face), approximate size of population, number of plants collected from, and date. It’s a good idea to include a sketch of the site to jog your memory about where the species occurred within the prairie.

Example of Seed Collecting Label

Seedhead of pale purple coneflower (Echinacea pallida) sliced in half to reveal lighter-colored seeds tucked in between bracts.

Keep in mind two important ideas:

- Attempt to collect roughly equal amounts of seed from several individuals in the population.
- Generally-speaking, near neighbors are more closely related genetically than distant individuals, so it is important to collect seed from throughout the population.

Collecting from Remnants?

Collecting from remnants is generally a last resort, and should be done only with the proper agency before collecting. Proper agency befor collecting in these areas.

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**What is Debearding?**

Many grass species have seeds with “beards” (hair-like awns), and many forb species have “parachutes” (pappus) attached to seeds (e.g., fluffy seeds of asters and goldenrods). These awns and pappus are adaptive and aid seed dispersal in nature. Debearding is the process of removing these hair-like appendages. The terms debearding and dehulling are sometimes used interchangeably and applied to both grass and forb seed.

**What is Dehulling?**

Seeds of native legumes (bean family) are tightly held in small pods or hulls (e.g. prairie clover, showy tick trefoil, leadplant, round-boat bushclover). Dehulling removes seeds from these pods.

**Are Debearding and Dehulling Necessary?**

Debearding fluffly grass and forb seed and dehulling legume seed isn’t absolutely necessary for seed to germinate and grow, at least eventually, and are impractical to do by hand except on a small scale. These techniques do provide important benefits, however, and are used routinely by commercial native seed producers. Both of these techniques improve flowability of the seed allowing it to be cleaned to greater purity and germination. Seed will flow through a seed drill more efficiently when planted, and removing awns or hulls improves seed-to-soil contact important for timely germination.

In addition, mechanical debearding provides scarification, a process that prepares the hard seed coat of legumes to more readily absorb water for germination. Removing the hull also allows for more accurate laboratory seed testing, since hulls can mask seed quality.

Dehulling or dehulling small lots of seed by hand is time consuming and dusty, but can be done. It can be accomplished by rubbing fluffly seed over a small mesh screen with openings just large enough for the seed to pass through, then using air-flow to separate seed from chaff. A small gallon-sized Forsberg huller/scarifier machine is useful for de-awning small quantities of seed. This type of machine is very aggressive and only a few seconds of treatment are typically needed. Another inexpensive device is the Hoffman Mfg. hand deawner/debearder.

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**Dehulling removes seeds from these pods.**

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Debearding fluffy grass and forb seed and dehulling legume seed isn’t absolutely necessary for seed to germinate and grow, at least eventually, and are impractical to do by hand except on a small scale. These techniques do provide important benefits, however, and are used routinely by commercial native seed producers. Both of these techniques improve flowability of the seed allowing it to be cleaned to greater purity and germination. Seed will flow through a seed drill more efficiently when planted, and removing awns or hulls improves seed-to-soil contact important for timely germination.

In addition, mechanical debearding provides scarification, a process that prepares the hard seed coat of legumes to more readily absorb water for germination. Removing the hull also allows for more accurate laboratory seed testing, since hulls can mask seed quality.

Dehulling or dehulling small lots of seed by hand is time consuming and dusty, but can be done. It can be accomplished by rubbing fluffly seed over a small mesh screen with openings just large enough for the seed to pass through, then using air-flow to separate seed from chaff. A small gallon-sized Forsberg huller/scarifier machine is useful for de-awning small quantities of seed. This type of machine is very aggressive and only a few seconds of treatment are typically needed. Another inexpensive device is the Hoffman Mfg. hand deawner/debearder.

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Some Simple and Effective Cleaning Techniques

Simple techniques are available to effectively clean modest amounts of seed. Proper cleaning will remove much of the inert material and dust, and also remove empty, non-viable seed. These cleaning techniques involve various ways of threshing (knocking seed free of seedheads) and sorting seed using screens and airflow. Material should be properly dried before further cleaning.

**Threshing — Stomp Method**
Species with large, coarse seed heads that tend to hold the seed tightly can be threshed by thumping on seed heads. This method is very effective on species of wild indigo (Baptisia), rattlesnake master (Eryngium), composite plant and rosinweed (Silphium), sunflowers (Helianthus), black-eyed susan and sweet coneflower (Rudbeckia), golden Alexander (Zizia). Using large plastic tubs, place about a 2-1/2 layer of bulk material in the bottom and stomp on it with waffle-type boots. Toe kicks to the corners of the tub help break up any stubborn seed heads. Stomped material is then screened through a coarse 1/8-inch or 1/4-inch screen into a second tub. Continue in batches, returning any intact seed heads remaining to the stomping tub. Pale purple coneflower (Echinacea) tends to be stubborn and may require machine threshing, unless it’s collected late in the season after seed heads naturally begin to break apart.

**Threshing — Shake Method**
Many species have seeds that shake free of a capsule or open pod. This method can be effective for dry seedheads of Culver’s root (Veronicastrum), cardinal flower and great blue lobelia (Lobelia), shootingstars (Dodecatheon), mints (Pycnanthemum, Monarda), and gentians (Gentiana). Either hold dry seedheads upside down against the inside of a tub or place in a bag and shake or beat gently to free seed. This method has the advantage of minimizing the amount of chaff and inert material in the seed.

**Threshing — Screen Method**
Hand clipped and dried seedheads of blazingstars (Liatris), asters (Symphyotrichum), and goldenrods (Solidago, Olgoneuron), and spiderworts (Tradescantia), for example, can be threshed by rubbing the seed heads over a large screen made of 1/2-inch or 1/4-inch hardware cloth using gloved hands or aluminum scoop shovels. Elevate the screen on sawhorses over a tarp; fluff seed will float down onto the tarp and can easily be scooped up for further processing.

**Grading or Sizing**
Grading sorts desired seed, or “crop” seed by size. Any given species’ seed will contain a range of seed sizes. Avoid intentionally grading seed intended for restoration plantings, since selection for seed size can happen in one generation, i.e., large seeds will give rise to plants with large seeds, and may reduce genetic variability. Large rosinweed seeds, for example, may not go through a 1/4-inch screen, but smaller rosinweed seeds will. Using a 3/16-inch screen in this case would not be advisable.

**Screens**
Screens are used for sorting by shape and size and are essential for cleaning. Any kind of mesh can be made into a ready-made screen including kitchen sieves, colanders, window screens, hardware cloth, decorative grating are just a few ideas. Commercially available screens are made in a wide range of pore sizes and shapes for specific purposes. Handheld pan-type screens are handy for small batches. Homemade screens of hardware cloth, available in 1/8-inch, 1/4-inch, and 1/2-inch mesh attached to wood frames are effective for rough cleaning. Depending on the application, screens are classified as scalping, grading or sizing, and sifting, as described below.

**Scalping**
Scalping removes objects larger, longer, and wider than the desired crop seed. Screens used for scalping have pores larger than the seed. Most compassplant seeds will fall through a 1/8-inch mesh, for example, which scaps off larger bits of leaves, stems, and bracts. Scalping material through a much larger screen first, and then one closer to seed size is often more efficient, allowing material to flow more freely through each screen.

**Grading**
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**Airflow — Winnowing**
Winnowing uses horizontally moving air to separate heavy from light particles. Winnowing seed in a gentle breeze can be very effective in removing chaff and light seed. To achieve more control, place a tarp on the floor and an ordinary box fan at one end of the tarp. Pour seed gently in front of the fan. Heavier seeds fall closer to the fan than light seed or empty seed. Fine-tune the process by experimenting with fan speed and distance from fan. Once you find the most effective combination, continue to pour the seed in front of the fan in a consistent manner. The seed should now be laying somewhat fanned out on the tarp, with the heavier seed nearer to the fan and light or empty seed further away. Using a thumbslap, push down on the seed coats closest to the fan at first, repeating this test as you gradually move away from the fan. Heavy seed will fell first and resist being crushed with gentle, downward pressure; empty seeds, on the other hand, will offer little resistance and crush easily. Make a determination where the heavy seed ends and the light or empty seed begins, and draw a line through the pile of seed at this point. Clean, heavy seed can then be swept up and stored for planting, while the rest is discarded.

**Airflow — Aspirating**
Aspirating uses vertically moving air to suspend particles in a column. Lighter seeds are either captured in a pocket of the column, as in a South Dakota seed blender, or blown completely out of the column. Heavier seeds drop out of the column. Desired separation is achieved by adjusting airflow in the column.

Fanning mills and air/screen cleaners are machines designed to combine the screening and aspiration processes and are very efficient once the proper screens and settings have been made. Old fanning mills, which both screen and aspirate seed, can sometimes be purchased at farm sales for a modest price, but may require modest repairs.

**Important Tips on Seed Drying**
Drying bulk material immediately after harvest is critical for preventing mold and mildew. Drying will also allow some immature seeds to open and aid threshing of the seed out of seed heads or pods, and thus help maximize seed yield. Small amounts can be placed loosely in cloth or paper bags or spread out on screening or newspaper in a cool, draft-free place with good air circulation. If using paper bags, leave tops open and turn the contents once or twice daily. Take care not to pack collected bulk material into bags too tightly; keep it loose so air can circulate.

Larger quantities can be spread on tarps and turned once or twice daily with pitchforks. Place box fans strategically to keep air circulating over and around bulk material. Do NOT use any form of direct heat! It can damage and kill seeds. Drying may take several days to two weeks, depending on quantity and drying conditions.
**Preventing ‘Damping Off’**

If otherwise healthy seedlings suddenly fall over, appearing to be cut off at soil level, then “damping off” fungus is present. Legumes need adequate drainage, and the seed itself can be affected if planted too deeply. Maintain good air circulation and avoid overwatering, especially during the growing season. A box fan set on low facing seedlings will help reduce the risk of damping off.

**Roots**

almost any plant with fibrous roots and multiple stems can be propagated by division. Dig up or un-pot plant and use a sharp knife or trowel to cut down into root mass. Some damage will occur, but be sure to include intact root and shoot portions for repotting/transplanting. Divide in half for two large plants, or multiple times for maximum number of smaller plants. Fall or early spring are the best times for division, depending on the species (see Table).

**Corns**

A corn is a short, fleshy, vertical underground stem. The blazingsasters (Liatris sp.) grow from corns. In the fall these can be dug up and divided in a way similar to potatoes, and transplanted for mature flowering plants the next growing season. Small corns (corms) can be broken off the main corn, or cut larger corms (2 inch diameter or more) in half.

**Bulbs**

A bulb is thickened, underground bud with fleshy scales. Species like prairie onion and wild garlic (Allium spp) and Michigan and Wood lily (Lilium spp) have bulbs. In vigorous plants smaller side bulbs (bulbils) may develop that can be removed and re-planted. Lilies have scaly bulbs, and each scale can grow into a separate plant. Under good growing conditions, lilies will send out one or two short rhizomes a short distance (2-3”) and a new bulb will form which can be carefully dug up and transplanted for mature flowering plants the next season.

**Propagating native plants is hands-on learning at it’s best**. Gain experience with individual species life-cycles, growth habits, and natural history...and bring important biodiversity to your out-door living space at the same time!

**Equipment Needed**

This is a list of equipment needed for propagating native plants.

<table>
<thead>
<tr>
<th>Native plant materials</th>
<th>Seedling trays</th>
<th>Ziploc bags/ permanent marker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry/Dormant plant material</td>
<td>Containers/Labels</td>
<td>Sterile potting soil</td>
</tr>
<tr>
<td>Plastic or paper pots</td>
<td>Pruning shears, knife</td>
<td>Trowels and shovel</td>
</tr>
</tbody>
</table>

**Starting from Seed**

Propagating native plants from seed is a great learning experience, and a great way to grow a large number of plants from a diverse genetic source(s). It is the best way to develop seed identification skills for assessing new restoration plantings. Be sure the seed your planting is viable, either from seed test results or from an experienced collector. It’s important to know a bit about seed dormancy and how to overcome it to successfully germinate native seed.

**Seed Dormancy and Germination**

Dormancy is an important trait of native plants. It can slow or prevent germination in stressful conditions. Sowing native seeds at the right time and in the right season can be critical for successful germination.

**Funded by**

Michigan lily scaly bulbs (left), dug in fall, all from a single plant. Side bulbs or individual scales can be broken off and transplant. Bulb scale (right) growing new leaves and roots.


Ontario Rock Garden Society: www.onrockgarden.com

Prairie Moon Nursery Cultural Guide: www.prairiemoon.com

Missouri Botanical Garden, www.mobot.org/gardeninghelp/plantfinder/Alpha.asp


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University of Northern Iowa
Adding wet sand to an equal amount of seed in preparation for stratification.

**Species with a hard or waxy seed coat require scarification.** Scarification is a technique that simulates the natural disintegration (such as weathering, abrasion, or partial digestion) of the seed coat to allow water uptake for timely germination. Species in the Sumac, Fig, Geranium, and Buckthorn families may require scarification (Baskin and Baskin 1998). A simple scarification technique is to rub a single layer of seed between two sandpaper-covered boards for a minute or so until seed coat begins to appear dull. Percussion scarification involves shaking seeds vigorously inside a heavy glass bottle for a few minutes. Commercial scarifiers are also available from seed equipment manufacturers, such as a Forbsger scarifier. In all cases, care is necessary to avoid breaking or damaging seeds.

**Special Case: Wet-Heat Scarification**

New Jersey tea (*Ceanothus americana*) and false gromwell (*Gnousium mollis*) require wet-heat treatment. Pour boiling water (212 °F, 100 °C) over the seeds just to cover them all and allow to cool to room temperature, or immerse seeds in boiling hot water for five to twenty seconds and remove to rinse and cool. Be sure not to boil the seed! Germination of these species will improve with stratification after wet-heat treatment.

**Soil-less Mix Recipe**

This recipe makes about 1 cubic yard of potting medium:

- Peat moss (4 cu. ft/bag) 2 bags (8 cu. ft)
- Vermiculite (medium -4 cu. ft/bag) 1/2 bag (2 cu. ft)
- Perlite (4 cu. ft/bag) 1/2 bag (2 cu. ft)
- Sterile soil two 5-gal buckets
- Composted (sterile) manure 40-lb bag
- Osmocote® Plus Fertilizer 15-6-12 (6 lb/days)
- Water

For best consistency, screen peat moss, soil, and composted cow manure through a 7/16-inch mesh hardware cloth. Add remaining ingredients, mix with shovels on clean floor. Caution: All of these materials are extremely dusty in their dry form. Wear high quality dust mask and monitor materials thoroughly with water as they are mixed to reduce dust and aid water uptake of finished medium. Store unused medium in plastic tubs with tight fitting lids to prevent drying out.

**Sowing**

Sow several seeds in each container. Thin later if necessary. Cover with no more than 1/4 inch of soil for most species. Caution: very tiny seeds should not be covered! Species such as Culver’s root (*Veronicastrum virginicum*), mountain mints (*Pycnanthemum spp.*), grass-leaved goldenrod (*Euthamia graminifolia*), Joe-pye weed (*Eupatorium spp.*), great blue lobelia (*Lobelia siphilitica*), and prairie sage (*Artemisia ludoviciana*) do best if sprinkled on top of the soil surface and kept continually moist until the seed leaves (cotyledons) are evident.

**Growing**

Prairie seedlings need full sunlight for normal development. Sow seeds in early February in a greenhouse environment (mid-March in cold frames). Keep the soil surface moist until germination has occurred. Use a gentle spray wand to seed is not dislodged, forced deeper into the soil, or splattered out of the containers. Expect germination and emergence to occur over a 2-6 week period. Warm season grasses and legumes germinate best in warm soils greater than 70 °F (21 °C). Cool season grasses and many forbs germinate more readily in cool soil temperatures 40 to 50 °F (5 to 10 °C) and may cease germination at temperatures above 77 °F (25 °C). If sowing seed in flats, precise regulation of soil temperature can be achieved with propagation mats. These are commercially available at a reasonable cost from nursery or greenhouse supply companies. Water established seedlings thoroughly at least once a day, maintaining the entire soil column. Allow the soil to drain and surface soil to begin to dry somewhat between waterings.

**Transplanting Seedlings**

Strong root development is the key to successful transplanting. Roots should fully occupy the entire soil column forming an intact root “plug” (retains the shape of the container when removed for transplanting). The ideal time for transplanting is in the spring after the last frost-free date for your region. Transplanting gradually to outdoor conditions of sun and wind through a process called “hardening off.” Set flats or trays outside (sheltered from strong winds and full sun) for a few hours each day from mid-morning to mid-afternoon about a week before transplanting. If transplanting in summer, be prepared to water regularly and deeply until plants are established. Transplanting in the fall (early to mid-September) is best if strong root development is present to survive the winter months.
Exotic and Invasive Species

The presence of exotic (non-native) or invasive species will influence longterm management cost and strategies. Weed species in the first category are considered invasive. Invasive species will lower the remnant’s quality over time and can present significant challenges to long-term restoration and management of the site. Applying no management to the site means losing the remnant plant community to the invasive species, yet control methods used on invasive species may in themselves be detrimental to the remnant.

Invasive: weed species that out compete native species and management objectives. Major influences of quality are native species diversity, (particularly the presence of conservative species, i.e., those most sensitive to disturbance); prior management history of the site (grazing, over-sowing, filling, grading, etc.); and the presence of exotic or invasive species that pose an immediate threat to the remnant (see Remnant Quality Indicators). There are three major objectives of remnant assessment: 1) to determine appropriate management strategies for the site (i.e., Do No Harm), 2) to monitor the recovery of the remnant in response to management activities, and 3) to prioritize resources for acquisition, preservation, rehabilitation, and management of remnant sites if natural areas are to be compared, inventories of consistent scope and precision must be conducted. A thorough plant inventory requires at least monthly surveys throughout the growing season. Factors that will affect the total number of species identified include the skills of the observer(s), the number of observers, and the amount of time spent surveying the site. It is important to assess the quality of the remnant areas so that meaningful comparisons can be made between sites.

Comparing Assessment Quality

Assessment gives a measure of the quality of a remnant, which guides and prioritizes long-term management objectives. Major influences of quality are native species diversity, (particularly the presence of conservative species, i.e., those most sensitive to disturbance); prior management history of the site (grazing, over-sowing, filling, grading, etc.); and the presence of exotic or invasive species that pose an immediate threat to the remnant (see Remnant Quality Indicators). There are three major objectives of remnant assessment: 1) to determine appropriate management strategies for the site (i.e., Do No Harm), 2) to monitor the recovery of the remnant in response to management activities, and 3) to prioritize resources for acquisition, preservation, rehabilitation, and management of remnant sites if natural areas are to be compared, inventories of consistent scope and precision must be conducted. A thorough plant inventory requires at least monthly surveys throughout the growing season. Factors that will affect the total number of species identified include the skills of the observer(s), the number of observers, and the amount of time spent surveying the site. It is important to apply equal effort toward each inventory so that meaningful comparisons can be made between sites.

Other Factors Affecting Remnant Quality/Management

Other factors that may affect the remnant’s quality and management include the size and shape of the remnant, distance and connectivity to other remnants, and land-use surrounding the remnant (Saunders et al. 1991). The smaller the remnant, the greater the impact external forces (invasive species, herbicide drift, nutrient and water influx) will have on the quality and long-term survival of the remnant. Larger remnants are likely to have greater diversity because they are more likely to encompass different types of habitat, yet high-quality remnants as small as 10 acres (4 ha) may possess most of the local diversity present in a much larger prairie (Robertson et al. 1997). The size of a remnant also determines the potential population size of a species. Larger populations tend to have greater levels of genetic diversity, and thus may be more resilient (adaptive) to environmental stressors and more resistant to extinction (Gilpin and Soule 1986). There is also evidence that seed viability increases with larger populations, possibly because they attract more pollinators and/or are more genetically diverse (Menges 1991). Mitigating these negative impacts to small isolated remnants by modifying surrounding land use will enhance the quality of the remnant areas being preserved.
Awareness of where remnants are likely to persist on the landscape, experience recognizing native plants, and aerial photo interpretation skills are all useful tools in locating remnants. Perhaps the most effective method, however, is to seek out local knowledge from landowners, hunters, and native plant enthusiasts familiar with the area of interest.

Where Do Remnants Persist?

Surprisingly, remnants do persist in the highly fragmented and intensely farmed landscape of the modern Midwest. Leopold, in first half of the 1900’s, observed that prairie plants were “content with any rocky, sandy hillside not needed for cow and plow” (Callcott and Freyfogle 1999). These remain likely places to look for remnant prairie, today. Prairie also persist in early transportation corridors (i.e., rights-of-way) for roads and railroads, and recovering pastures if not too heavily grazed. Prairie may persist in out-of-the-way corners of farm fields cut off by creeks or otherwise inaccessible to tillage equipment and protected from herbicide drift. Historic old-settler cemeteries, established on prominent hilltops and protected from grazing may harbor remnant prairie. Many of these sites have been mowed at times in the past but recovered when mowing ceased, or the prairie plants survived in the surrounding fence line. A few are preserved as prairie and maintained by volunteers and county or state resource managers. Until the mid-1900s, prairie hay was prized as high-quality forage for workhorses, and typically harvested once in mid-summer each year. Most prairie hay meadows were lost with the widespread mechanization of farming after World War II. A few hayed prairies remain in areas that were too wet, rocky, or small to row-crop, or where the landowner preserved the practice as a cultural tradition.

Aerial photographs, particularly infrared, can help pinpoint likely areas to field check for prairie remnants. Knowledge of the vigor and density of vegetation and time of year of the photo is key to interpreting the red colors of infrared aerial photography. The red tone of color infrared aerial photographs is usually associated with live vegetation. Very intense reds indicate dense vegetation growing vigorously at the time the photograph was taken. In any case, it’s critical to field check potential sites. In Iowa, aerial photographs, including historical, black and white, and infrared, are available from the Iowa Geographic Map Server at carto-gis.iastate.edu. Aerial photographs are also available at local natural resources conservation service (NRCS) offices.

Remnants really are islands of biodiversity remaining after large-scale conversion of the prairie ecosystem. Remnants are repositories of biological, ecological, and cultural values, and deserve preservation and management. They may contain once common animal and plant species now threatened with extinction, or harbor rare populations of species with unique genetic traits and adaptations. Remnants, too, may be benchmarks against which to measure the success of modern day prairie restorations, providing a reference point for species composition, ecosystem functions, and soil health. The untilled soils of remnants are the “gold” standards of fertility, soil structure, and soil. Ultimately, prairie reconstruction would not be possible without the seed sources and ecological information that remnant prairies offer. The greatest threat to small remnants is continued isolation from gene flow and remnant prairies offer. The greatest threat to small remnants is continued isolation from gene flow and remnant prairies offer. The greatest threat to small remnants is continued isolation from gene flow and remnant prairies offer.
The Importance of Seed Quality (Pure Live Seed)

Seed quality is critically important to the success of a restoration! Seed quality is measured as pure-live seed (PLS), which can only be obtained from a seed test by a certified seed testing lab. This is essential for calculating seeding rates for each species, allowing for a balanced mix of grasses, forbs, shrubs, and sedges. Fortunately, seed quality has improved dramatically as growers gain experience and acquire better equipment for producing, harvesting, and cleaning native seed. Seed dispersal apparatus like awns on grass seed and hairy parachutes on forb seed are routinely removed. This means the seed lot can be cleaned to greater purity and viability and will flow more efficiently through the seeding equipment.

Quality native seed is sold on a pure live seed, or PLS basis. Three factors are used to calculate the percentage of pure live seed: purity, germination, and dormancy. Purity is a measure of pure, unbroken crop seed units as a percent by weight of the seed lot. Percent germination is determined by placing seed in a germination chamber for an approved time period. Many species, particularly forbs, have dormancy mechanisms that require several weeks of cold-moist stratification to break dormancy, allowing germination to occur. For most native species, no standard protocol exists for breaking dormancy for germination testing purposes. Therefore, any remaining non-germinated seed is tested biochemically with tetrazolium chloride (TTC), a clear compound that stains living tissue cherry red. The analyst determines the potential viability of stained seed – non-germinated seed considered viable by a TZ test is counted as dormant. A seed test showing a high percentage of dormancy is common in many native forb species and some grasses (Figure 2). This should be expected of natives, particularly in seed lots harvested within the past year. A high percentage of dormancy means much of that seed won’t germinate until dormancy is broken, either artificially or by natural environmental conditions.

Calculating Pure Live Seed Amounts

PLS is a measure of the proportion of the viable seed of a species or variety per unit weight for a given lot of seed. PLS for forage crops and turf grass is normally calculated using percent purity and percent germination only, as dormancy is not a significant issue for these types of species. Native species, however, may have a significant proportion of dormant, yet viable seed, particularly among forb species. The native seed trade recognizes this fact and uses all three factors – purity, germination, and dormancy – to calculate the PLS of any given native seed lot per below:

\[
#\text{PLS} = \frac{#\text{Bulk}}{(#\text{purity}) \times (\%\text{germination} + \%\text{dormant})}
\]

For example, a 50-pound bulk bag of seed that is 98% pure seed, with 60% germination and 21% dormant seed, really contains only 39 pounds of pure viable seed (seed that potentially will germinate):

\[
#\text{PLS} = \frac{50\text{# bulk}}{0.98 \times (0.52 + 0.21)} = 38\text{# PLS or 50-pounds bulk} \times 0.7742
\]

If however, you request 50-pound PLS bag of that same seed, you would receive a bag weighing 64.58-pound bulk:

\[
#\text{Bulk} = \frac{#\text{PLS}}{(0.98 \times (0.52 + 0.88))} = 50\text{# PLS of that same seed} \times \frac{0.27}{0.7742} = 38\text{# PLS or 50-pounds bulk}
\]

Pounds (#) PLS is calculated as:

#PLS = #Bulk x (#purity) x (%germination + % dormant)

Where % is expressed as a proportion, i.e. 98% = 0.98

where # is the number of seed in a seed lot, #bulk is the number of seed in the bulk lot, #PLS is the number of seed in the pure live seed lot, purity is the percentage of pure seed, germination is the percentage of seed that will germinate and dormant is the percentage of seed that will not germinate.

Native Seed Source

It is important to select a seed source appropriate for the goals and objectives of the prairie restoration (summarized in Table 5). Considerations for selecting an appropriate seed source that balance ecological and economic realities may include the following:

- Proximity to the restoration site
- Source of seed
- Seed quality
- Genetic integrity
- Economic realities

Options for obtaining seed range from harvesting your own, to purchasing either bulk-harvested material or commercially produced seed from native seed producers. These types of seed sources are described below.

To request copies, or for more information, contact Greg Houseal at 319.273.3005 or email gregory.houseal@uni.edu

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Cultivated Varieties of Native Species

The USDA Plant Materials Center’s (USDA-PMC) develops cultivated varieties, commonly known as cultivars, of several native grass and forb species. Traditionally, an entire plant or seeds from a plant that exhibited a desired characteristic, such as vigor, were collected for further testing. These collections are evaluated for desired traits in common gardens. A selection of individuals or populations is then made for further breeding and increase. Desired traits include good germination, establishment, high forage yield, height, vigor, and winter hardiness. Cultivars may be desirable for pasture, forage or biomass production, but generally are not recommended for prairie restoration either because they have been derived from distant, out-of-state sources, or have been selectively bred for specific traits, often competitiveness and vigor, possibly narrowing their genetic diversity. If cultivars must be used for reconstructions, two or three different varieties should be used to increase the genetic diversity of the planting.

More recently, USDA-PMC plant selections have reflected the trend toward broad genetic based regional seed sources. Badlands “ecotype” little bluestem (Schizachyrium scoparium) for example, is a composite of 68 accessions (collections) selected for disease resistance from an initial evaluation of 588 vegetative accessions collected from throughout North and South Dakota and Minnesota (USDA-NRCS 1997). This broad selection of a diverse assemblage of little bluestem populations may be a desirable and appropriate seed source for restorations in those states from which it was derived. Cultivar material has been developed for a limited number of native species. Many native species that are in demand for restoration can only be obtained through direct harvest from native stands or through the source-identified seed program described above.

Regional Seed Sources

In the Midwest, remnant prairies are scattered, small, and isolated and there may be no local remnant sources of seed for over large areas of the landscape. Regional seed sources, pooled from several remnant populations, have a broad genetic base that favor the odds that the right genotypes are present to best establish and persist in reconstructed (planted) prairie. Seed-source regions (or provenance zones) based on geography, landforms, water sheds, species range distribution, and political boundaries have been variously defined and applied to restoration efforts around the Midwest.

Local Ecotype

The term ‘local ecotype’ implies that unique, possibly adaptive, genetic traits (more properly, genotypes) may exist in a remnant population. The assumption that local seed is always better adapted to a proposed restoration site than non-local seed should be qualified. A single local seed source may be adequate if a large, genetically diverse population is available and seed is collected from throughout the population. Very small or degraded remnants may lack specific or genetic diversity appropriate to the site. Seeds/germplasm from other remnants of similar soils and hydrology in the area may be desirable additions for severely degraded remnants. Seed harvested locally from the remnant, or from nearby remnants, is a desirable seed source for plantings intended as genetic buffers (e.g. to conserve local gene pool of existing remnants). The challenge of this approach is harvesting enough quality seed from a remnant in a single year to seed the new planting; therefore, the seeding may need to be done in phases over successive years (but see section on bulk harvesting).

Bulk Harvest

Seed can be bulk harvested from prairie with a combine, seed stove, or fall seeder. Diversity will be limited to species in seed at time of harvest and within the rating of the combine/stove. Bulk harvested material is a mixture of seed, chaff, leaves, and stems. A certified seed test for purity, species composition, and weed content is possible, but tests are costly because of the time required to sort material for analysis. Bulk material harvested from seed management stand may contain 1-10% seed by weight, or a seeding rate of 10 lbs per acre will require 100-1000 lbs of bulk material to be broken up per seeded acre. Supplementing bulk harvested material with seed from very low or high growing species, or those that ripen very early or late, is an important consideration since these species may otherwise be unrepresented in the machine harvest. Purchasing bulk material, requests a copy of the seed lot analysis to be sure of species composition and lack of noxious weeds. Commercial Seed Sources

We are fortunate in the Midwest to have many native species commercially available, even for large-scale prairie restorations. Providing enough seed for commercial production usually requires growing out source material in nursery or production fields to increase seed quantity. Larger quantity’s usually translates into lower cost, depending on market demand, which can fluctuate widely from year to year. Source material (foundation seed) for commercial production may be from one or more original sources, or more commonly, regional source material. Caring for Remnants When Harvesting Seed

Producers of bulk seed need to take great care to isolate accessions in the stand since they cannot be cleared out post-harvest. It is a natural process for all seed to be mixed together, and bulk harvested material is a mixture of seed, chaff, leaves, and stems. A certified seed test for purity, species composition, and weed content is possible, but tests are costly because of the time required to sort material for analysis. Bulk material harvested from seed management stand may contain 1-10% seed by weight, or a seeding rate of 10 lbs per acre will require 100-1000 lbs of bulk material to be broken up per seeded acre. Supplementing bulk harvested material with seed from very low or high growing species, or those that ripen very early or late, is an important consideration since these species may otherwise be unrepresented in the machine harvest. Purchasing bulk material, requests a copy of the seed lot analysis to be sure of species composition and lack of noxious weeds. Source-Identified Seed

Standards for source-identified, or “Yellow Tag” seed, were developed by the Association of Official Seed Certifying Agencies (AOSCA) in the mid 1990’s. Source-identified standards provide a “fast-track” plant material release procedure for commercial production of native species for restoring specific plant communities (Young 1995). AOSCA affiliate state crop improvement associations administer the program for participating commercial native seed producers. Source-identified seed may originate from a single source or from several sources pooled together as a regional source. No intentional selection or testing of traits occurs. Original collection sites are documented, and nursery and production fields are inspected and certified annually. Commercially produced seed is marketed with an official AOSCA yellow certification tag, identifying the source and the producer of the material. Hundreds of native species are now available as source identified seed (ICA 2010).

As the commercial native seed industry has developed, several Midwest states have adopted source-identified seed programs. Individual states differ in their application of source-identified program guidelines regarding native species, so it’s important to check specific policies for the particular state in question.
Developing a Seed Mix (using the seed calculator)

High-quality seed of hundreds of native prairie species is commercially available today. The cost of seed varies greatly by species, but forb seed can be costly. The Tallgrass Prairie Center has developed a seed calculator program to design seed mixes based upon the number of seeds per square foot for each species. The seed calculator will automatically calculate the cost of seeds based upon species selected and their cost. Seed cost can be rapidly recalculated with changes in species selection and seed quantities using the seed calculator. Seeding rates are the total number of live seeds sown per unit area (seeds per square foot). Go to www.tallgrassprairiecenter.org for a free copy of the seed calculator. When using the seed calculator, consider the following recommendations:

1. All prairie reconstructions should be planted with a minimum of 40 seeds per square foot. Planting fewer than 40 seeds per square foot may result in a weakly planted community. For edges 3:1 or greater, we recommend 60 to 90 seeds per square foot because of potential loss due to erosion.

2. Always use a nurse crop on erodible sites (Table 2).

3. Develop a species-diverse seed mix. Include a minimum of 6 grasses (cool- and warm-season), 3 sedges, and 25 forbs (5 legumes and 20 nonlegume species).

4. A 50:50 mix of grass and sedge to forb seed will produce a prairie planting rich in forbs. Therefore, if the seeding rate is 40 seeds per square foot, 20 seeds per square foot are grass and sedge seed, and 20 seeds per square foot are forb seed.

5. Choose grass, sedge, and forb seed native to your region and most appropriate for the soil moisture conditions of the site.

6. Include annual, biennial, and perennial forb species in the seed mix. Generally, 1 seed per square foot of native annuals and biennials will result in many adult plants. Annuals and biennials should not exceed 10% of the total forb seed. Try to equalize the number of seed per square foot of the perennial forbs as much as your budget will allow.

7. Consider including some expensive species that are appropriate for the site at a seeding rate that you can afford. If the site conditions are appropriate, add a little cream false indigo, prairie phlox, or flowering spurge. A small amount of seed is better than no seed.

8. For a dormant planting, increase the seeds per square foot of warm-season grass species by 50% due to increased seed mortality (Henderson and Kern 1999; Meyer and Gaynor 2002). For example, if the seed mix contains 20 grass and sedge seeds per square foot for a nonseeded planting, 30 seeds per square foot should be used for a dormant seeding. A possible exception to this may be switchgrass, which has a hard seed coat that can overwinter. Seeding rate of switchgrass need not be changed for a dormant seeding.

9. Planting seed at the proper depth (1/4 inch) and insuring good seed-to-soil contact are essential for any seed to germinate and establish. Proper seed placement is less certain when broadcast seeding (hydroseeding, hand-seeding, and broadcast drop seeding). If broadcast-seeding methods are used, seeding rates for grasses, sedges, and forbs should be increased up to 20% (Henderson and Kern 1999).

To request copies, or for more information, contact Greg Houseal at 319.273.3005 or email gregory.houseal@uni.edu.
### Table 1 – Mesic Soil Seed Mix

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Quantity Needed</th>
<th>Seeding Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asclepias incarnata</td>
<td>Butterfly Milkweed</td>
<td>2.02</td>
<td>2.0</td>
</tr>
<tr>
<td>Asclepias verticillata</td>
<td>Whorled Milkweed</td>
<td>5.80</td>
<td>5.5</td>
</tr>
<tr>
<td>Asclepias tuberosa</td>
<td>Butterfly Weed</td>
<td>1.00</td>
<td>1.0</td>
</tr>
<tr>
<td>Carex brevior</td>
<td>Long-awned bracted sedge</td>
<td>0.40</td>
<td>0.4</td>
</tr>
<tr>
<td>Carex gravida</td>
<td>Grass-leaved Goldenrod</td>
<td>2.00</td>
<td>2.0</td>
</tr>
<tr>
<td>Carex molesta</td>
<td>Round-Headed Bush</td>
<td>0.10</td>
<td>0.1</td>
</tr>
<tr>
<td>Carex pratensis</td>
<td>Purple Prairie Clover</td>
<td>0.30</td>
<td>0.3</td>
</tr>
<tr>
<td>Coreopsis tripteris</td>
<td>Copper-shoulder oval</td>
<td>0.30</td>
<td>0.3</td>
</tr>
<tr>
<td>Elodea canadensis</td>
<td>Horned Broken Arrowhead</td>
<td>0.10</td>
<td>0.1</td>
</tr>
<tr>
<td>Festuca idahoensis</td>
<td>Idaho Festuca</td>
<td>3.00</td>
<td>3.0</td>
</tr>
<tr>
<td>Heuchera sanguinea</td>
<td>Coral Bells</td>
<td>0.10</td>
<td>0.1</td>
</tr>
<tr>
<td>Ipomopsis longissima</td>
<td>Pink Floyd</td>
<td>0.10</td>
<td>0.1</td>
</tr>
<tr>
<td>Leucopus densiflorus</td>
<td>Prairie Phlox</td>
<td>0.20</td>
<td>0.2</td>
</tr>
<tr>
<td>Melampodium leucanthemum</td>
<td>扫帚属白花</td>
<td>0.10</td>
<td>0.1</td>
</tr>
<tr>
<td>Phlox pilosa</td>
<td>Chickweed</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Silphium laciniatum</td>
<td>Silphium</td>
<td>0.10</td>
<td>0.1</td>
</tr>
<tr>
<td>Solidago altissima</td>
<td>Yellow Aster</td>
<td>0.50</td>
<td>0.5</td>
</tr>
<tr>
<td>Symphyotrichum novae-angliae</td>
<td>New England Aster</td>
<td>0.50</td>
<td>0.5</td>
</tr>
<tr>
<td>Verbena cardinalis</td>
<td>Cardinal flower</td>
<td>0.10</td>
<td>0.1</td>
</tr>
<tr>
<td>Veronica longifolia</td>
<td>Longifolia Veronica</td>
<td>0.50</td>
<td>0.5</td>
</tr>
<tr>
<td>Veronica spicata</td>
<td>Speedwell</td>
<td>0.10</td>
<td>0.1</td>
</tr>
<tr>
<td>Veronica sanguinea</td>
<td>Red-crowned speedwell</td>
<td>0.30</td>
<td>0.3</td>
</tr>
<tr>
<td>Veronica spicata</td>
<td>Speedwell</td>
<td>0.10</td>
<td>0.1</td>
</tr>
<tr>
<td>Veronica spicata</td>
<td>Speedwell</td>
<td>0.50</td>
<td>0.5</td>
</tr>
</tbody>
</table>

### Criteria for Species Selection

Selecting the appropriate species of native plants is one of the first steps in planning a reconstruction project. Each soil type is a unique blend of sand, silt, clay, and organic matter that affects how the soil drains and retains water. Every plant species has evolved to grow within a certain range of soil moisture conditions. Planting species that are best adapted to the soil moisture(s) of the site will ensure their persistence in the planting.

To determine the soil type and drainage class of your site, visit your local Natural Resources Conservation Service (NRCS) office to obtain a soils map or look online at www.nrcs.usda.gov.

### Soil Types/Moisture

There are five general soil moisture categories: wet (hydric), wet-mesic, mesic (moderate), dry-mesic, and dry (xeric). Hydric soils include poorly drained, and very poorly-drained soils that typically have standing water for part or most of the growing season. These areas may harbor prairie remnants because they were typically too wet to farm. Wet-mesic soils include somewhat poorly drained lightly colored clay soils. Mesic soils include well drained and moderately well drained, dark loamy soils. Dry-mesic soils include somewhat excessively drained grey-brown soils. Xeric soils include excessively drained sandy or gravelly soils and shallow loamy soils often found on steep slopes and ridges. See Table 1 for a recommended native seed mix for 1-acre mesic soil sites in Iowa (Except Loess Hills).

### Species Geographic Distribution

Select species that are native to the region of the planting site. A “region” can be defined as the home county and the contiguous counties around it. If a species is not present in the region of the planting site, it should be left out of the seed mix. To obtain a list of tallgrass prairie species (grasses, forbs, and sedges) native to your county, visit the USDA-NRCS Plants Web site at plants.nrcs.usda.gov.

### Species Phenology

Tallgrass prairie plants have evolved to take advantage of available resources throughout the growing season. Some grasses and all sedges germinate, grow, and flower in spring or fall (cool-season plants), while others germinate in late spring, and grow and flower in the summer (warm-season grasses). For a prairie planting to resist non-native weed invasion, the planting must include native species from both cool- and warm-season grasses, forbs, and sedges. Leaving out cool-season grasses and sedges will expose the planting to weed invasion from plants like smooth brome, Bromus inermis and Kentucky bluegrass, Poa pratensis.

### Species Diversity

A prairie seed mix that includes species from each plant group (warm- and cool-season grasses, legume and non-legume forbs, and sedges) will result in a stable, weed-resistant plant community and it will attract and sustain wildlife. A species-rich prairie planting will eliminate perennial weed seed by being a better competitor for resources. It may be infeasible on the front end of the project to plant only a few grass and forb species, but eliminating weeds that have invaded a native planting can be difficult and costly down the road. Species diverse seed mixes should be strongly considered for all native plantings.

### Slope and Aspect

The site conditions on a slope and the direction it faces (aspect) affect the establishment of native plants. The upper portion of a slope is usually drier than the lower portion; south and west aspects are relatively more xeric than the north and east aspects at the same elevation. Thus, there is a difference in species along the moisture gradient from top to bottom of a slope and around it as the aspect changes. Roadsides right-of-ways in particular often transition from dry to mesic to wet soils in a small area, and the changes in species composition associated with those soil moisture conditions can be dramatic. If the slope is gradual and the changes in moisture conditions can be easily seen, seeding species that match the moisture condition of the soil will improve establishment of those species. If the soil moisture gradient isn’t as apparent, slopes can be “shotted” seeded with all species; including species in the seed mix that match each moisture condition.

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**Potential Range Expansion**

**Historic Distribution**

Invasion of Canada thistles into a species poor native grassland at Black Hawk County, Iowa.

Big Woods planting in Cedar Falls, Iowa. A species diverse prairie reconstruction planted in 2001 at Big Woods Lake in Cedar Falls, Iowa. This seed mix included 75 species of grasses, forbs and sedges... 61 species were detected in 2007.
2. Stand Enhancement (Interseeding)

Stand enhancement techniques are often applied to sites that are dominated by grasses with few to no prairie forbs. Stand enhancement adds native grasses and forbs without eliminating the established vegetation.

Direct Interseeding (Option 1)

Seed is sown into the established vegetation without disrupting the established vegetation. Prairie plant establishment can be low in stands of persistent perennial plants and non-native vegetation can persist for many years after seeding. Any seeding method can be used. This site preparation option is quick and can be done without any specialized equipment, but will require patience.

Repeated Mowing and Interseeding (Option 2)

- Remove standing dead material and thatch by prescribed burning in fall or by late summer haying.
- Seed in fall or in early spring with a no-till drill.
- Mow from late April to early September, four inches high every two or three weeks the first growing season.
- Spray, Mow and Interseed (Option 3).
- Remove standing dead material and thatch in spring by prescribed burning, haying or mowing.
- Spray 50 percent of the stand with a grass herbicide when there is four to six inches of new growth.
- Seed in fall or in early spring with a no-till drill.
- Mow once in early summer in the first growing season.

Disk and Interseed (Option 4).

- Removed thatch and standing dead material in late summer by grazing, haying or mowing.
- Lightly disk (to the four inch depth) 50 percent of the site in early fall.
- Seed in late fall or in early spring. Any seeding method can be used.
- Mow in late spring and mid-summer in the first growing season.

Spray, Mow and Interseed (Option 3).

- Remove standing dead material and thatch in spring by prescribed burning, haying or mowing.
- Spray 50 percent of the stand with a grass herbicide when there is four to six inches of new growth.
- Seed in fall or in early spring with a no-till drill.
- Mow once in early summer in the first growing season.

The “Screwdriver Method” For Compacted Soil

Soil compaction is a condition when there is a decrease in air space between soil particles. Heavy machinery operation or prairie livestock trampling can cause soil compaction. Compacted soil can severely reduce establishment of natives by preventing seeds from being planted at a proper depth and by inhibiting root penetration of newly germinated seedlings. To check for soil compaction near the soil surface, stick a large flat screwdriver into the soil at multiple spots in the compacted region. If the screwdriver cannot be pushed more than 2 inches into the soil at least half of the spots, there is a good chance that the soil surface is too compacted. To eliminate surface compaction, remove all the soil to the upper 4 inches of soil. Any large (greater than ½ inch) soil clods need to be broken into smaller pieces. To reduce clog size, hang the site using a drag harrow or a piece of chain link fence with some weight added.

Removing Trees and Shrubs

The species composition of a planted prairie will change over time if volunteer trees and shrubs are not eliminated. Shade from trees and shrubs will create cooler environments and impede the growth and development of native prairie species. In addition, woody plants that are left on the site will spread by suckering and seed, further displacing prairie plants. Woody plants can also interfere with no-till drilling and broadcast seeding of the natives. Some practitioners leave a few clone groups of native trees like wild plum and choke cherry on the site for habitat. However, native trees and shrubs like bowlder (Acer negundo), red cedar (Juniperus virginiana) and gray dogwood (Cornus sericea) may need to be removed because they can aggressively spread in a planted prairie (Table 1). We recommend the removal of all non-native trees and shrubs.

Herbicides are very effective at killing woody plants. Smaller trees and shrubs can be foliar-sprayed. Trees greater than ½ inch diameter need to be cut and the stump chemically treated to prevent resprouting (Table 2). Herbicide should only be applied to the inner bark (cambium layer) of the cut surface. The inner bark region of the cut stump is a thin layer adjacent to the outer bark of the tree. Because of the high concentration of chemical in stump treatment herbicides, it is important to be careful not to dribble herbicide off the cut surface onto the ground. Coniferous trees (pines and cedars) do not need to be treated after being cut because they will not re-sprout, but all deciduous trees will need to be treated. Stumps need to be cut flat and as close to the ground as possible to prevent interference with seeding equipment.

### Table 1 — Persistent Perennial Plants

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Genus Species</th>
<th>Class*</th>
<th>Water Stage*</th>
<th>Time*</th>
<th>Application Format*</th>
<th>Cut Stump Treatment Method*</th>
<th>Herbicide Application Format*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kentucky bluegrass</td>
<td>Poa pratensis</td>
<td>grass</td>
<td>cut stump</td>
<td>anytime</td>
<td>cut stump</td>
<td>cut stump</td>
<td>triclopyr</td>
</tr>
<tr>
<td>quackgrass</td>
<td>Agropyron repens</td>
<td>grass</td>
<td>cut stump</td>
<td>anytime</td>
<td>cut stump</td>
<td>cut stump</td>
<td>triclopyr</td>
</tr>
<tr>
<td>sweet clover</td>
<td>Phacelia tanacetifolia</td>
<td>grass</td>
<td>cut stump</td>
<td>anytime</td>
<td>cut stump</td>
<td>cut stump</td>
<td>triclopyr</td>
</tr>
<tr>
<td>smooth bushclover</td>
<td>Buxus sempervirens</td>
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<td>anytime</td>
<td>basal</td>
<td>basal</td>
<td>triclopyr</td>
</tr>
<tr>
<td>tall fescue</td>
<td>Festuca arundinacea</td>
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<td>basal</td>
<td>anytime</td>
<td>basal</td>
<td>basal</td>
<td>triclopyr</td>
</tr>
<tr>
<td>bush clover</td>
<td>Euphorbia esula</td>
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<td>anytime</td>
<td>basal</td>
<td>basal</td>
<td>triclopyr</td>
</tr>
<tr>
<td>Canada thistle</td>
<td>Cirsium arvense</td>
<td>grass</td>
<td>cut stump</td>
<td>anytime</td>
<td>cut stump</td>
<td>cut stump</td>
<td>triclopyr</td>
</tr>
<tr>
<td>cross vetch</td>
<td>Corvinella varia</td>
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<td>cut stump</td>
<td>anytime</td>
<td>cut stump</td>
<td>cut stump</td>
<td>triclopyr</td>
</tr>
<tr>
<td>misty spurge</td>
<td>Euphorbia wulfenii</td>
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<td>anytime</td>
<td>basal</td>
<td>basal</td>
<td>triclopyr</td>
</tr>
<tr>
<td>black locust</td>
<td>Robinia pseudacacia</td>
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<td>anytime</td>
<td>basal</td>
<td>basal</td>
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<tr>
<td>box elder</td>
<td>Acer negundo</td>
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<td>anytime</td>
<td>basal</td>
<td>basal</td>
<td>triclopyr</td>
</tr>
<tr>
<td>common broomhorn</td>
<td>Humulus celticus</td>
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<td>anytime</td>
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<td>basal</td>
<td>basal</td>
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<tr>
<td>red cedar</td>
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<td>basal</td>
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<td>silver maple</td>
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<td>basal</td>
<td>triclopyr</td>
</tr>
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<td>Lonicera tatarica</td>
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<td>anytime</td>
<td>basal</td>
<td>basal</td>
<td>triclopyr</td>
</tr>
</tbody>
</table>

* Always read and follow label directions.

Funded By

[Logo]

University of Northern Iowa

Caution - Most of the site preparation methods described in this publication involve killing the existing vegetation and should NOT be used if remnant prairie vegetation (prairie plants that were not planted) are present at the site. Restoration techniques should be applied if remnant prairie plants are present.

Site preparation alters the existing vegetation and soil structure in advance of seeding, increasing emergence, growth and survivorship of the seeded natives by removing thatch, improving seed to soil contact, and reducing weeds. From construction sites to cornfields, site conditions can be drastically different and require specific site preparation techniques. There are two broad categories of site preparation: one associated with bare soil sites, and one with vegetated sites.
Site Preparation For “Bare Soil” Sites

Construction Sites

In many construction sites, the original soil profile has been altered during the construction process. Some areas within the site may have compacted soil from construction equipment (see Assessing for Soil Compaction). Many construction sites have large cloths and compacted soil. An ideal seedbed for a native seeding should consist of friable soil particles (1/8 inch or smaller) in the top 1 inch of the soil.

Field examples of light crop residue not needing any tillage prior to seeding:

- No other site preparation needed if seeded with a no-till drill.
- If broadcast or drop seeding, first cultivate with a spiked toothed harrow to roughen the soil surface.
- Seed in fall or in early spring.
- Cultipack after seeding improves seed-to-soil contact.

Third disking pass

Caution - This option is not recommended for erosional sites as repeated discing will create bare soil.

» Mow (4 inches high or less) or prescribe burn in early-spring.
» Apply glyphosate to actively growing vegetation when there is 4 to 6 inches of new growth.
» Wait 10 days after the herbicide application and Disk the site at 3-4 week intervals for the entire growing season.
» Seed in fall or in early-spring.
» Cultipack after seeding improves seed-to-soil contact.

Assessing Crop Residue

Sites that have been row cropped may require different kinds of site preparation. The amount of site preparation needed depends upon the quantity of crop residue (see Assessing Crop Residue Section) left on the field and the type of seeding equipment used.

Feedlots, Overgrazed Pastures

Bare soil can result from severe overgrazing and livestock trampling. By removing livestock from the site, vegetation can re-emerge from underground rootstock. Livestock should be removed for at least one entire growing season to allow the vegetation to recover and be identified. If remnant (not planted) prairie plants are detected, the site should be consid-
ered a prairie remnant and site preparation techniques for prairie remnants should be used. Typically, feedlots and overgrazed pastures will contain persistent perennial plants and high levels of weed seed in the soil. Manure can also contribute to high levels of nitrogen in the soil, which will stimulate weed germina-
tion and weed growth. If no remnant prairie plants are detected, use site preparation techniques from the Stand Replacement subsection of this publication.

Topsoil, Soil Tillage, and Seedling

Armed boom sprayer

Site Preparation For “Vegetated” Sites

Types of vegetated sites include: turf grass lawns, pastures, hayfields, and conservation plantings. Vegetation on these sites can vary from smooth brome/alfalfa hayfields and Kentucky bluegrass lawns to dense stand of prairie grasses on a site enrolled in a federal government Conservation Reserve Program (CRP). Caution - If a site contains remnant (not planted) prairie plants, the site should be considered a prairie remnant and site preparation techniques for prairie remnants should be used.

There are two site preparation options: stand replacement (starting over) and stand enhancement (interseeding). Stand replacement site preparation techniques should be used to replace a current stand of non-native grasses and legumes with prairie grasses and wildflowers. Stand enhancement site preparation techniques are typi-
cally used when the goal is to add additional prairie species to sites that currently have some native plants or are dense stands of prairie and pasture grasses with few to no wildflowers.

1. Stand Replacement (Starting Over)

Stand replacement has three primary methods of site preparation. Select a site preparation tech-
nique based upon the speed in which you want to complete the project, the budget for the project, and the kind of equipment available to conduct site preparation activities.

Spray and Plant (Option 1)

» Mow (4 inches high or less) in spring or in late summer or burn when the vegetation is dormant.
» Apply an appropriate herbicide(s) to actively growing vegetation when there is 4 to 6 inches of new growth. For legume grass stands, a mixture of a broadleaf and grass herbicide, such as glyphosate and 2,4-D should be used. It can take 2 to 4 weeks after mowing or burning for the vegetation to have enough new growth for a herbicide treatment. Re-spray any green plants after 14 days from the first herbicide treatment. Wait another 14 days after the last herbicide treatment to seed. Seed can then be broadcasted or drilled.

- Large boom spraying
- Backpack spraying

- Repeated Spray and Plant (Option 2)

This site preparation technique requires an entire growing season and is more expensive than option 1, but control of persistent perennial plants is greatly improved.

» Mow (4 inches high or less) or prescribe burn in early-spring.
» Apply glyphosate to vegetation when there is 4 to 6 inches of new growth. Re-spray or spot treat each time it ‘greens up’ throughout the summer and into early fall.
» No further site preparation is needed if the site is seeded with a no-till seed drill. If seeding with a broadcast seeder or drop seeder, the area should be roughed up with a spiked toothed harrow before seeding, breaking apart thatch and loosen-
ing the surface soil. After seeding, the site should be cultipacked (rolled).

Spray, Till and Plant (Option 3)

This method controls established persistent peren-
nial plants and germinating weed seed in the soil.
Caution - This option is not recommended for ero-
sive sites as repeated discing will create bare soil.

» Mow (4 inches high or less) or prescribe burn in early-spring.
» Apply glyphosate to actively growing vegeta-
tion when there is 4 to 6 inches of new growth.
» Wait 10 days after the herbicide application and Disk the site at 3-4 week intervals for the entire growing season.
» Seed in fall or in early-spring.
» Cultipack after seeding improves seed-to-soil contact.
Deciding when to plant a prairie is a challenge. Some species establish better when spring planted, other species establish better when fall planted and some species are hard to establish whenever they are planted. Seeding rates of some species may need to be increased depending on when and how they are planted.

Prairie seed can be planted by broadcast seeding, hydroseeding and drill seeding. Regardless of the seeding method used, it is essential that seed be planted at the proper depth and with good seed to soil contact.

Prairie Seed

Tallgrass prairie plants exhibit a wide range of growth characteristics. With adequate soil moisture, cool-season grasses and many forbs germinate in early spring when minimum soil temperatures are between 39° to 45°F (3° to 7°C) while warm-season grasses germinate in late spring when soil temperatures reach 55° to 60°F (12° to 13°C) (Smith et al. 1998). Real time soil temperatures for the tallgrass prairie region can be found at www.gemcatoonline.com/SoilTempMaps.aspx. Native seed mixes often contain both cool and warm-season species, and there is no single best time to plant. However, choosing a planting time to maximize germination and establishment depends upon the species selected and their contribution to the seed mix. A seed mix with a strong forb component (50 percent or greater forb seed) should be dormant seeded. By contrast, a seed mix of mostly warm-season grasses (70 percent or greater grass seed) should be seeded in mid-spring.
Dormant Seeding

A dormant seeding is defined as planting seed during a time when there is the least chance of germination and seed will be dormant for several months. For most of the tallgrass prairie region dormant seeding can begin in early November. Early onset of very cold weather in the fall, or cold weather into late winter can extend the calendar times for dormant seeding. The benefits of dor-
mant seeding are twofold. First, seeding when soil temperatures are below 32° F at 1-inch depth and packed. Seed broadcasted onto ice or frozen ground is not recommended as it will expose the seed to wind erosion and predation. Dormant planting mimics the natural process of seed ripening and autumn/winter dispersal of many prairie species. However, dormant seeding of most native grasses, except switchgrasses, (Panicum virgatum) and Canada wild rye (Elymus canadensis) increases seed mortality (Beyer and Gaynor 2002). In addition, the effect on germination of Prairie grass and forb seed by a frost seeding as compared to other seeding times is unknown. Therefore, seeding at other times may improve germination and some species increase throughout spring. A late spring seeding may not permit adequate stratification for some forbs to break dormancy. Spring seeding favors warm-season grasses and some

Frost Seeding (February to March)

Seeds on cracked soil

Frost seeding is a special form of dormant seeding done at the tail end of winter when temperatures are below freezing at night and above freezing during the day. If the soil surface is free of snow or ice, seed can either be drilled or broad-
cast. The freeze-thaw action creates small cracks in the soil and allows seeds to settle into the soil. The effect on germination of Prairie grass and forb seed by a frost seeding as compared to other seeding times is unknown. However, further research on non-native forbs has shown that frost seeding can improve seed germination, but an unusually dry and warm spring can result in poor establishment (Barbetti 2002). In addition, the effect on germination of non-native cool-season grasses that are frost sensitive can vary and is not recommended for some species (West et al. 1997).

The benefit of frost seeding Prairie seed may be related to the length of time the seed remains in the soil before germinating. As compared to a dormant seeding in November, Frost seeding reduces the time seed remains in the soil before germination and may reduce seed mortality from pathogens and predation (Heymes and Heymes 2001). We believe that frost seeding can be a good time to seed for most native species. We recommend seeding with a no-till grass drill to maximize seed-to-soil contact. If broadcast seeding is used, the seeding rate should be increased by 25% to compensate for seed loss due to wind erosion and predation (Henderson and Kern 1999). Frost seed-
ing is not recommended on eroded sites with rills and gullies. If the site is prone to erosion, sow oats up to 1 bale per acre to stabilize the soil and seed the other crops one by one with the Prairie seed and/or a mulch should be applied and crimped into the soil to keep the seed in place.

Summer Seeding (July to September)

Planting mid and late-summer is risky business. New germinates exposed to excessive heat and drought will perish. In addition, many Prairie species require 2-6 weeks to germinate. By the end of the growing season, it is likely that seedlings may be too small to survive. Winter seedings native during this time is not recommended.

Seeding Methods

Planting seed at the proper depth with good seed-to-soil contact is essential. Seed placed too deep will not emerge resulting in poor stand establishment. Likewise, seed not covered by soil can germinate, desiccate and die. It’s the responsi-

Table 2 — Seed that Should be Broadcasted

<table>
<thead>
<tr>
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Hydroseeding

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Manual Maintenance

There are non-herbicide methods to control weeds and woody plants in a native planting. These methods require extra physical exertion and time, but can be the least damaging to the surrounding native plants. The severity of the infestation and the stamina of the land manager will dictate whether these methods are practical.

Hand weeding

The best time to hand weed is immediately after a rainstorm when the ground is soft and a large portion of the root can be extracted. Perennial rhizomatous weeds like Canada thistle and leafy spurge require several pullings in the same year and may require weeding two or more years. Wear thick gloves- Canada thistle plants are prickly and leafy spurge sap can cause dermatological reactions.

Hoeing, spade shovel, hedge/pruning shears

Chopping works very well on biennial plants. Cutting the plant under the soil surface or near its base as it begins to flower will greatly reduce its ability to re-grow and produce seed.

Heavy duty string trimmer (fitted with a steel brush blade or plastic knives)— A gas powered string trimmer can selectively cut small weed patches and smaller diameter woody plants scattered throughout a planting. This piece of equipment can be dangerous to operate. Always wear proper safety equipment that should include gloves, long-sleeved shirt, safety glasses, hearing protection, hard hat, chaps, and steel-toed shoes. Read and follow recommendations in the owner’s manual for safe operation.

Girdling

Girdling (like rabbits do to young trees and shrubs in cases, fertilization may also damage or kill native plants until the prairie plant community is established. The severity of the infestation and the stamina of the land manager will dictate whether these methods are practical.

Prescribed Burning

A prairie planting should be burned as soon as the site can carry a continuous fire. Proper use of prescribed fire will accelerate growth of most prairie plants and deter cool season weeds and small woody plants. Typically, there is not enough fine fuel (grass leaves) to carry a fire in a one or two year old newly planted prairie due to frequent mowing. By the end of third growing season however, there should be enough grass growth to carry a fire. The first prescribed fire on a newly reseeded prairie often is done in the spring to stimulate the warm-season prairie grasses. The management objectives should determine frequency and timing of prescribed fires for subsequent prescribed burning. Caution - Prescribed burning should only be done by trained and experienced personnel. To learn more on prescribed burning visit the Iowa Natural Resources and Conservation Service (NRCS) website at ia.nrcs.usda.gov/news/brochures/publications.html to download a free copy of Prescribed Burning.

Irrigation

Irrigation can be an important management tool. Once a seed germinates, there is a critical phase of development between emergence and the time the seedling develops its first true leaf. While the plant is still in this cotyledon stage, it cannot survive an extended period of drought. If rainfall is not adequate, seedlings will benefit from being watered 1 to 2 inches every three days during the first growing season (Morgan 1995). Irrigation increases the probability that the plants will survive into the second growing season and beyond.

Fertilizers

Fertilizers are not recommended for native plantings. Most plants including natives benefit from fertilizers, but weeds benefit more, making fertilizers a poor management strategy. Fertilizing a newly planted prairie will disproportionately favor opportunistic weed species. Most native species are well adapted for nutrient poor soil. In some cases, fertilization may also damage or kill native seedlings.

Note:
Always wear protective clothing and gloves to guard against thorns and plant compounds that can cause severe skin reactions.

Table 1 — Persistent Perennial Plants

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Grain years</th>
<th>Height</th>
<th>Opening Phase</th>
<th>Flower Color</th>
<th>Flower Type</th>
<th>Nectar</th>
<th>Nitrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Sunflower</td>
<td>3-5</td>
<td>Tall</td>
<td>Early</td>
<td>Yellow</td>
<td>discs</td>
<td>Metal</td>
<td>Present</td>
</tr>
<tr>
<td>Switchgrass</td>
<td>4-5</td>
<td>Tall</td>
<td>Late</td>
<td>Yellow/White</td>
<td>spikes</td>
<td>Iron</td>
<td>Present</td>
</tr>
<tr>
<td>Kentucky Bluegrass</td>
<td>4-6</td>
<td>Tall</td>
<td>Late</td>
<td>White</td>
<td>spikes</td>
<td>Copper</td>
<td>Present</td>
</tr>
<tr>
<td>Quailbait</td>
<td>2-3</td>
<td>Short</td>
<td>Early</td>
<td>White</td>
<td>spikes</td>
<td>Silicon</td>
<td>Present</td>
</tr>
<tr>
<td>Reed canarygrass</td>
<td>2-3</td>
<td>Short</td>
<td>Early</td>
<td>White</td>
<td>spikes</td>
<td>Silicon</td>
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<td>Present</td>
</tr>
<tr>
<td>Red clover</td>
<td>3-5</td>
<td>Tall</td>
<td>Early</td>
<td>Pink</td>
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<td>Copper</td>
<td>Present</td>
</tr>
</tbody>
</table>
By the third growing season, most of the vegetative growth through the use of selective mowing will have been used by the plants and mowing should not be needed. If there is a threat of a weed canopy in Year 3, a stand evaluation should be conducted to determine if there are adequate numbers of prairie plants remaining in the site (see Evaluating Stand Establishment in this section). If native plant establishment is less than 1 plant per square foot, we recommend using a stand enhancement technique to add more prairie grasses and forbs to the stand (see Site Preparation in this section).

Plants that are allowed to grow high enough to creatae a closed canopy during the first few years of a prairie planting will reduce germination, growth, and survival of the perennial prairie plants (Williams et al. 2007). This can create long-term maintenance problems. Frequent mowing is an effective technique to prevent a weed canopy from forming in a prairie planting. Mowing can be done with any type of mower as long as the mower deck can be raised at least 4 inches. Some practitioners prefer using a flail type mower because the biomass is cut into smaller pieces and does not leave a windrow (thick layer of thatch) on the surface. As a general rule of thumb, do not let the weeds and other vegetation get taller than knee high in the first growing season. Mow to a height of 4 to 6 inches whenever the vegetation grows 12 to 18 inches high in the first growing season. Don’t be concerned about damaging the natives by mowing. Most prairie seedlings will grow below the 4 to 6 inches whenever the vegetation grows 12 to 18 inches high in the first growing season. The frequency and duration of mowing depends upon the weed density and climate conditions during the growing season. Typically in Iowa, with average precipitation, mowing may be needed every three weeks from early-May to early-September in the first growing season. This frequent mowing regime will curtail the growth and seed set of weeds while preventing thatch build-up that can smother native seedlings.

Mowing in the second growing season depends upon the density of persistent perennial and biennial weeds. To avoid damaging the native plants, mowing height should never go below 12 inches in the second growing season. Time between mowing treatments can be monthly or longer depending upon the weed pressure. For scattered weed patches, consider spot mowing or hand pulling to minimize the impact upon developing prairie plants. If there is a flush of tall rank biennial weeds like Queen Anne’s lace (Daucus carota), sweet clovers (Melilotus spp.) or parsnip (Pastinaca sativa), it is important to mow or pull just prior to flowering to severely curtail or eliminate the plants ability to flower and go to seed (Shelley 2001).

Establishment Mowing

Herbicides, when used carefully at rates listed on the label, can be very effective at controlling persistent perennial weeds and woody plants (Table 1). CARELESS application will result in killing native species. Just how many weeds are considered ‘weedy’ in a native planting is a matter of personal preference, but addressing weed issues early can save heartache later on. There will be less damage to native plants if chemical control is used within the first few years of a seeding, when weeds are less abundant and can be spot sprayed. Waiting until the weeds are abundant in the planting can turn spot spraying into blanket spraying which is extremely damaging to natives. States require certification testing and licensing to purchase and apply certain pesticides. Contact your State Department of Agriculture to obtain more information on pesticide certification. Always read and follow label directions. The following are some examples of specific label recommendations for optimum spraying times.

1. Spray only the persistent perennial weeds and woody plants (Table 1). Over time prairie plants will exclude most other weeds from the planting.
2. Spray when the natives are dormant. Crown vetch (Coronilla varia) and leafy spurge remain green into fall and can be sprayed after most native plants are dormant (Figure 1).
3. Use herbicides that are species specific. Some herbicides work better than others on individual weed and woody species. Cyclopyr dil or chlorosul furon is more effective at controlling Canada thistle than glyphosate. Fosamine can be foliar sprayed on woody plants without affecting native forbs (non-woody) and grasses.
4. Select mowing of weeds in a first year prairie planting. The label will indicate at what stage of development the weed species is most susceptible to the effects of the chemical. ‘Rosette to bud’, ‘Up to 5 leaf stage’, ‘1 to 3 leaf stage before vining’, and ‘boost to early seedhead stage’ are some examples of specific label recommendations for optimum spraying times.
5. Apply the herbicide at the rate specified by the label. The herbicide application rate will vary according to the weed species and severity of infestation.
6. Use spot spraying. To minimize over-spraying onto non-target plants, use a hand wand instead of boom sprayer. A backpack sprayer with a spray wand extension allows the operator to place the nozzle tip very close to the weed and minimizes over-spraying.
7. Use boom spraying only on large dense weed patches.
8. Avoid creating drift when spraying. Lower the spray pressure and increase the nozzle orifice size to reduce spray drift. Don’t spray on windy days.
9. Cut rather than fallow spray woody plants. Many brush her- bicides require complete coverage when foliar sprayed. There is the potential for excessive over-spraying onto non-target plants. A cut stump herbicide to prevent the stump from resprouting can be applied precisely to where it is needed without damaging surrounding vegetation (Table 1).
10. Do not apply a herbicide to a cut stump that is actively flowing with sap. Sap flow will cause the herbicide to run off the cut stump into the soil and kill nearby vegetation. This is often referred to as ‘the ring of death’.

**Herbicides**

**Establishment Mowing**

**Selective mowing of weeds in a first year prairie planting**

**Plants that are allowed to grow high enough to create a closed canopy during the first few years of a prairie planting will reduce germination, growth, and survival of the perennial prairie plants (Williams et al. 2007). This can create long-term maintenance problems. Frequent mowing is an effective technique to prevent a weed canopy from forming in a prairie planting. Mowing can be done with any type of mower as long as the mower deck can be raised at least 4 inches. Some practitioners prefer using a flail type mower because the biomass is cut into smaller pieces and does not leave a windrow (thick layer of thatch) on the surface. As a general rule of thumb, do not let the weeds and other vegetation get taller than knee high in the first growing season. Mow to a height of 4 to 6 inches whenever the vegetation grows 12 to 18 inches high in the first growing season. Don’t be concerned about damaging the natives by mowing. Most prairie seedlings will grow below the 4 to 6 inches whenever the vegetation grows 12 to 18 inches high in the first growing season. The frequency and duration of mowing depends upon the weed density and climate conditions during the growing season. Typically in Iowa, with average precipitation, mowing may be needed every three weeks from early-May to early-September in the first growing season. This frequent mowing regime will curtail the growth and seed set of weeds while preventing thatch build-up that can smother native seedlings.**

**Mowing in the second growing season depends upon the density of persistent perennial and biennial weeds. To avoid damaging the native plants, mowing height should never go below 12 inches in the second growing season. Time between mowing treatments can be monthly or longer depending upon the weed pressure. For scattered weed patches, consider spot mowing or hand pulling to minimize the impact upon developing prairie plants. If there is a flush of tall rank biennial weeds like Queen Anne’s lace (Daucus carota), sweet clovers (Melilotus spp.) or parsnip (Pastinaca sativa), it is important to mow or pull just prior to flowering to severely curtail or eliminate the plants ability to flower and go to seed (Shelley 2001).*
To calculate prairie plant establishment (by frequency) follow the three steps listed below:

Step 1 – Sum the number of quadrats where there was a prairie plant present. Prairie plants occurred in quadrats # 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 16, 18, 20 = 16 quadrats had at least one prairie plant.

Step 2 – Divide the total number of quadrats with prairie plants present by the total number of quadrats sampled.

Prairie plant frequency (%) = 0.80 x 100 = 80.0 %

Step 3 – Multiply plant frequency by 100

Prairie plant frequency (%) = 0.80 x 100 = 80.0 %

This example, prairie plant establishment exceeds the minimum of 50% and the planting is well on its way to being successful. However, the presence of Canada thistle, considered noxious weed, should trigger the need to control this weed (see Brochure 9).

Sampling Terminology

Quadrat - A frame of known area (usually 1 square foot) that the investigator places on the ground and samples only rooted plants inside of the frame.

Random Sampling - A technique to ensure that all locations of the planting and all individuals of the population have an equal chance of being sampled.

Sample Size - Something that was done in sampling to produce results that do not represent the actual condition.

Photographic Monitoring

A picture is worth a thousand words. In 1994, at the 14th North American Prairie Conference in Manitoba, Canada, Dr. Paul Christiansen presented his research project of establishing prairie species in a roadside by oversowing them into non-native smooth brome (Bromus inermis) after a burn. He had established a permanent photo point on his research site and took images of the site before seeding and at 2, 5, 10, and 13 years after seeding. Watching the plant community transform from a man-made culture stand of non-native grass to a diverse prairie plant community that resembled a prairie remnant was fascinating. Photographic monitoring can be extremely useful in reconstructed prairies to document the long-term vegetation changes.
Sampling is a systematic process used to gather a small part (or sample) of something and analyze it to answer a basic question. A basic question asked by managers and landowners about a new prairie planting might be: Are there enough prairie plants in the planting? To answer this question you can proceed in one of two methods. The first method would be to identify all the prairie plants in the planting. Then, take that number and divide it by the total square feet in the planting which will result in the number of seedlings per square foot. This number can be compared with the recommended number of seedlings per square foot that are needed for adequate native plant establishment. The first method would be extremely time consuming but one could accurately calculate prairie plant establishment for the planting. The second method would be to choose many different locations throughout the planting, and identify and count only the prairie plants that occur in a very small area (one square foot) at each location. Prairie plant establishment could then be calculated by adding up all prairie plants found then dividing them by the total square foot that was sampled. This number, as with the number in the first method, can be compared with the recommended number of seedlings that are needed for adequate native plant establishment. Clearly the second method is easier and saves time. If the second method is correctly done, the number of plants per square foot can be averaged over the entire planting to get the first method. Sampling is an excellent assessment tool in prairie management.

**How Much And Where To Sample**

Determining how much vegetative sampling is needed depends upon the complexity of the landscape. For planting sites, regardless of the site, that don’t have much variation in topography and soil type, a minimum of 20 to 30 samples are needed to account for the total vegetative density (Dayton 1999). In plantings that have varying habitats (such as varying slopes and aspects, rock outcrops, swales, or waterways) and additional vegetative sampling is required. To accurately assess seeding establishment in plantings with a variety of habitats, areas of the site with similar environments should be sampled and analyzed separately. This is called stratified sampling. Stratified sampling requires dividing the site into habitat types based on environment and calculating prairie plant establishment for each habitat. We recommend a minimum of 20 to 30 samples be taken for each habitat type. An advantage of stratified sampling is that areas in the planting that have poor seedling establishment can be identified that may otherwise go undetected.

Vegetation sampling in grasslands is often done using a quadrat. Vegetation sampling within the frame. A good way to assess prairie plant establishment in a newly reconstructed prairie is by measuring plant density. This involves identifying and counting the prairie plant within the quadrat frame. Plant density is an excellent sampling method in early reconstructions (Year 1) because prairie seedlings have not yet spread by rhizomes and/or produced new tillers and stems. Counting individual plants/stems is feasible. A native prairie plant should have a minimum of 1 prairie plant/ square foot (Morgan 1995). A planting that has less than 1 prairie plant/ square foot by the end of Year 2 is susceptible to weed invasion and may require additional management to control weeds (see Initial Seeding in the readings). Developing a good data sheet is critical to any sampling method. Use a spreadsheet format to create a data sheet for the field. The data sheet should be identical to the spreadsheet on the computer. This will reduce mistakes when entering data from the field into the computer. Organize the data sheet by rows and columns. Each row represents a quadrat sample and each row represents a plant species. Arrange the species first by genera, then by species. List all the native species seeded on the data sheet. They should be listed by the native forbs, saving the weeds for last. Quadrat sampling with another person can be efficient. With a two-person sampling team, one person records the data while the other person identifies the plants. Plants that are difficult to identify should be collected and bagged for later identification or flagged (label the flag A, B, C, etc.) and returned to in a couple of weeks. When collecting unknown species in bags, assign each plant a letter on its bag and record it on the data sheet so it can be changed on the sheet when identification is made. Periodically check the data sheet to make sure that the quadrat column that is recorded is the one that seedlings are sampled from.

### Table 1: Plant Density Example

<table>
<thead>
<tr>
<th>Quadrat</th>
<th>Big bluestem</th>
<th>Switch grass</th>
<th>Canada thistle</th>
<th>Side-oats grama</th>
<th>Black-eyed Susan</th>
<th>Wild bergamot</th>
<th>Shrubby selecting</th>
<th>Canada millet</th>
<th>Smooth bromegrass</th>
<th>Total Seedlings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 square foot</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>2 square foot</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

### Calculating Vegetative Density

#### Step 1: Sum the total number of seedlings recorded in all quadrats.

Total prairie seedlings: $5 + 3 + 2 + 3 + 1 + 4 + 1 + 1 + 0 + 1 + 0 + 0 + 1 = 19$

#### Step 2: Sum the total quadrat area sampled.

Total sampling area: 30 quadrats * 1 square foot (quadrat area) = 30 square feet (See Table 1)

#### Step 3: Divide Total prairie seedlings by the Total sampling area.

Prairie plant density: 30 seedlings/20 square feet = 1.5 seedlings per square foot

In this example, prairie plant establishment exceeds the minimum of 1 prairie plant per square foot, which is an adequate stand. Note: In this example, the presence of Canada thistle should trigger the need for control of this weed (See Initial Post Seeding in this section).