REVEGETATION GUIDELINES:

Considering Invasive and Noxious Weeds

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(Photo: Steffany Rogge)

INTRODUCTION

Revegetation can help degraded plant communities recover after disturbance. Disturbances can be natural, such as floods and fires, or human-caused, such as roads and construction sites, overgrazing, and even weed control activities. Disturbed areas may recover naturally, but in some cases, it may be many years before a desired plant community becomes established or recovers. Some areas may never naturally recover, and invasive and noxious weeds may establish first and prevent desired plants from re-establishing.

What is an invasive weed, and what is a noxious weed? An invasive weed is a non-native plant that can establish on many sites and spread to other areas, disrupting plant communities. A noxious weed is an invasive weed with a special designation per the Montana County Weed Control Act. Noxious weeds are non-native to Montana and, when introduced, may render land unfit for agriculture, forestry, livestock, wildlife, or other beneficial uses or may harm native plant communities. It is unlawful for any person to allow noxious weeds to go to seed or propagate on their land. For a current list of Montana's noxious weeds, see the Montana Department of Agriculture website: https://agr.mt.gov/Noxious-Weeds.

Invasive and noxious weed-infested sites may require revegetation with competitive, desirable plants to meet land management goals. Weed control without revegetation on degraded sites can be short-lived because desired plants are not available to occupy open spaces created after controlling weeds. In these cases, introducing competitive plants through revegetation is essential for successful long-term management of weed infestations and the restoration of desired plant communities.

This publication provides a practical, step-by-step guide to establishing desired plants in Montana through revegetation, specifically in the context of integrated weed management. We have outlined seven steps to plan and execute a revegetation project. Users should reference the steps and additional resources noted throughout the publication for optimum success. The steps are designed to be used as a unit, and important information in one step may be needed to fully understand the information in another step. Throughout the revegetation process, keep in mind that we are addressing the process from a vegetative perspective – the plants' ability to establish, survive, and provide an intended benefit (e.g., weed management, conservation, or forage production). There is a practical difference between a plant merely surviving versus a plant thriving. Our goal is that the seeded plants thrive; otherwise, it is unlikely they will compete with re-invading weeds and help meet land management objectives.

Connect with local resources

Detailed information for every situation is beyond the scope of this publication. Site-specific or expert advice should be obtained locally for species selection, establishment methods, and maintenance of a revegetation project. Contact your local MSU Extension office, Natural Resources Conservation Service (NRCS) field office, or county weed district for assistance.

Find an MSU Extension office: https://msuextension.org/localoffices.html; 406-994-1750

Find an NRCS field office: https://www.nrcs.usda.gov/contact/find-a-service-center; 406-587-6811

Find a county weed district: https://www.mtweed.org/weeds/weed-districts/

Does the site require revegetation to meet land management objectives? If unsure about this question, work with local resources to help determine whether revegetation is necessary. Degraded rangeland dominated by invasive perennial forbs and annual weeds, illustrated in this photo, may require revegetation as part of integrated weed management if there is inadequate desired vegetation at the site (Photo: Mangold Lab).

STEP 1:

Site Assessment

A thorough site assessment is critical to a revegetation project. While it may be tempting to jump right into selecting species for a project, choosing the right plant species involves first knowing the site conditions and the goals. Make sure to complete a site assessment and thoroughly document the findings. See "Resources to help with the Site Assessment" at the end of this section for more information on different aspects of site assessments.

For seeding to be successful, the seeded plants must be well-adapted to the site. Not surprisingly, weak site assessments often lead to poor plant selection choices. Often overlooked is the distinction between site conditions now and at some previous reference point, like when an Ecological Site Description (ESD) or Soil Survey was conducted. To ensure proper plant species selection, a site inventory should be conducted to identify the prevailing and important aspects of:

- Climate
- Landscape position
- Soils
- Vegetation
- Equipment accessibility

Table 1 (see Appendix) provides a list of species used for revegetation projects in Montana and critical information about their suitability for planting. For information not included in Table 1, see Plant Guides on the USDA Plant Database.

Climate

One of the first items in a site assessment is obtaining basic climate data. Use the most localized information available. See the end of this section for suggested resources for this information. Determine the length of the growing season and average annual high and low temperatures to choose well-adapted species. Also determine annual precipitation and its seasonal distribution. This information provides a seasonal window for timing the seeding. In high rainfall areas, select species tolerant of wet conditions. Conversely, for low rainfall areas (without irrigation), use drought-tolerant species. If only marginal irrigation is available (1 to 2 irrigations total), consider planting species with some drought tolerance. **Table 1** provides selected species' planting season, timing window, and minimum annual precipitation requirements (precipitation required for the species to thrive).

Landscape Position

Landscape position factors such as elevation, slope, aspect, hydrology, and flooding potential play a role in successful plant establishment. It is important to know which species are adapted to the conditions specific to the site. Some plants, like meadow brome, grow well at higher elevation, moist sites, while some grow well on drier, south-facing slopes, like bluebunch wheatgrass. Other plants need extra moisture, like Canada wildrye, whereas some can tolerate spring flooding, like western wheatgrass. **Table 1** lists optimal moisture conditions for plant species under "hydrology." Matching plant species to the landscape where they are typically found increases seeding success.

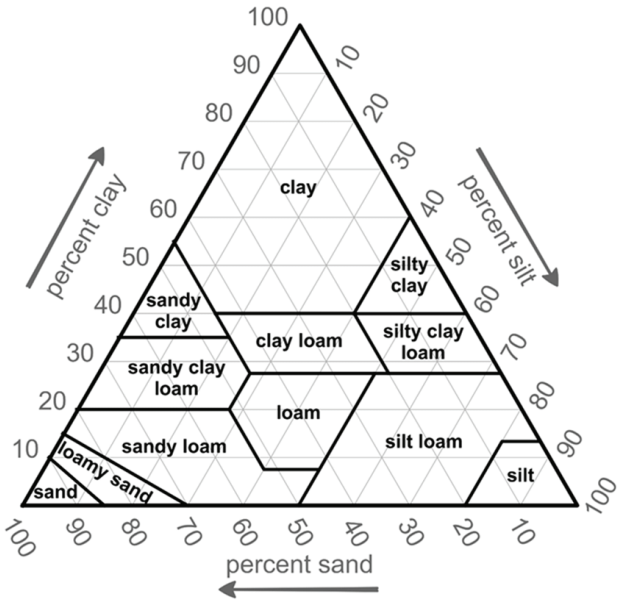
Soils

Soil characteristics are almost as important and limiting as annual precipitation. Soil characteristics impact plant growth and are relevant to most aspects of a seeding, including site preparation, planting, and species selection. Plant species are adapted to and typically grow well on specific soil types. Plant survival is directly linked to specific soil characteristics of a site. If more is known about the soils, better decisions can be made about species selection. Become familiar with the local soil survey and consider conducting a soil analysis of the site to determine the following information:

- Soil texture
- Soil depth
- Soil water-holding capacity
- Soil chemistry

Soil texture, the relative amount of sand, silt, and clay particles in the soil, affects plant establishment and growth. It affects important soil properties like water-holding capacity, soil water availability, water drainage and flow, nutrient retention and availability, soil surface crusting, soil workability, seedling emergence, and more. Plant species often establish best on soils characterized by a certain texture. When selecting species for seeding, be sure they are suited to the soil texture of the site. For example, Indian ricegrass is well-adapted to coarse sandy and medium-texture soils, while western wheatgrass does well on fine clay and medium-texture soils. **Table 1** provides information about preferred soil texture for referenced plant species.

Manual soil texturing



You can approximate the amount of sand, silt, and clay in soil using a simple method called "manual texturing." The feel of the moist soil sample, when rubbed between the thumb and forefinger, determines the texture. If the sample is predominantly sand, it will feel coarse and gritty. If it is predominantly silt, it will feel smooth or slippery to the touch. And if mainly clay, it will feel sticky and fine. Soil texture can also be determined by sending a sample to a laboratory.

Soil depth affects plant establishment and distribution by influencing water-holding capacity, nutrient availability, and rooting depth. As an example, bluebunch wheatgrass is adapted to moderately deep to very deep soils, whereas Sandberg bluegrass is dominant on shallow soils. Sandberg bluegrass grows on deeper soils, but generally does not dominate those sites.

Soil water-holding capacity is influenced by the soil organic matter (i.e., percent organic materials in the soil) and soil bulk density (i.e., weight of the soil within a specific volume). As organic matter increases, soil porosity, water infiltration, water-holding capacity, and nutrient reserves also increase. In addition, soil organic matter can improve soil structure. Montana soils are generally low in organic matter and range from 1% to 5% naturally, depending on the site. For sites with abnormally low soil organic matter, such as roadside construction sites, adding organic matter such as compost can improve soil properties and enhance the establishment of seeded species.

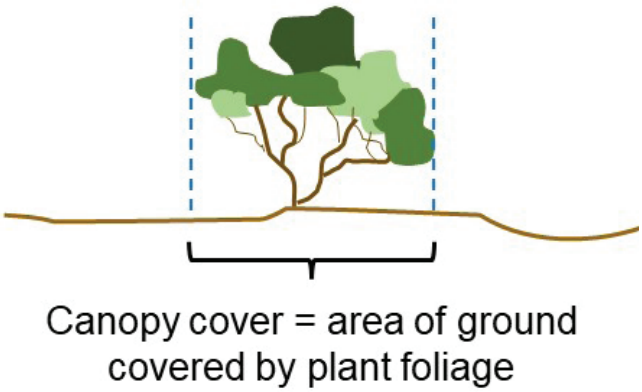
Soil chemistry is extremely important in plant establishment. Soil salinity, pH, and nutrient content are important factors in soil chemistry. Many species are not tolerant of soil salinity, while other plants may tolerate salinity at low levels but experience a toxic effect at high levels. Soil salinity (measured as electrical conductivity [EC]) can be a major limiting factor, but some species such as creeping foxtail, tall wheatgrass, manystem wildrye, and western wheatgrass can tolerate soil salinity relatively well. Knowing the range of salinity tolerance in plants makes it easier to select species adapted to the site (**Table 1**). Similarly, plants are adapted to a range of soil pH (i.e., acidity or alkalinity). For example, tall wheatgrass is best adapted to soils in a pH range of 6.6 to 10, western wheatgrass and basin wildrye are adapted up to a pH of 9, whereas bluebunch wheatgrass is not well-adapted to such a high pH. Know the site's soil chemistry to select species that will thrive.

General soil nutrition, typically nitrogen (N), phosphorous (P), and potassium (K), are determining factors in plant distribution and establishment, and plants differ in their need for these nutrients. In general, native species compete better in low nutrient environments. In contrast, annual plants, weeds, and introduced desired grasses tend to compete better in high nutrient environments because they are fast growing and can utilize excess nutrients better than most native species. Therefore, fertilizer application usually

is not made during revegetation on Montana rangelands and grasslands as it can encourage weed growth. Nutrient and pH levels should be corrected as recommended by a standard soil test prior to seeding an irrigated pasture or planting where biomass production is the objective.

Vegetation

As part of the site assessment, characterize the current vegetation. Remember that different herbaceous (non-woody) species are present at different times of the year, so it is important to visit the site and gather vegetation information more than once during the growing season. Note the species or lifeforms (grasses, flowering plants, shrubs) present and if they are beneficial (i.e., desired plants) or weedy species. Make a note of invasive or noxious weeds at the site. A more advanced site assessment might include gathering information on the species composition, canopy cover, density on the site, and if the species are native or introduced. If it is difficult to identify the existing vegetation, collect a sample or take a picture of the plant and share it with the county weed district, local Extension office, or NRCS field office for identification.



Canopy cover is the area of ground covered by plant foliage, and is a measurement that can be used to characterize abundance of different types of plants.

Equipment Accessibility and Availability

As part of the site assessment, note the type of equipment available for site preparation and planting steps of the project. The type of equipment available or the timing of its availability may limit species options or make seeding a particular site difficult to impossible (e.g., it is dangerous to drill seed a steep site). Similarly, site conditions may limit the type of equipment that will be effective. Consult with local agencies (e.g., county weed district offices, conservation districts, etc.), non-profit organizations (e.g., Pheasants Forever), and farm dealers to explore equipment options and available rental equipment. Another consideration is whether the seeding can be installed with the available labor force for the project. Consider all these factors in the planning stage to help make the seeding project more viable.

Resources to help with the site assessment:

Climate

1. USDA Snow Survey
2. Frost Freeze Data for Montana
3. National Weather Service

Soil

4. Web Soil Survey
5. Soil Sampling and Laboratory Selection
   - Contact the local Extension agent or NRCS county field office to assess soil condition.

Vegetation

6. Plant Guides on the USDA Plants Database
7. Major Land Resource Areas
8. Ecological Site Descriptions
   - On-the-ground inventory
   - Reference site

See page 31 for details about these references.

Historic Vegetation of Your Site

In addition to identifying the current vegetation on the site, gather information on the vegetation potential (or historic vegetation). There are many valuable sources of information, including:

- **Major Land Resource Areas (MLRAs)**
- **County Soil Survey**
- **Ecological Site Descriptions (ESDs)**
- **Habitat Type descriptions**

Use MLRAs and County Soil Surveys to get a general idea of the plant communities a region can support. For example, MLRA 58B – Northern Rolling High Plains for Montana – describes the area as supporting grassland vegetation. It lists several grass species found on deep soils, grass species for shallow soils and ridges, grass species for bottomlands and streams, and indicates that big sagebrush is the dominant shrub species.

Ecological Sites and Habitat Types describe the historic climax (or potential) plant community for a site and the composition (i.e., kind and amount) of plant species adapted to the site. ESDs and Habitat Type descriptions contain information on physiographic features, climate, soil characteristics, historic climax plant communities, forage value, wildlife value, and more. The plant community information is divided into species composition and their normal percentages. These can be useful resources for selecting species appropriate to the site, especially if a reference point is needed for a significantly altered site. Of course, the native species listed in the ESD may not be suited for the site's purpose, given current conditions and management objectives.

As you gather historical information, also consider how recent site management may have changed growing conditions. Just because certain species grew well in the past does not mean they will thrive in current conditions. For example, a site that was historically a native grassland but has been managed as an irrigated pasture with introduced grasses for 50 years will be difficult to seed to native vegetation because soil and nutrient levels have changed, and the site may contain competitive introduced grass species.

Sagebrush is a historic component of the vegetation at many sites in Montana (Photo: Megan Van Emon).

STEP 2:

Determine Project Goals and Objectives

Defining project goals and objectives is critical in planning a revegetation project. Setting goals and objectives is a way to determine if management is working or if management practices should be adapted. When setting goals and objectives, consider the site's current state and what it can support based on the site assessment.

Goals

Goal statements should describe the desired conditions to be developed based on how the land will be used and what the land can support. To make a goal statement, ask, "What do I want to accomplish on my land?" While revegetation is an excellent weed management approach, land management goals can be more than simply managing weeds. Think about what to accomplish on the land and manage the weeds to help achieve goals.

Revegetation goals may include any of the following:

- Establish species that can compete with and minimize weeds.
- Re-establish vegetation to minimize erosion.
- Improve forage production for livestock.
- Restore a healthy native plant community to improve wildlife habitat.
- Re-establish plant communities that support pollinators.

Objectives

Objectives provide a measurable link between goal statements and revegetation actions. To increase the likelihood of successful revegetation, objectives should consider existing site characteristics, current and future land use, economic constraints, realistic timeframes, and performance measures. Consider using the acronym "SMART" to help understand how to formulate objectives. Objectives should be:

- **Specific** – concrete and detailed, with enough information to know when the objective has been met.
- **Measurable** – formulated so numbers and data can be used to determine if objectives have been met (see "Step 6: Monitor Establishment").
- **Achievable** – mindful of the existing site conditions, economic feasibility, accessibility to equipment, future land use, and other constraints to ensure objectives are possible to meet.
- **Relevant** – helpful in moving the project area closer to meeting the land use goal(s).
- **Time-Bound** – feasible to achieve within a set time frame.

The following are examples of revegetation objectives:

- Reduce invasive weed canopy cover by 20 percent and increase native grass canopy cover by 10 percent one year after herbicide treatments and revegetation to improve forage production.
- Reduce bare ground by 50 percent and increase native perennial plant cover by 50 percent two years after revegetation to reduce erosion.
- To support pollinator habitat, establish five native forbs each at 5 percent canopy cover by three years after seeding.

An example of a goal for a revegetation project might be to re-establish a diverse plant community that supports pollinators (Photo: Jane Mangold).

STEP 3:

Control Weeds

Controlling weeds before, during, and after revegetation helps reduce weed competition with seeded species. Integrated weed management (IWM) uses a combination of control methods including:

- Chemical
- Mechanical
- Biological
- Cultural

These methods are combined to manage weed populations in a way that can be economically and environmentally sound. Revegetation is a type of cultural control, and its use, along with any other method aimed at reducing weeds, constitutes IWM. However, each weed management control method has advantages and disadvantages when integrated with revegetation, and these need to be carefully considered to improve outcomes.

Chemical

Chemical control involves using herbicides to kill or suppress weeds and is the weed management method most commonly integrated with revegetation. One of the most significant advantages of chemical control is its efficiency, or the ability to treat many weeds in a short amount of time and with high efficacy. The type of herbicide to use and the timing of the application depend on which weeds are present at the site. Where noxious weeds have been growing for many years, multiple herbicide applications over several seasons or even years may be necessary to deplete weed seeds in the seed bank. This will help to reduce competition between seedlings of weeds and seeded species. Herbicide recommendations for specific weeds are beyond the scope of this publication, but they can be found by contacting the county weed district or local Extension office or searching the MSU Extension Store.

The weed seed bank

Most weeds are prolific seed producers, a trait that enables them to be successful. When weeds grow on a site, their seeds accumulate in the soil in the "seed bank." The seed bank allows a weed to grow back even after existing plants have been controlled, and seeds of many species remain alive in the seed bank for years. Revegetation places seeds of desired species in a position to grow and thrive, but weed seeds in the seed bank will still germinate and grow. This means that controlling weeds will likely be an ongoing component of vegetation management, albeit a lesser component than it was prior to revegetation.

While chemical control is efficient, seeded species can be injured by an herbicide depending on the herbicide used and timing of application relative to seeding. Herbicides vary in how long they persist in the soil, and while herbicide persistence can be good for residual weed control, persistent herbicides may require the delay of seeding or risk injury to seeded species. For example, indaziflam provides multiple years of weed control, but the label (Rejuvra™) states that replanting desirable species should be delayed for at least eight months, and a field bioassay should be completed before planting. In contrast, glyphosate does not persist in the soil, and seeding can occur hours to days or weeks after application without any injury to seeded species. Carefully read product labels for directions associated with revegetation, restoration, planting, or seeding.

Herbicides also vary in selectivity, with some herbicides selectively controlling broadleaved species (e.g., 2,4-D, dicamba, aminopyralid, metsulfuron) or grassy species (e.g., clethodim, sethoxydim). In contrast, other herbicides are non-selective (e.g., glyphosate, imazapyr, indaziflam, paraquat) and control any species. Selecting the suitable herbicide depends on the weed(s) that needs to be controlled

Testing for herbicides with a bioassay

A field bioassay involves collecting soil from the field and planting seeds into it to see if they will grow or if there is still enough herbicide in the soil to prevent growth. To conduct a bioassay, collect several random but representative soil samples from the field and fill three to six pots with half field soil mixed with half potting soil. Prepare two to three pots with only potting soil to serve as the "control." Plant three bean, pea, or grass seeds into each pot and allow them to grow for three to four weeks. Maintain the pots in conditions good for plant growth, i.e., adequate water, sunlight, and moderate temperature. Observe the pots. If there is no difference in plant growth between pots with field soil and those without field soil, there is likely not enough herbicide in the soil to affect species seeded during revegetation. If, on the other hand, plants in pots with field soil display symptoms of herbicide injury (e.g., yellowing or curling and twisting of leaves and stems) compared to plants in the pots without field soil, herbicide is likely persisting in the soil and revegetation should be postponed. Another way to conduct a bioassay is to plant test strips of the selected species in the field prior to seeding the entire field.

From Milestone® VM label:

- **Seeding grasses**:
  - **Preemergence:** Milestone VM may be applied in the spring or early summer, depending on the target weed species, and grass planted the following fall or winter when appropriate for the grass species being planted.
  - **Postemergence:** During the season of establishment, Milestone VM should be applied only after perennial grasses are well established (have developed a secondary root system and are vigorous. Most perennial grasses are tolerant to Milestone VM at this stage of development. Milestone VM may suppress certain established grasses, such as smooth bromegrass (*Bromus inermis*), especially when plants are stressed by adverse environmental conditions. Plants should recover from this transient suppression with the onset of environmental conditions favorable to grass growth and upon release from weed competition.
- **Seeding Legumes or Susceptible Wildflowers:** Do not plant legumes or susceptible wildflowers until a soil bioassay has been conducted to determine if residues of Milestone VM remaining in the soil will adversely affect establishment of legumes and wildflowers.

From Plateau® label:

REVEGETATION WITH PRAIRIEGRASSES AND OTHER FORAGE GRASSES

Plateau may be applied at the rate of 2 to 12 oz per acre to newly established or existing stands of labeled species (see below for details) in such areas as pasture, rangeland (see "GUIDELINES FOR RANGELAND USE" section), Conservation Reserve Program (CRP) land and noncropland sites such as roadsides, industrial sites, prairie restoration sites, drainage ditch banks, and other similar areas. Certain
suppressed by **Plate**
cool temperatures, p
disease, insects and
poor stands. Additio
other factors contribu

Establishment: For optimum results in establishing mixed grass stands with **Plateau**, make application at planting before grass seedlings emerge. Newly emerged grasses can be sensitive to **Plateau** and/or the adjuvant used. If grasses have begun to emerge, it is best to wait until they have reached the five leaf stage to make a **Plateau** application and use a nonionic or silicone surfactant. **DO NOT** use a methylated seed oil at this time as some grass species tolerance will be lost. **Plateau** will control annual weeds preemergence or early postemergence. See "WEEDS CONTROLLED" section for maximum height of weeds and see below for more details on best rate and timing for grass and wildflower species. Postemergence applications may result in stand thinning due to variability in seedling grass tolerance to the use of spray adjuvants. Seedling grasses are generally more tolerant to the use of spray adjuvants after they have reached the five leaf stage. When planting into a field which was row cropped the previous year, compounded injury may occur from herbicide carry-over (see "DIRECTIONS FOR USE" section).

From Rejuvra™ label:

Replanting of Desirable Species in Rangeland, CRP or Natural Areas
Desirable rangeland and CRP species may be planted into areas treated with Rejuvra. If planning to plant desirable species in the treated area, avoid planting for at least eight months after application. A field bioassay must then be completed before planting. To conduct a field bioassay, grow to maturity test strips of the species you plan to plant. The test strips should cross the entire area including knolls and low areas. Response to the field bioassay will indicate whether or not to plant the species grown in the test strips. If no injury (e.g., poor germination, stunting, chlorosis, malformation, or necrosis) the species grown in the test strips may be planted.

Read herbicide labels to find recommended planting intervals between herbicide application and seeding.

and the species that will be seeded. Again, consult labels for special considerations about integrating the herbicide product with seeding. Sometimes, even selective broadleaf herbicides can injure seeded grass species at the seedling growth stage. For example, labels for aminopyralid (e.g., Milestone®), a broadleaf herbicide, include directions for integrating the products with grass seedings. Please see the resources at the end of this section for more information on herbicides.

Planning for future weed management

If revegetating areas infested with broadleaved noxious weeds like hoary alyssum, leafy spurge, spotted knapweed, or toadflax, and re-invasion of the site is likely due to seeds in the seed bank or regeneration from root fragments, try seeding grasses only instead of a grass-forb mix. This approach allows chemical control of the noxious weeds with a broadleaf herbicide even after seeding because the herbicide will not injure seeded grasses. Contact the local weed district or Extension office for more information on herbicides and how to integrate them with revegetation.

Mechanical

Mechanical control reduces growth or kills noxious weeds by physically damaging them and is achieved using hand tools or farm equipment. It includes pulling, digging, mowing, cultivating, raking, and tilling. For species that reproduce only through seed, mechanical control should occur prior to seed production. For example, mowing spotted knapweed during early bud stage can reduce seed production and decrease an infestation over time. For species that reproduce by seed and creeping roots, like Canada thistle and leafy spurge, mechanical control is more challenging and must be repeated multiple times to weaken an infestation. When considered as a stand-alone noxious weed management method, repeated mechanical control that disturbs the soil (i.e., cultivating and tillage) can be detrimental. However, this approach may be beneficial when integrated with revegetation because it can be used as part of seedbed preparation (refer to "Step 5: Site Preparation").

Biological

Biological control is the use of living organisms to reduce noxious weed populations. Classical biological control involves releasing natural enemies, such as insects or pathogens, that feed exclusively on a specific noxious weed. Using livestock to eat noxious weeds is also classified as biological control but is more accurately described as "targeted grazing." Biological control and targeted grazing stress weeds and reduce overall plant production, but these approaches do not usually kill the plants or eradicate infestations. Furthermore, these noxious weed control methods work slowly, and a decrease in noxious weed abundance may not be obvious for three to five years. Biological control and targeted grazing are most effective when integrated with other control measures, including revegetation. Revegetation should be considered in areas where biocontrol agents have been established, or targeted grazing has occurred, and noxious weed abundance has decreased over time, but desired plants are not recovering on their own. See the Montana Biological Weed Control Coordination Project for more information on classical biological control and the University of Idaho Targeted Grazing Handbook for more information on targeted grazing.

Cultural

Cultural control includes methods that shift the competitive balance between weeds and desired vegetation. Examples include proper livestock grazing, fertilization, irrigation, and prescribed fire. Revegetation is considered a type of cultural control too. In some situations, combining cultural control methods with revegetation is helpful, but in others, it is detrimental. For example, integrating revegetation with fertilization is not recommended because weeds take advantage of extra nutrients more quickly than many native plants. In contrast, irrigation and prescribed burning may be helpful when integrated with revegetation. Irrigation, if available, can assist with establishment of seeded species. Prescribed fire can remove dead plant material and prepare a seedbed for seeded species. Note that fire releases nutrients and, if not integrated properly with other weed control activities, can lead to increased weeds. Grazing should be deferred for at least one year, preferably two, following revegetation to allow seeded species to become established; afterward, proper grazing will help to maintain desired vegetation.

Integrating weed control with revegetation requires careful planning, and there is no "one size fits all" approach. Work with the local Extension office or county weed district to develop a plan for a specific situation that considers the identity of weed(s), site conditions, seeding plan, and land management goals.

Resources to help with weed control:

Noxious weed information, including identification, biology, and control methods:

1. MSU Extension Invasive Plants Publications
2. MSU Extension Store

Pesticide safety

3. Pesticide Education Publications & Resources

Biological control of weeds

4. Montana Biological Weed Control Coordination Project

Targeted grazing

5. University of Idaho Targeted Grazing Handbook

Mowing to Manage Noxious Weeds

6. Mowing to Manage Noxious Weeds MontGuide

See page 31 for details about these references.

STEP 4:

Planning a Seeding

Planning a seeding is not always a linear process; use the sections in this step collectively when planning a seeding. This process involves:

- Selecting species for a seed mix
- Determining the seeding rate
- Creating the seed mix
- Determining the seeding method and timing

Select Species for a Seed Mix

Once the site inventory is complete and goals and objectives are identified, one can select the appropriate plant species. When selecting plants to use in a revegetation project, choose those most appropriate to the site's land use goals and environmental conditions. If possible, identify plant species growing in weed-free areas close to the project's vicinity as they will indicate what can grow in the area. Keep in mind that environmental conditions may vary across the revegetation area. Considerations when selecting a species for a seed mix include:

- Species characteristics that meet site goals and objectives
- Species lifecycle (i.e., annual or perennial)
- Species origin (i.e., native or introduced)
- Species growth form (i.e., bunchgrass or sod-forming grass)
- Number of species in a mix

Species Characteristics that Meet Site Goals and Objectives

Not all species are equally good at doing all things; choose species that best address the site objective(s) and are suited to the site conditions. **Table 2** (next page) lists several characteristics of plants and shows their ability to address different goals. Use **Table 1** (Appendix) and the resources listed at the end of this section to select species with these characteristics. Contact the local NRCS or Extension office to assist in species selection and seed mix development.

An effective seed mix that provides **weed suppression** and prevents weed re-invasion includes competitive, fast-establishing grasses and forbs. The species in the mix should provide good ground cover and be active throughout the growing season. Generally, a diverse plant community will resist invasion better than a species-poor community.

For **erosion control** on sloped landscapes and sites with loose soils, choose soil-stabilizing species that are quick to establish and fast growing with extensive root systems and large amounts of aboveground biomass to cover the ground surface. Rhizomatous grasses are ideal for long-term erosion control because of their extensive networks of soil-stabilizing underground stems and roots. For short-term erosion control, for example, stabilization of steep slopes after a wildfire, consider seeding fast-growing annuals, and short-lived perennial species with long-lived perennials to stabilize slopes in the short- and long-term.

Make sure your seed mix includes:

- Species with characteristics that meet the site goals and objectives
- Fast establishing species
- 5 to 10 species
- No forbs (i.e., broadleaf plants with showy flowers) if managing weeds with broadleaf herbicides
- Species with different seasons of growth
- Bunchgrasses and sod-forming grasses
- Short- and long-lived perennials
- Avoid pre-made mixes from unknown or far away sources

Table 2. An example of species characteristics and site goals and objectives to evaluate when selecting plant species for a seed mix.

Objective	Species Characteristics											
	Fast Establishing	Fast Growing	Biomass Production	Ground Cover	Competitive	Diverse Species	Extensive Roots	Palatable and Nutritious	Grazing Tolerant	Disease / Pest Resistant	Thermal Cover and Structure	Forage and Fruit Production
Weed Suppression	X	X	X	X	X	X						
Erosion Control	X	X	X	X		X	X					
Forage Production			X					X	X	X		X
Wildlife Habitat						X		X	X		X	X
Pollinator Habitat				X		X		X		X	X	X

Ideal plants for **forage production** need to be palatable, nutritious, digestible, and have ample biomass production. Select species that can tolerate grazing, especially during the intended season of use. Mixtures of species with differing palatability are usually not recommended, as some will be overgrazed while others are underutilized. The selected species should be tolerant to heavy grazing and disease and insect-resistant.

Appropriate species mixes for **wildlife and pollinator habitats** optimize forage and food resources (browse, nectar, berries, etc.) throughout the year. Include species to provide structure for nesting, cover from predators, and protection from cold winter wind or summer heat (e.g., dense vegetation to block wind and provide shade). In general, diverse native plant communities provide good wildlife and pollinator habitat.

Lifecycle

Lifecycle is the period from germination of a seed to when the plant dies. Species in seed mixes are usually a combination of annuals (one year of growth), short-lived perennials (3 – 5 years), or long-lived perennials (5+ years). Annuals and perennials are included in a mix for different reasons. Species with a shorter lifespan establish quickly, and including them in a mix will help get vegetation growing while the slower and longer-lived species establish. Annuals such as annual ryegrass or triticale may be used on irrigated sites to prepare a site for future long-lived plants and erosion control. Short-lived perennials such as slender wheatgrass may be used to stabilize the site or act as a nurse crop for longer-lived species. Limit the annual and short-lived perennial species in a mix so they do not inhibit the growth of the long-term desired species (for example, limit short-lived perennial slender wheatgrass to 5 – 10% of a seed mix).

Long-lived perennials are commonly seeded for dryland, grassland, rangeland, and pasture plantings and forage production. They are late successional species (see page 26, "Understanding Succession for Successful Revegetation") and usually create a more stable plant community. Most species in a seed mix should be long-lived perennials.

Species Origin

Species origin, or whether a species is native or introduced (**Table 1**), is another consideration when selecting species for a seed mix. A native plant has developed in a particular region or ecosystem in North America. A plant introduced with human help (intentionally or accidentally) to a new place or new type of habitat where it was not previously found is considered introduced. Many of our introduced forage species came from similar climates in the Northern Hemisphere and were introduced as cultivars for their specific beneficial qualities.

The choice between native and introduced species depends on many factors, but the most important are the environmental conditions at the site, the site goals and

Table 3. Species characteristics and applicability of native or introduced origin. These broad generalizations should not be applied to all species of these origins.

Species Characteristics	Species Origin	
	Native	Introduced
Well-adapted to environmental extremes in Montana	X	X
Function well as part of the native plant community	X	
Maintain the genetic or ecological integrity of the plant community	X	
May form monocultures or limit species diversity		X
May compete well with weeds		X
Fast to establish		X
Concerns about spreading to non-target areas		X
Adapted to sites with low soil nutrients	X	

objectives, and the advantages of the place of origin (**Table 3**). Whether using native or introduced species, always select a cultivar or variety suited to Montana's climate.

Consider the following when choosing between native or introduced species for a seed mix:

- If the site is heavily infested with invasive weeds, then the use of introduced species that can establish quickly and compete with the weeds may be a practical choice. If natives are used, use species known to establish quickly.
- If the primary use of an area is spring pasture, consider using introduced forage species.
- When combining native and introduced species in a seed mix, remember that most introduced species are very competitive and may out-compete natives when planted together. The introduced species may dominate the site, leading to lower-than-desired species diversity. In seed mixes of mixed origin, plan for a lower seeding rate of introduced, competitive species. For example, when adding introduced alfalfa to a native grass mix, limit the alfalfa to 5 – 10 % of the seed mix.
- In sites significantly altered from a natural state, introduced species may be better suited. For example, a site that has been an irrigated pasture with introduced species and grazed for 40 years may have increased soil organic matter and nutrients. Consider seeding fast-growing, competitive species to inhibit weeds.
- For a disturbed site with native soils where nutrient levels have not been altered, native species may be appropriate.
- There may be regulations governing the choice of native or introduced species. For example, if working on public land, the only choice may be to seed native species.

Life and Growth Forms

Plant communities are naturally a mix of plants with different life forms and growth forms, which are groups of species with similar structures and functions. When developing seed mixes, include a variety of life forms (grasses, legumes, forbs, shrubs) and growth forms (bunchgrass, sod-forming grass, deep and shallow-rooted, early and late season growth). A mix of species with different life and growth forms will occupy more ecological niches on a site, utilize resources more completely in time and space, leave fewer resources available for weed species, and better prevent weed encroachment. Including various life and growth forms in a seed mix will also create diverse structure on the site, which can benefit other site objectives such as improving wildlife habitat.

Number of Species in Mix

Single species seedings are not commonly used but offer some advantages, including simplified forage production and weed management. Pure grass or legume stands are generally easier to manage for hay production than mixtures because all plants mature and can be harvested at the same time. If an area is weedy, planting a single species may aid in weed control because several herbicides will be available to apply to the single species for weed control (e.g., broadleaf herbicides or grass-specific herbicides), but few herbicides are available for managing weeds in mixed grass-forb-legume stands.

Diverse seed mixes are more commonly used because they have many advantages. Diverse seed mixes can:

- Increase forage or biomass production and protect from soil erosion.
- Use resources more completely and better resist weeds.
- Increase the chance of revegetation success because each species responds slightly differently to the range of site conditions (i.e., weather patterns, diverse soils, environmental conditions, and microsites within a planting site).
- Resist pests by providing diverse habitats for beneficial insects.
- Provide forage to extend the grazing period.
- Diversify plant structure to improve wildlife habitat and forage.
- Improve soil health by adding living roots to the soil, extending the season of growth, and increasing diversity of soil microbes.
- Add aesthetic value.

How many species should be in a seed mix?

As a rule of thumb, include 5 to 10 species in the seed mix; a minimum of 5 species to gain the advantages of diverse mixes but no more than 10 species to limit competition between species. Research and monitoring have shown that seed mixes with 10 or more species usually have only 5 to 9 species establish. In addition, seed mixes with 10 or fewer species tend to have a greater proportion of species in the seed mix establish.

Determine Seeding Rate

The seeding rate is based on the desired number of live seeds per square foot. It is expressed as pure live seed (PLS) pounds per acre (see below). **Table 1** provides the number of seeds per pound of many species and the number of PLS pounds per acre recommended for a full stand of that species. These rates are based on 12-inch row spacing for drill seeding in most cases and have been adjusted for seed size.

The standard rule of thumb is to use 20 to 25 seeds per linear or square foot for most seedings, although adjustments should be made for:

- Seed size
- Seeding method
- Weedy situations / site conditions
- Pure live seed (PLS)

Seed size: Seeding rate should be adjusted for seed size, and **Table 1** has made these adjustments. Small seeds are seeded at a higher number of seeds per foot because they have fewer carbohydrate reserves and perish more easily than large seeds; also, they have a greater potential to be planted too deep where they will not germinate. Large seeds are seeded at a lower number of seeds per foot because they produce robust competitive seedlings that tend to survive well and result in larger stature mature plants requiring more growing space. Large seeds are also difficult to sow in high numbers because they can clog a seeder.

Standard seed rates are expressed as the desired number of seeds per square foot because seed size dramatically affects the seeding density. For example, a large-seeded species with 80,000 seeds/pound seeded at 1 PLS lb/ac results in approximately 2 seeds/ft^2, while a small-seeded species with 800,000 seeds/pound seeded at 1 PLS lb/ac results in approximately 18 seeds/ft^2.

Seed size classes, number of seeds per pound and target seeding rate (PLS seeds/ft) adjusted for seed size.
Note: Seeding rate for species listed in Table 1 have already been adjusted for seed size.

Seed Size Class	# Seeds/lb	Target # PLS Seeds/ft
Small	> 800,000	30 to 50
Medium	80,000 to 800,000	20 to 25
Large	< 80,000	15 to 20

Seeding method: The seeding method will influence the seed rate. If broadcast seeding (as opposed to drill seeding), increase the seeding rate to twice the standard drill seeding rate in **Table 1**. See "Determine Seeding Method" section for more information.

Weedy situations/site conditions: Seeding rate can vary with the site conditions. For sites with weed infestations, poor soil quality, high burn severity from a wildfire, or high erosion potential (i.e., critical area plantings), increase the seeding rate to twice the recommended drill seed rate in **Table 1**. If a critical area planting is broadcast seeded or hydroseeded, the seeding rate is then four times the recommended rate in **Table 1**. A higher seeding rate can be more expensive, but it increases the chance the seed will find a suitable site to germinate and establish.

Pure Live Seed (PLS) describes the percentage of a seed lot (designated quantity of seed uniquely identified by a lot number) that will germinate when placed in the right growing conditions. PLS equals the percent purity multiplied by percent germination. Purity is the amount of pure seed of the species in the lot and excludes other material (dirt, plant parts, damaged or dead seed, weed seed) in the lot. Germination is the percent of seed that will readily germinate, including dormant seed in the lot. Percent purity, germination and PLS should all be on the seed tag when purchasing seed.

PLS = (% purity x % germination) / 100

Always order seed quantities in Pure Live Seed (PLS). In addition, when purchasing seed, ensure the seed is free of noxious weed seed and buy certified seeds that bear blue "certified seed" tags if available. Noxious weed seed that is restricted or prohibited will be listed separately from other weed seed. Seed certification programs attempt to ensure that seeds have the same genetic potential to perform in the field as the breeder seeds of the variety when it was first released for production. For more information, please see the Montana Seed Program website.

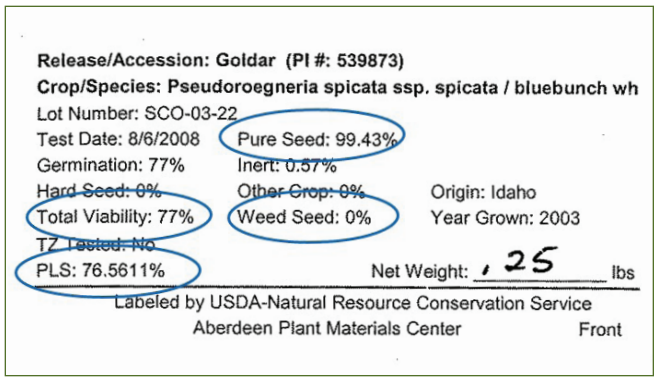
Comparing seed lots using pure live seed

Because the PLS measurement factors in quality, purchasers can compare the quality and value of different seed lots. To properly compare the value, a purchaser would calculate the cost per PLS pound by dividing the bulk cost by the percent PLS (PLS cost = bulk cost x 100/percent PLS).

Consider this example:

Seed lot A might appear to be the better value because its cost is only $1 per bulk pound, whereas the cost for seed lot B is $1.50 per bulk pound. However, the 53% PLS content of seed lot A is far inferior to seed lot B's PLS of 92%. The calculation shows seed lot B is the better value at $1.63 per PLS pound. Precise ordering of seed based on PLS helps purchasers get full value for the money spent on seed.

	Seed Lot A	Seed Lot B
Purity (%)	75%	97%
Germination (%)	70%	95%
PLS (%)	(75% x 70%) / 100 = **53%**	(97% x 95%) / 100 = **92%**
Cost bulk pound	$1.00	$1.50
Cost PLS pound	($1.00 x 100) / 53% = **$1.89**	($1.50 x 100) / 92% = **$1.63**



Seed tags provide vital information for planning your seeding project.

Create a Seed Mix

When a species is seeded as a full stand (i.e., single species), use the recommended amount of pure live seed (PLS) lbs/ac for a full stand found in **Table 1**. Since most seedings will include multiple species, determine the desired percent of each species in the mix and then use the following calculation to determine the amount of PLS lbs/ac for each species:

lbs PLS mix per acre = (desired % of seed mix) x (lbs PLS recommended/acre)

Three example seed mixes are available in the appendix for use in western Montana valley and foothill grasslands, western Montana mountains, and eastern Montana grasslands (**Tables 5, 6, and 7,** see Appendix).

Determine Seeding Method

The seeding method used will depend on site accessibility and terrain, seedbed characteristics, species and seed characteristics, and project budgets. The most common seeding methods are:

- Drill seeding
- Broadcast seeding
- Hydroseeding

Whatever seeding method is used, calibrate the seeder so that the desired seeding rate is obtained. Information for calibrating a drill seeder can be found under "Resources to Help with Planning a Seeding" at the end of this section.

Drill seeding is the preferred seeding method because it provides the best seed-to-soil contact and leads to the best seedling establishment. Drill seeders (also called rangeland drills or no-till drills) are tractor-pulled machines that open a furrow in the soil, drop seeds in the furrow at a specified rate and depth, and then roll the furrow closed.

Benefits of drill seeders include minimal soil disturbance and accurate seeding depth and rate. They can be used in non-rocky grasslands, rangelands, and on flat or low-angle slopes. Before using a drill seeder, remove as much existing vegetation and litter as possible by mowing, grazing, spraying, and/or burning the site to increase the drill's ability to penetrate the soil and place the seed in the soil (i.e., get the seed below the litter/thatch layer), and to prevent vegetation build-up in the drill mechanisms. No-till drilling into sod thatch is discouraged because the seed will not have proper contact with the soil.

Example: An example seed mix and calculations to determine PLS lbs/acre for each species in a seed mix.

Species	Recommended Full Stand Rate (PLS lbs/ac)	Desired % of Seed Mix	Calculate the PLS lbs/ac for each species in the mix
wheatgrass, bluebunch	7.0	35%	0.35 x 7.0 = **2.45 PLS lbs/ac**
wheatgrass, intermediate	10.0	30%	0.30 x 10.0 = **3.00 PLS lbs/ac**
bluegrass, Nevada	2.0	20%	0.20 x 2.0 = **0.40 PLS lbs/ac**
fescue, sheep	2.0	10%	0.10 x 2.0 = **0.20 PLS lbs/ac**
wheatgrass, slender	7.0	5%	0.05 x 7.0 = **0.35 PLS lbs/ac**

Drill seeders are suited to relatively flat areas with access for equipment (Photo: Jane Mangold).

Additional considerations when using a drill seeder include:

- Seed in two perpendicular passes if the visible result of row-established plants is undesired.
- Drill seed on the slope contour to prevent drill furrows from becoming erosive waterways.
- Use agitators in the seed boxes to continually mix the seed. Without agitators, seeds of various sizes will separate in the seed boxes, causing small seeds to vibrate to the bottom of the box and fall faster than larger seeds.
- Use seed carriers such as cracked corn or rice hulls to prevent seed separation during drilling, meter extremely small seeded species, and prevent fluffy seed from becoming tangled.
- If the drill seeder is equipped with two seed boxes, use them to separate and plant large and small seeds at the same time. It is possible to calibrate the drill to seed the large seed at the correct seeds/acre and plant at a specific depth while broadcasting small seed from another box directly on the soil surface.

Broadcast seeding simply scatters the seed on the soil surface. Seedling establishment is lower with broadcast seeding than drill seeding; therefore, seeding rates are doubled when using broadcast seeding. Broadcast seeding is commonly used on steep or rocky sites or when drill seeding equipment is unavailable. In addition, extremely small seeds are often broadcast seeded instead of drill seeded to place the seed at the soil surface. Harrows and/or rollers are often used with broadcast seeders to lightly cover the seed with soil and press the seed into the soil for good seed-to-soil contact.

Some of the benefits of broadcast seeding are that it can adapt to changing site conditions and weather constraints

and allows for the application of a variety of species, including fluffy forb seeds. Motorized spreaders effectively distribute seed at large scales in a short amount of time. Broadcast seeders can be mounted to four-wheeled ATVs, tractors, trucks, or bulldozers. Small areas can be seeded with a hand-held seed spreader. Aircraft can aerially broadcast seed sites inaccessible by vehicles or remote sites that are inaccessible to equipment. Aerial broadcast seeding has a lower success rate than regular broadcast seeding because site preparation is usually not possible, and seed is not evenly distributed. Aerial broadcast seeding usually quadruples the normal drill-seed rate.

Seedbed preparation is recommended before broadcast seeding to create soil surface texture to retain seed on the site and improve seed-to-soil contact. On accessible sites, harrowing or imprinting can roughen and loosen the soil surface, aiding water capture, infiltration, and soil aeration. Soil surface roughening also creates safe sites for improved seedling germination and establishment.

Hydroseeding is a common roadside revegetation practice that helps stabilize bare soil while applying the seed mix. Hydroseeding is a form of broadcast seeding in which seeds are applied in a liquid slurry, often with other organic nutrients and additives. Depending on the equipment, ingredients are mixed mechanically or hydraulically agitated, then sprayed on the slope under hydraulic pressure. This is not to be confused with hydromulching, which is applying mulch to prevent erosion. Hydroseeding is the preferred technique for stabilizing and seeding steep slopes that cannot be accessed by heavy equipment.

Typical hydroseeding applications include seed and one or more of the following:

- Mulch material to retain moisture and limit weeds.
- Tackifier for binding mulch to the slope to prevent soil erosion.
- Soil amendments are used to modify soil pH or nutrients or improve soil tilth.
- Dye colorant to assist the applicator in determining coverage.

Hydroseeding can result in lower seed establishment rates than drill or broadcast seeding because the seed does not always contact the soil surface. Seed-to-soil contact can be improved if site preparation occurs before seeding. Other hydroseeding limitations include seedling's inability to grow through mulch material, seed damage from equipment, and the large amount of water needed for application.

Accessing Equipment

Drill and broadcast seeders can often be rented from local conservation districts, non-profit organizations (e.g., Pheasants Forever), county weed districts, or Extension offices. Also, inquire at local farm and ranch stores and tractor implement dealers. Contractors can be hired for seeding, too, especially hydroseeding.

Island seeding

Island seeding is a less common method for establishing plants on a site. "Islands" are relatively small seedings within a larger management area that are seeded or planted with one or more species. Island seeding is used to increase species diversity on the site. For example, seed islands can increase flowering (pollinator) plant diversity in an area that is also managed for noxious weed control. The islands can be protected from herbicide use, easily allowing species diversification of the site. Over time, the species in seeded islands are expected to spread throughout the larger area. An increase in species diversity throughout the larger revegetation area is a long-term goal of island seeding, and an immediate increase in the number of seeded species should not be anticipated.

Species may be seeded in islands because they are more difficult to establish, more expensive, need additional site preparation techniques, and/or are live plants. The island size can vary; for example, they may be 3 x 10 feet square or 20-foot diameter circles of habitat. Species may be drill- or broadcast-seeded or even transplanted into islands. Sometimes mulches are added to the islands to retain soil moisture and improve seeded species establishment.

Choosing the right timing can increase the chances of a successful seeding (Photo: Monica Pokorny).

Determine Seeding Timing

There are two suggested seeding windows for successful seeding in Montana: fall-dormant seeding and early spring seeding. The right time to seed depends on the species being seeded. Some species need a winter cold period before they emerge, so it is important to know what is being planted and the appropriate season to plant (see **Table 1**).

Fall-dormant seeding occurs in the late fall just before the first snowfall or soil freeze when the soil temperature has fallen below 55°F for one to two weeks (e.g., late October or early November for most of Montana in most years). The air and soil temperatures should be cool enough that the seed does not germinate that fall. If the seed germinates in late fall, it will be susceptible to freezing over the winter. Dormant seed will overwinter without germinating; germination will occur when the soil warms in the spring and emerging seedlings will have adequate soil moisture to grow. Cool season species and species requiring a winter cold stratification period establish well with a fall dormant seeding. Cool season grass species predominate herbaceous plant communities in the western two-thirds of Montana.

Early spring seeding occurs before May 15 for most of Montana when the soil is moist and soil and air temperatures are cool. Warm season grass species, species not requiring cold stratification, and many cool season species establish well with early spring seeding. Warm season grass species are more common in the eastern third of Montana. One drawback with early spring seeding is that soil is often too wet to access with equipment. By the time soil dries to the point that is workable, the soil may be too dry for seeds to germinate, emerge, and grow big enough to establish before seasonal drought during July and August.

Late summer planting (i.e., mid-August) of cool-season species should only be done if supplemental water is available from irrigation. If regular irrigation is available, seeding can occur in the late summer to get the seedlings established and to the three-to-five-leaf stage before growth stops in the fall with cooler temperatures. This requires at least 30 to 45 days of growth from the seeding date to establish plants mature enough to survive winter conditions.

Resources to help with planning a seeding:

1. A Guide to Understanding Seed Labels for Seeding Certification
2. Montana Seed Program website
3. Calibrating a Seed Drill for Conservation Plantings
4. Conservation Plant Selections from the Montana-Wyoming Plant Materials Center
5. Conservation Plant Species for the Intermountain West
6. Seeding Rates for Conservation Species for Montana
7. Plant and Seed Vendors for ID, MT, NV, OR, UT, WA and WY
8. Cover Crop Seed Vendors for Western States

See page 31 for details about these references.

STEP 5:

Site Preparation and Implementation

Preparing the site for seeding is important to ensure revegetation success. Much time and effort have gone into the revegetation process thus far (e.g., Step 4: Planning a Seeding), and good site preparation improves the chances that revegetation will be successful. The overarching goal is to prepare the site to achieve the best contact between seeds in the seed mix and the soil at the site. Various techniques and practices exist, and the appropriateness of these will vary with site conditions, seeding method, species selection, available resources, and revegetation goals.

Seedbed Preparation

Seed requires an environment where it will have optimal conditions for germination, and seedbed preparation is important to meet these conditions. Seeds require water, oxygen, and favorable temperatures for germination. Seeds that have good contact with the soil are less likely to experience widely fluctuating wet-dry cycles because the soil transfers water efficiently to the germinating seed, allowing it to grow roots to reach deeper soil moisture. Good seedbed preparation provides seed-to-soil contact by creating the ideal soil firmness and safe sites. When soil is too loose, air in the soil increases the wetting and drying cycles. In contrast, when a seedbed is too firm, it is difficult to get the seed into the soil and for the seedling to emerge.

The degree of seedbed preparation needed before seeding depends on the method. If seeds will be planted with a drill seeder, seedbed preparation may not be necessary. Also, seedbed preparation may not be necessary if the site was burned, either prescriptively or because of a wildfire. Seedbed preparation is recommended when broadcast seeding.

Seedbed preparation includes both soil and vegetation considerations. Common seedbed preparation of the soil consists of shallow chiseling, plowing, harrowing, and/or discing. Such activities loosen the upper layer of soil and increase the number of seed safe sites. However, these activities are a soil disturbance and can provide favorable conditions for weeds and cause erosion on slopes or in fine-textured soils. A good rule of thumb is to use the least intensive seedbed preparation possible. Operations that use spiked or toothed implements to roughen the soil surface uniformly are usually more appropriate than plows or discs. Harrowing, raking, and dragging small chains are examples

What is a "safe site?"

The purpose of seedbed preparation is to ensure adequate safe sites for the seeds that will be planted. The term "safe site" refers to small spaces within the upper layer of the soil where a seed will experience the right conditions (e.g., moisture, light, protection from predators) to germinate, emerge, and establish. The seedbed should be firm enough to allow good seed-to-soil contact and loose enough for the seed's root to penetrate deeper into the soil and its shoot to emerge through the surface. Seedbed firmness is ideal when, walking across it, footprints remain that are about ½ inch deep.

(Photo: Noelle Orloff)

of less-intensive operations. Such activities can also be used after broadcast seeding to lightly cover seeds with soil. Light packing of the soil following broadcast seeding is also beneficial for adequate seed-to-soil contact.

Common seedbed preparation techniques to address existing vegetation include using herbicide, cover crops, grazing, mowing, or prescribed burning. Herbicide applications are a common method for controlling existing vegetation and weeds as part of seedbed preparation (see "Step 3: Control Weeds"). Cover crops are another method for controlling existing vegetation and weeds before establishing a perennial conservation seeding. The cover crop should grow quickly, utilize excess soil nutrients, and reduce the competitiveness of weeds. When seeding into a site with a lot of vegetative litter or biomass, use grazing, mowing, or prescribed fire to remove the standing dead biomass before seeding.

Sites with Compacted Soil

Soil consists of organic material, air spaces, and particles of sand, silt, and clay. A loss of soil structure from compaction affects water and air infiltration into soil and can hinder seedling establishment. Consider more intensive seedbed preparation like plowing or discing at sites with compacted soils.

One rule of thumb for seedbed preparation is that firmness is ideal when footprints remain that are about ½ inch deep after walking across the site (Photo: USDA).

Understanding Succession for Successful Revegetation

Plant communities change over time, from year to year and over longer time frames of decades to centuries. The process of vegetation changing over time is called "succession." Colonizing or pioneer species are usually the first plants to begin to grow after a disturbance. For example, fast-growing but short-lived species like "weedy" annuals might appear after a wildfire or after the ground is disturbed for construction. These colonizing species are eventually replaced by slower-growing, longer-lived species, such as perennial grasses, forbs, and shrubs. In many areas of Montana, trees may become more abundant, for example, conifer trees spreading into grasslands without a disturbance like fire. Weeds act as pioneer species, but they can also interfere with or stop succession from reaching the stage where perennial grasses, forbs, and shrubs dominate, which is the stage that many landowners hope to attain and that defines the prairies and foothills of most of Montana.

What does all this mean for revegetation?

Revegetation can be most successful when it works within the framework of succession and the understanding that plant communities change over time. There are three components required for succession to occur, and these components should be considered when managing invasive and noxious weeds and integrating revegetation with weed control. These are:

1. **Site availability —** Site availability refers to openings in the plant community where new species can grow; sites or openings are created by disturbance. Disturbance is a change in conditions that results in the death or reduction of certain species of plants. Many activities associated with noxious weed control (e.g., herbicide application, biological control, tillage) kill or decrease weeds and create openings in the plant community for new species to grow. During revegetation, disturbance is designed to remove noxious weeds and produce safe sites where seeds of desired species can grow.

2. **Species availability —** Once sites are available, seeds or propagules of species need to be present to occupy those sites. Integrating revegetation into noxious weed management ensures the availability of desired species by intentionally seeding them. At the same time, weed seeds in the seed bank need to be considered and depleted as much as possible to reduce competition with seeded species. Species availability is arguably the crux of revegetation; if weed management focuses only on killing weeds (creating site availability) but does not direct what species are available to grow in place of weeds, restoration of desired vegetation is less likely.

3. **Species performance —** Plants interact with each other and the environment around them. Species performance describes how well a species grows relative to other plant species growing in the same area. In revegetation, sites are created and filled by desired species, but that is not the end of the story. How quickly a species germinates and grows, acquires water and nutrients, responds to stressors in the environment like herbivory or drought, and how long-lived a species is are just a few factors that will affect the long-term dynamics of a plant community. Revegetation is most likely to succeed if the species chosen for seeding are suitable for that site and follow-up management promotes their growth while hindering the growth of noxious weeds.

Many land managers strive to attain late successional plant communities (Photo: Jane Mangold).

Resources to help with site preparation and implementation:

1. Principles of Seedbed Preparation for Conservation Seedings, Tech Note PM-13
   https://www.nrcs.usda.gov/plantmaterials/idpmctn10748.pdf

STEP 6:

Monitor Establishment

Monitoring involves periodically assessing the vegetation growing at the site to see if it is on track to meet management objectives and goals. Monitoring identifies problems that could prevent or interfere with a successful revegetation project, such as:

- Unexpected changes to species composition or abundance
- Invasion by new weeds or re-establishment of existing weeds
- Preferential foraging of seeded plants by wildlife or livestock
- Soil erosion
- Areas where revegetation failed
- Seedling stress caused by dry conditions

Monitoring can identify the problems above in time to allow for interventions such as:

- Controlling weeds that have re-established or invaded the site.
- Mitigating selective grazing by wildlife and livestock.
- Using mulch to protect seeds, prevent soil erosion and conserve soil moisture.
- Re-seeding areas where no seedlings emerged.
- Providing temporary irrigation to alleviate seedlings stressed by dry conditions.

Monitoring can range from quick visual inspection to an in-depth recording of species composition and abundance. The monitoring approach, including how often to monitor, will depend on project goals, site conditions, and time commitment to the revegetation project. Monitoring a couple of times per growing season (i.e., spring through fall) is recommended for the first year or two. As time passes, monitoring at least once per growing season or every other growing season should suffice. Sites more likely to have problems, for example, those with poor soils, low precipitation, steep slopes, frequent or intense disturbance, or high weed pressure, should be monitored more frequently than other sites.

Monitoring can be qualitative or quantitative. With qualitative monitoring, information collected is descriptive and observational (i.e., not numerical). One of the most common types of qualitative monitoring is photo points (see description below). With quantitative monitoring, information collected is numerical as vegetation is measured in some manner (e.g., canopy cover, the density of individuals, biomass (weight) of vegetation). This is commonly done by running a measuring tape a certain distance (hereafter called a "transect"), placing a frame at set distances along the transect, and recording vegetation within each frame. Step-by-step guidance for this procedure can be found in the appendix (Step 6 Worksheet: Monitor Establishment using Transects).

Seeded species, especially native perennial grasses and forbs, may take several years to establish as they grow more slowly than non-native weedy species. In addition, seeds can sometimes lie dormant in the soil until climate conditions are appropriate for germination. Research from several sites in western Montana demonstrated that short-term results (1 to 3 years after seeding) were not indicative of long-term results (9 to 15 years after seeding). In one situation, seeded grasses maintained high abundance initially, but then all or nearly all of them died. In another situation, seeded grasses were initially low but increased to greatly suppress the noxious weed, spotted knapweed, over time. Revegetation requires patience and monitoring helps to assess whether vegetation at a site is moving in the right direction.

Setting Up Photo Points for Monitoring

A photo point is a general landscape photograph taken repeatedly over a period of time from the same spot and filling the same frame so that changes over time can be compared visually. The picture must be taken at the same time of year and from a permanent reference point. The best time to take photos in Montana is usually late June or early July. Below are step-by-step directions for establishing a photo point.

1. Pick a location within the project area from where the photograph will be taken. The boundary or edge of the revegetation area often works well. Select a location that includes a distinctive landmark, e.g., hill or mountain, building site, fence line, clump of trees, etc. The distinctive landmark will facilitate finding and aligning the photo point in future years. Drive a post (e.g., T-post or wooden stake) into the ground to serve as a permanent marker.
2. Create a photo point identification sign using a broad, felt-tip marker so the writing is large and bold enough to show up in photographs. Include date, site name, name of the photographer, and any other relevant information on the sign. A whiteboard and dry erase marker works well, but even a blank piece of white or off-white paper will work.
3. Place a photo point identification sign next to the permanent marker (T-post or wooden stake), stand 8–10' from the post, and take a photo. The photo should show the information on the sign and enough area to see vegetations.
4. Label and save photo points in a manner that makes sense now and in the future.

It is important to monitor revegetated sites to increase the likelihood of revegetation success (Photo: Noelle Orloff).

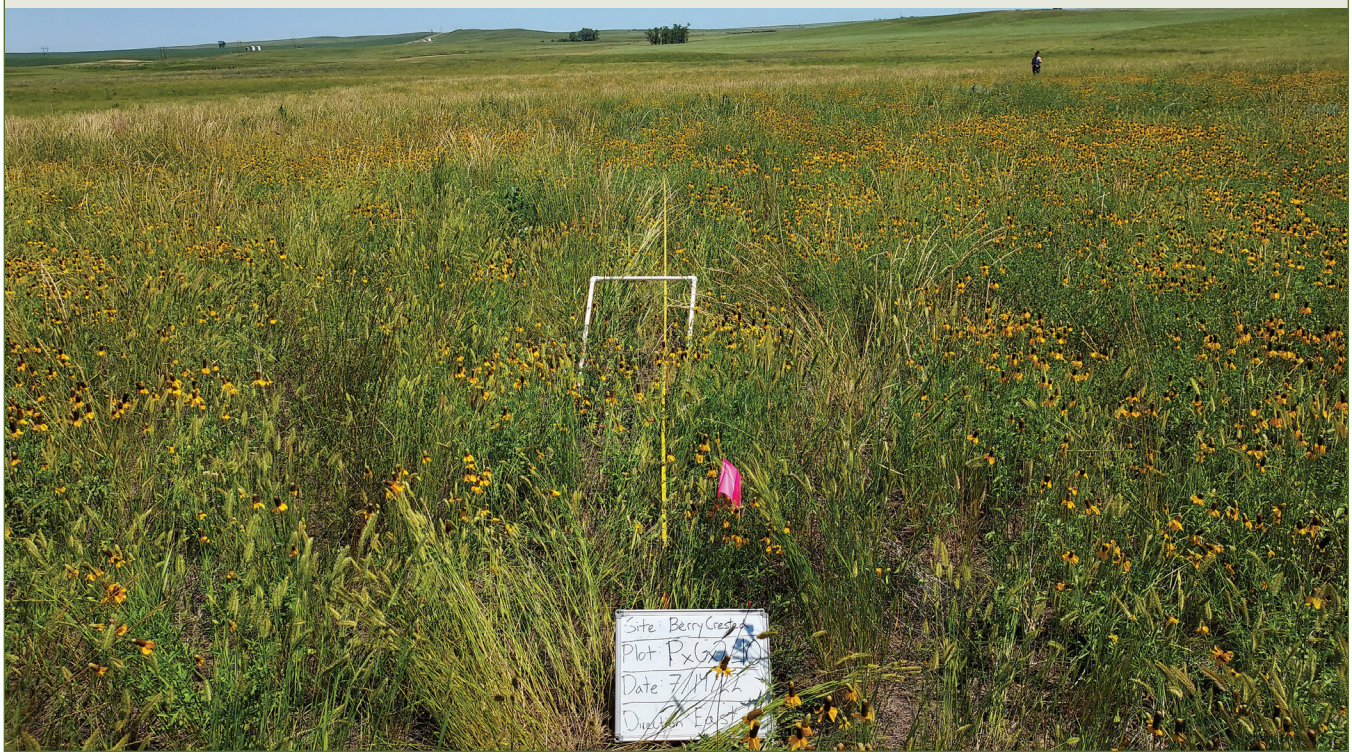


Photo points can be helpful for monitoring revegetation projects (Photo: Conner Nelle).

STEP 7:

Long Term Management

After a revegetation project has been established, long-term management is important to help maintain a healthy plant community. The site's management must favor growth of desired species over invasive plants for the long-term success of the project. Important aspects of long-term management are periodic monitoring, implementing weed control as needed (see "Step 3: Control Weeds"), and managing grazing on the site (if applicable).

If livestock have access to a revegetated site, grazing management is critically important. A long-term grazing management plan should be designed to encourage desired species in a revegetation project. The following grazing strategies benefit sites that have been revegetated in Montana:

- Defer grazing until seeded species are well-established, usually after two growing seasons.
- Fence seeded pastures separately from native rangeland. Also, fence seedings of different species or mixtures based on differences in maturity, palatability, and grazing tolerance among species.
- Avoid close grazing during fall green-up. This practice is very damaging to all grasses. This rest period allows roots to replenish reserves for winter survival and early spring growth.
- Follow proper stocking rates and grass utilization levels. Heavy grazing stops grass growth and reduces vigor. Even aggressively growing grasses cannot tolerate close and continuous grazing.
- Rotate livestock among pastures to allow plant recovery before grazing again. Plants with abundant leaves remaining after grazing will recover more quickly than closely-grazed plants. A minimum recovery period of 21 to 30 days is usually needed when growing conditions are optimal in spring. Recovery periods of two to three months may be required after summer or early fall grazing.
- Avoid grazing the same plants at the same time year after year by altering the season of pasture use.
- Equalize grazing pressure among rangeland plants with multi-species grazing. For example, horses and cattle may target perennial grasses, while domestic sheep tend to apply grazing pressure to forbs, including some weeds.
- Monitor regularly to evaluate whether the grazing program maintains the desired plant community. Monitoring should include detecting changes in desired plant cover and noting conditions like litter accumulation and exposed soil. Evaluate grazing management practices at least annually and modify them when necessary.

Periodically monitor the site to ensure land management goals and objectives are being met. If goals and objectives are not being met, changing how the site is managed may be necessary. For example, overgrazing or other types of disturbance that caused the decline of the original plant community will also affect the revegetation site if these disturbance patterns are not changed. It is likely not enough to plant desired species; land management strategies may also need to change to achieve a desired plant community that meets land use goals on a site.

Resources to Help with a Revegetation Project:

Site Assessment

1. USDA Snow Survey; https://www.nrcs.usda.gov/resources/data-and-reports/snow-survey-and-water-supply-forecasting
2. Frost Freeze Data for Montana; https://mtmastergardener.org/linksandresources/frostfreezedata.html
3. National Weather Service; www.weather.gov
4. Web Soil Survey; https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
5. Soil Sampling and Laboratory Selection, MSU Extension Nutrient Management Module; https://apps.msuextension.org/publications/pub.html?sku=4449-1
6. Plant Guides on the USDA Plants Database; https://plants.usda.gov/home
7. Major Land Resource Areas; https://www.nrcs.usda.gov/resources/data-and-reports/major-land-resource-area-mlra
8. Ecological Site Descriptions; https://www.nrcs.usda.gov/getting-assistance/technical-assistance/ecological-sciences/ecological-site-descriptions

Control Weeds

1. Noxious Weed Information including Identification, Biology, and Control Methods; http://www.msuinvasiveplants.org/extension_publications.html
2. MSU Extension Publications; store.msuextension.org
3. MSU Extension Pesticide Safety; https://pesticides.montana.edu/reference/index.html
4. Montana Biological Weed Control Coordination Project; mtbiocontrol.org
5. Targeted Grazing: A Natural Approach to Vegetation Management, University of Idaho; https://www.webpages.uidaho.edu/rx-grazing/handbook.htm
6. Mowing to Manage Noxious Weeds; https://store.msuextension.org/Products/Mowing-to-Manage-Noxious-Weeds-MT200104AG__MT200104AG.aspx

Planning a Seeding

1. A Guide to Understanding Seed Labels for Seeding Certification, Tech Note PM MT-125; https://www.nrcs.usda.gov/plantmaterials/mtpmctn13828.pdf
2. Montana Seed Program website; https://agr.mt.gov/Seed-Program
3. Calibrating a Seed Drill for Conservation Plantings, Tech Note PM-19; https://www.nrcs.usda.gov/plantmaterials/idpmctn7247.pdf
4. Conservation Plant Selections from the Montana-Wyoming Plant Materials Center; https://www.nrcs.usda.gov/plantmaterials/mtpmcbr13778.pdf
5. Conservation Plant Species for the Intermountain West, Tech Note PM-24; https://www.nrcs.usda.gov/plantmaterials/idpmstn10793.pdf
6. Seeding Rates for Conservation Species for Montana, Tech Note PM MT-46; https://www.nrcs.usda.gov/plantmaterials/mtpmctn12046.pdf
7. Plant and Seed Vendors for ID, MT, NV, OR, UT, WA and WY, Tech Note PM-33; https://www.nrcs.usda.gov/plantmaterials/idpmstn10795.pdf
8. Cover Crop Seed Vendors for Western States, Tech Note PM-3; https://www.nrcs.usda.gov/plantmaterials/orpmctn13328.pdf

Site Preparation and Implementation

1. Principles of Seedbed Preparation for Conservation Seedings, Tech Note PM-13; https://www.nrcs.usda.gov/plantmaterials/idpmctn10748.pdf

Connect with Resources in Your Area for Assistance

1. Find a county weed district: https://www.mtweed.org/weeds/weed-districts/
2. Find an NRCS field office: https://www.nrcs.usda.gov/contact/find-a-service-center
3. Find an Extension office: https://msuextension.org/localoffices.html; 406-994-1750

APPENDIX

Table 1. Plant species and their characteristics, full stand seeding rates, and recommended selections for seedings in Montana. All seeding rates are based on pure live seed (PLS) and 12-inch row spacings.

Common Name	Scientific Name	Seeds/lb	Full Stand Drill Seed Rate (PLS lb/ac)[1.]	PLS/sq ft or linear ft[1.]	Min. Precip (inch)[2.]	Lifecycle[3.]	Growth[3.]	Season[3.]	Timing[3.]	Salinity[4.]	Hydrology[4.]	Soil Texture[4.]	Seeding Depth (inch)	Proven Selection[5.]
NATIVE GRASSES														
alkali sacaton	*Sporobolus airoides*	1,750,000	1	40	12	P	B	W	NP		WD	C, M, F	0.25	Saltalk
bluegrass, big	*Poa secunda (P. ampla)*	882,000	2	40	10	P	B	C	NP		WD	M, F	0.25	Sherman
bluegrass, Canby	*Poa secunda (P. canbyi)*	925,000	2	42	10	P	B	C	NP		WD	C, M, F	0.25	Canbar
bluegrass, Nevada	*Poa secunda (P. nevadensis)*	1,029,000	2	47	10	P	B	C	NP		WD	M, F	0.25	Opportunity
bluegrass, Sandberg	*Poa secunda (P. sandbergii)*	900,000	2	41	6	P	B	C	NP		WD	C, M, F	0.25	High Plains, Reliable
bluestem, big	*Andropogon gerardii*	130,000	8	24	12	P	B	W	S		WD	M, F	0.5	Sunnyview, Bison, Bonilla, Champ
bluestem, little	*Schizachyrium scoparium*	260,000	4	24	12	P	B	W	S		WD	C, M	0.5	Badlands , Blaze, Camper
bluestem, sand	*Andropogon hallii*	113,000	9	23	14	P	S	W	S		WD	C, M	0.5	Garden, Goldstrike
brome, mountain	*Bromus marginatus*	80,000	10	18	16	P	S	C	NP		WD	C, M, F	0.5	Bromar, Garnet
buffalograss	*Bouteloua dactyloides*	48,000	15	17	10	P	S	W	NP	MT	WD	M, F	0.5	Bison, Plains, Tatanka, Texoka, Cody, Bismarck
cordgrass, prairie	*Spartina pectinata*	183,000	6	25	14	P	S	W	NP	MS	SF	M, F	0.5	Red River
fescue, Idaho	*Festuca idahoensis*	450,000	2.5	26	12	P	B	C	NP		WD	M, F	0.25	Joseph, Nezpurs, Winchester
grama, blue	*Bouteloua gracilis*	825,000	2	38	12	P	S	W	S	MS	WD	C, M, F	0.4	Alma, Bad River, Birdseye, Willis
grama, sideoats	*Bouteloua curtipendula*	191,000	6	26	10	P	B/S	W	S		WD	C, M, F	0.5	Butte, Pierre, Trailways, Killdeer
hairgrass, tufted	*Deschampsia cespitosa*	2,500,000	0.75	43	14	P	B	C	NP		SS	M, F	0.25	Peru Creek
Indiangrass	*Sorghastrum nutans*	170,000	6	23	11	P	S	W	NP		WD	C, M, F	0.5	Tomahawk
Indian ricegrass	*Achnatherum hymenoides*	235,000	5	27	8	P	B	C	NP		WD	C, M	0.75	Rimrock, Nezpar, Paloma, White River
needle and thread	*Hesperostipa comata*	115,000	9	24	5	P	B	C	NP		WD	C, M	0.75	AC Sharptail
needlegrass, green	*Nassella viridula*	186,000	6	26	12	P	B	C	F		WD	M, F	0.5	Lodorm, Cucharas, AC Mallard
prairie Junegrass	*Koeleria macrantha*	2,300,000	1	53	12	P	B	C	NP		WD	C, M	0.1	Common
prairie sandreed	*Calamovilfa longifolia*	273,000	4	25	10	P	S	W	S		WD	C, M	0.75	Goshen, Pronghorn
sand dropseed	*Sporobolus cryptandrus*	5,680,000	1	130	7	P	B	W	NP		WD	C	0.1	Common
squirreltail, bottlebrush	*Elymus elymoides*	192,000	5	22	5	P	B	C	NP		WD	C, M	0.5	Fish Creek, Sand Hollow, Wapiti
switchgrass	*Panicum virgatum*	389,000	3	27	12	P	S	W	S	LT	WD	C, M, F	0.25	Dacotah, Forestburg, Sunburst
wheatgrass, beardless	*Pseudoroegneria spicata spp. inermis*	145,000	7	23	8	P	B	C	NP	T	WD	M	0.5	Whitmar
wheatgrass, bluebunch	*Pseudoroegneria spicata*	139,000	7	22	10	P	B	C	NP		WD	M, F	0.5	Anatone, Goldar, P7
wheatgrass, slender	*Elymus trachycaulus*	140,000	7	22	10	P	B	C	NP	T	WD	M, F	0.5	Copperhead, Pryor, Revenue, San Luis, First Strike
wheatgrass, Snake River	*Elymus wawawaiensis*	135,000	7	22	8	P	B	C	NP		WD	C, M	0.5	Secar
wheatgrass, streambank	*Elymus lanceolatus spp. riparius*	152,000	7	24	7	P	S	C	NP		SS	C, M, F	0.5	Sodar
wheatgrass, thickspike	*Elymus lanceolatus spp. lanceolatus*	152,000	7	24	7	P	S	C	NP	MS	SS	M, F	0.5	Critana, Bannock
wheatgrass, western	Pascopyrum smithii	93,000	10	21	10	P	S	C	NP	MT	SF	M, F	0.5	Rosana, Rodan
wildrye, basin	Leymus cinereus	144,000	7	23	8	P	B	C	NP		WD	C, M	0.5	Trailhead, Washoe, Continental, Magnar
wildrye, Canada	Elymus canadensis	115,000	8	21	20	P	B	C	NP	MS	WD	C, M	0.5	Mandan

1. Standard drilled seeding rate will be doubled for broadcast and critical area seeding.

2. Minimum annual precipitation (inches) is the average annual minimum precipitation that occurs 20% of the time (i.e., the probability of it being this dry in any given year is 20%) within the known geographical range of the plant species. For cultivars, it is the range to which the cultivar is well adapted rather than marginally adapted.

3. Lifecycle: A=Annual, B=Biennial, P=Perennial; Growth form: B=Bunchgrass, S=Sod grass; Season: W=warm season grass, C=cool season grass; Seed Timing: S = Spring Seeding Preferred, F = Fall Seeding Preferred, NP = No Seasonal Seeding Preference.

4. Salinity Tolerance: T = Tolerant (EC 15-25), MT = Moderately Tolerant (EC 10-15), MS = Moderately Sensitive (EC 5-10), LT = Low Tolerance (EC 2-5), blank = assume Not Tolerant; Hydrology indicates the optimal moisture conditions. WD = Well-drained species may tolerate short periods of soil saturation. SS= Seasonally Saturated percies perfer soil that is satruated early in the season but later dry out. SF = Seasonally Flooded species perfer flooding in the early portion of the season. Soil Texture adaptation of species: C = Coarse (more sand), M = Medium (more silt), F = Fine (more clay)

5. Proven Selections include cultivars, tested-class, selected-class, and germplasm level plant releases to the commercial market.

6. Minimum between-row spacing of 18 inches.

* Species can dominate a site and become a monoculture.

For information on poisonous plants, see Plant Materials Technical Note MT-124, Plants Poisonous to Livestock in Montana and Wyoming, Considerations for Reducing Production Losses.

For more species specific information, see the species Plant Guides on the USDA Plants Database (https://plants.usda.gov/home).

Table 1 (continued). Plant species and their characteristics, full stand seeding rates, and recommended selections for seedings in Montana. All seeding rates are based on pure live seed (PLS) and 12-inch row spacings.

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INTRODUCED GRASSES														
bluegrass, Canada	*Poa compressa*	1,600,000	1.5	55	18	P	B	C	NP		WD	M, F	0.25	Foothills, Reubens, talon
bluegrass, Kentucky*	*Poa pratensis*	2,150,000	1	49	16	P	S	C	NP		SF	M, F	0.5	Troy, Park, Newport
brome, meadow*	*Bromus biebersteinii*	93,000	10	21	13	P	S	C	NP	MS	SS	C, M, F	0.5	Fleet, MacBeth, Montana, Regar, Paddock, Cache
brome, smooth*	*Bromus inermis*	125,000	8	23	20	P	S	C	NP	MS	SS	C, M, F	0.5	Lincoln, Manchar, Rebound
fescue, hard*	*Festuca brevipila*	565,000	2	26	12	P	B	C	NP		SS	C, M, F	0.25	Durar, Serra
fescue, sheep*	*Festuca ovina*	680,000	2	31	10	P	B	C	NP		SS	C, M, F	0.25	Covar
fescue, tall	*Schedonorus arundinaceus*	242,000	4	22	16	P	B	C	NP	MT	SF	M, F	0.25	Alta, Kenmont, Fawn
foxtail, creeping*	*Alopecurus arundinaceus*	720,000	2	33	18	P	S	C	NP	MS	SF	C, M, F	0.25	Garrison, Retain
orchardgrass	*Dactylis glomerata*	464,000	2.5	27	16	P	B/S	C	NP	LT	WD	M, F	0.5	Chinook, Latar, Potomac, Paiute
ryegrass, perennial	*Lolium perenne*	247,000	4	23	30	P	S	C	NP	MS	WD	C, M, F	0.5	Friend, Linn
timothy	*Phleum pratense*	1,300,000	1.5	45	18	P	S	C	NP	MS	SF	M, F	0.25	Climax, Drummond, Engmo
triticale, QuickGuard	*Triticum aestivum x Secale cereale*	13,000	25	7	12	A		C	NP		WD	C, M, F	1	
triticale, Regreen	*Triticum aestivum x Elytrigia elongata*	11,000	25	6	12	A		C	NP		WD	C, M, F	1	
wheatgrass, crested*	*Agropyron cristatum*	200,000	5	23	8	P	B	C	NP	MT	WD	C, M, F	0.75	Ephraim, Fairway, Parkway, Roadcrest, Ruff
wheatgrass, crested desert*	*Agropyron desertorum*	175,000	6	24	8	P	B	C	NP	MT	WD	C, M, F	0.75	Douglas, Nordan, Summit
wheatgrass (fairway x standard)*	*Agropyron x hybrid*	175,000	6	24	8	P	B	C	NP	MT	WD	C, M, F	0.75	Hycrest, CD II, Hycrest II
wheatgrass, hybrid*	*Elymus hoffmanii*	134,000	8	25	13	P	S	C	NP	T	SS	M, F	0.5	Newhy, AC Saltlander
wheatgrass, intermediate	*Thinopyrum intermedium*	79,000	10	18	12	P	S	C	NP	MT	WD	M, F	0.75	Greenar, Manifest, Oahe, Rush, Reliant
wheatgrass, pubescent	*Thino. intermedium spp. barbulatum*	80,000	10	18	11	P	S	C	NP	MS	SS	C, M	0.75	Luna, Manska, Greenleaf
wheatgrass, Siberian*	*Agropyron fragile (A. sibericum)*	170,000	6	23	8	P	B	C	NP	MT	SS	C, M	0.75	P-27, Vavilov
wheatgrass, tall	*Thinopyrum ponticum*	79,000	10	18	10	P	B	C	NP	T	SF	M, F	0.75	Alkar, Jose, Largo, Orbit
wildrye, Altai	*Leymus angustus*	80,000	10	18	14	P	B	C	NP	T	WD	M, F	0.4	Ejay, Pearl, Prairieland
wildrye, Dahurian	*Elymus dahuricus*	88,000	10	20	12	P	B	C	NP		WD	C, M, F	0.5	Arthur, James
wildrye, mammoth	*Leymus racemosus*	47,000	15	16	7	P	S	C	NP		WD	C, M	0.5	Volga
wildrye, manystem	*Leymus multicaulis*	181,000	6	25	9	P	S	C	NP		WD	C, M, F	0.1	Shoshone
wildrye, Russian*[6.]	*Psathyrostachys juncea*	170,000	6	23	8	P	B	C	NP	T	WD	M, F	0.25	Bozoisky-Select, Mankota, Swift, Bozoisky II

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Table 1 (continued). Plant species and their characteristics, full stand seeding rates, and recommended selections for seedings in Montana. All seeding rates are based on pure live seed (PLS) and 12-inch row spacings.

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NATIVE FORBS and LEGUMES														
beeplant, Rocky Mountain	*Cleome serrulata*	64,000	13.5	20	10	A					WD	M	0.25	
black-eyed Susan	*Rudbeckia hirta*	1,746,000	0.8	32	16	P			NP		WD	M, F	0.25	
blanketflower	*Gaillardia aristata*	186,000	6	26	9	P			NP	LT	WD	C, M	0.5	Meriwether
buckwheat, sulfur flower	*Eriogonum umbellatum*	140,500	9	29	8	P			F		WD	C, M	0.1	
flax, Lewis	*Linum lewisii*	294,000	3.5	24	8	P			NP	LT	WD	C, M	0.25	Maple Grove
geranium, sticky	*Geranium viscosissimum*	55,000	1.4	2	10	P					WD	M	0.25	
globemallow, scarlet	*Sphaeralcea coccinea*	500,000	2	23	6	P			NP	LT	WD	C, M	0.1	Common
goldenrod, missouri	*Solidago missouriensis*	2,000,000	1	46	15	P					WD	C, M, F	0.25	
leadplant	*Amorpha canescens*	90,000	1	2	15	P					WD	C, M	0.25	
lupine, silky	*Lupinus sericeus*	20,000	20	9	10	P					WD	C, M	0.25	
lupine, silver	*Lupinus argenteus*	126,000	8.6	25	10	P					WD	C, M	0.5	
milkvetch, Canada	*Astragalus canadensis*	270,000	4	25	12	P					WD	M	0.5	
milkweed, showy	*Asclepias speciosa*	75,000	15	26	16	P					WD	C, M	0.25	
penstemon, firecracker	*Penstemon eatonii*	315,000	3	22	10	P			NP		WD	C, M	0.25	Richfield
penstemon, fuzzytongue	*Penstemon eriantherus*	358,000	3	25	8	P			F		WD	C, M	0.25	Old Works
penstemon, Rocky Mountain	*Penstemon strictus*	478,000	2	22	14	P			NP		WD	M, F	0.25	Bandera
phacelia, silverleaf	*Phacelia hastata*	153,000	6.9	24	8	P			F		WD	C, M	0.25	Stucky Ridge
prairie clover, purple	*Dalea purpurea*	317,000	3.5	25	12	P			NP	LT	WD	C, M	0.25	Kaneb, Bismarck
prairie clover, white	*Dalea candida*	278,000	4	26	10	P			NP		WD	C, M	0.25	Antelope
prairie coneflower	*Ratibida columnifera*	600,000	2	28	9	P			NP		WD	M, F	0.25	Stillwater
purple coneflower	*Echinacea angustifolia*	128,000	9	26	10	P			F		WD	C, M, F	0.5	
sunflower, annual	*Helianthus annuus*	81,000	13	1	12	A			NP		WD	C, M, F	0.8	
sunflower, Maximilian	*Helianthus maximiliani*	250,000	4	23	12	P			NP	LT	WD	M	0.25	Prairie Gold, Medicine Creek
sweetvetch, northern	*Hedysarum boreale*	34,000	25	19	12	P			NP		WD	C, M, F	0.5	Timp
vetch, America	*Vicia americana*	33,000	33	25	10	P					WD	C, M	1.0	
yarrow, western	*Achillea millefolium*	2,850,000	0.25	25	8	P			NP	LT	WD	C, M	0.1	Great Northern

1. Standard drilled seeding rate will be doubled for broadcast and critical area seeding.

2. Minimum annual precipitation (inches) is the average annual minimum precipitation that occurs 20% of the time (i.e., the probability of it being this dry in any given year is 20%) within the known geographical range of the plant species. For cultivars, it is the range to which the cultivar is well adapted rather than marginally adapted.

3. Lifecycle: A=Annual, B=Biennial, P=Perennial; Growth form: B=Bunchgrass, S=Sod grass; Season: W=warm season grass, C=cool season grass; Seed Timing: S = Spring Seeding Preferred, F = Fall Seeding Preferred, NP = No Seasonal Seeding Preference.

4. Salinity Tolerance: T = Tolerant (EC 15-25), MT = Moderately Tolerant (EC 10-15), MS = Moderately Sensitive (EC 5-10), LT = Low Tolerance (EC 2-5), blank = assume Not Tolerant; Hydrology indicates the optimal moisture conditions. WD = Well-drained species may tolerate short periods of soil saturation. SS= Seasonally Saturated percies perfer soil that is satruated early in the season but later dry out. SF = Seasonally Flooded species perfer flooding in the early portion of the season. Soil Texture adaptation of species: C = Coarse (more sand), M = Medium (more silt), F = Fine (more clay)

5. Proven Selections include cultivars, tested-class, selected-class, and germplasm level plant releases to the commercial market.

6. Minimum between-row spacing of 18 inches.

* Species can dominate a site and become a monoculture.

For information on poisonous plants, see Plant Materials Technical Note MT-124, Plants Poisonous to Livestock in Montana and Wyoming, Considerations for Reducing Production Losses.

For more species specific information, see the species Plant Guides on the USDA Plants Database (https://plants.usda.gov/home).

Table 1 (continued). Plant species and their characteristics, full stand seeding rates, and recommended selections for seedings in Montana. All seeding rates are based on pure live seed (PLS) and 12-inch row spacings.

Common Name	Scientific Name	Seeds/lb	Full Stand Drill Seed Rate (PLS lb/ac)[1.]	PLS/sq ft or linear ft[1.]	Min. Precip (inch)[2.]	Lifecycle[3.]	Growth[3.]	Season[3.]	Timing[3.]	Salinity[4.]	Hydrology[4.]	Soil Texture[4.]	Seeding Depth (inch)	Proven Selection[5.]
INTRODUCED FORBS and LEGUMES														
alfalfa	*Medicago sativa*	225,000	5	26	10	P			NP	LT	WD	M, F	0.5	
alfalfa, yellow	*Medicago sativa ssp. falcata*	211,000	5	24	10	P			NP		WD	M, F	0.25	
birdsfoot trefoil	*Lotus corniculatus*	418,000	3	29	15	P			NP	MS	WD	C, M, F	0.25	Empire, Leo
clover, alsike	*Trifolium hybridum*	700,000	1.5	24	16	P			NP	LT	WD	C, M, F	0.25	Common
clover, berseem	*Trifolium alexandrinum*	206,900	12	57	12	P					WD	C, M, F	0.5	
clover, crimson	*Trifolium incarnatum*	150,000	5	17	32	P					WD	C, M, F	0.5	
clover, red	*Trifolium pratense*	275,000	4	25	14	P			NP	LT	WD	C, M, F	0.25	Common
clover, strawberry	*Trifolium fragiferum*	300,000	4	28	17	P			NP	MT	WD	C, M, F	0.25	Common
clover, white (Ladino)	*Trifolium repens*	262,000	4	24	14	P			NP	LT	WD	C, M, F	0.25	Common
flax, blue	*Linum perenne*	294,000	3.5	24	8	P			NP	LT	WD	C, M	0.25	Appar
milkvetch, cicer	*Astragalus cicer*	124,000	8	23	14	P			NP	MS	WD	M, F	0.5	Lutana, Monarch, Windsor
phacelia, lacy	*Phacelia tanacetifolia*	245,000	4	22	10	A			NP		WD	C, M, F	0.25	
sainfoin (without pods)	*Onobrychis viciifolia*	30,240	21	14	12	P			NP		WD	C, M	0.75	Eski, Melrose, Remont, Shoshone, Delaney
sainfoin (with pods)	*Onobrychis viciifolia*	18,500	34	14	12	P			NP		WD	C, M	0.75	Eski, Melrose, Remont, Shoshone, Delaney
small burnet	*Sanguisorba minor*	55,000	15	19	14	P			NP	LT	WD	M, F	0.25	Delar
sweetclover, yellow	*Melilotus officinalis*	262,000	4	24	9	All			NP	MS	WD	C, M, F	0.25	Common
sweetclover, white	*Melilotus alba*	258,000	4	24	9	All			NP		WD	C, M, F	0.25	Common
vetch, hairy	*Vicia villosa subsp. villosa*	16,300	27	10	12	All					WD	C, M, F	1.0	
NATVE SHRUBS / SUB-SHRUBS														
rabbitbrush, green	*Chrysothamnus viscidiflorus*	782,000	1	18	6	P			NP		WD	C, M	0.1	Common
rabbitbrush, rubber	*Ericamera nauseosa*	693,000	1	16	6	P			NP		WD	C, M	0.1	Common
sagebrush, big	*Artemisia tridentata*	2,500,000	0.5	29	8	P			NP		WD	C, M, F	0.1	Common
sagewort, cudweed	*Artemisia ludoviciana*	4,500,000	0.25	26	10	P			NP		WD	C, M	0.1	Common
saltbush, four wing (de-winged)	*Atriplex canescens*	44,000	4	4	8	P			F	MT	WD	C, M	0.5	Common
saltbush, four wing (winged)	*Atriplex canescens*	22,000	8	4	8	P			F	MT	WD	C, M	0.5	Common
winterfat (naked)	*Krascheninnikovia lanata*	93,000	3	6	7	P			F	MT	WD	C, M	0.1	Common
winterfat (fluffy)	*Krascheninnikovia lanata*	54,000	6	6	7	P			F	MT	WD	C, M	0.1	Common
yucca	*Yucca glauca*	25,000	8	5	7	P			F		WD	C, M	0.75	Common

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3. Lifecycle: A=Annual, B=Biennial, P=Perennial; Growth form: B=Bunchgrass, S=Sod grass; Season: W=warm season grass, C=cool season grass; Seed Timing: S = Spring Seeding Preferred, F = Fall Seeding Preferred, NP = No Seasonal Seeding Preference.

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5. Proven Selections include cultivars, tested-class, selected-class, and germplasm level plant releases to the commercial market.

6. Minimum between-row spacing of 18 inches.

* Species can dominate a site and become a monoculture.

For information on poisonous plants, see Plant Materials Technical Note MT-124, Plants Poisonous to Livestock in Montana and Wyoming, Considerations for Reducing Production Losses.

For more species specific information, see the species Plant Guides on the USDA Plants Database (https://plants.usda.gov/home).

Example seed mixes for Montana. These mixes can be simplified or adjusted to site-specific needs.
See page 15 for seed mix composition suggestions.

Table 5: Example seed mix containing native and introduced species suitable for western Montana valley and foothill grasslands. Add forbs (e.g., alfalfa) only when herbicide residual is not a concern.

Common name	Full Stand Rate (PLS lbs/ac)	% Mixture	Seeds/ft^2	Total PLS lb/ac for drill seeding
Bluebunch wheatgrass	7	30	6.7	2.1
Slender wheatgrass	7	5	1.1	0.35
Tall wheatgrass	10	10	1.8	1
Sheep fescue	2	15	4.7	0.3
Nevada bluegrass	2	15	7.1	0.3
Thickspike wheatgrass	7	20	4.9	1.4
Alfalfa	5	5	1.3	0.25
				5.7 PLS lb/ac

Table 6: Example seed mix containing native and introduced species suitable for western Montana mountains.

Common name	Full Stand Rate (PLS lbs/ac)	% Mixture	Seeds/ft^2	Total PLS lb/ac for drill seeding
Bluebunch wheatgrass	7	20	4.5	1.4
Slender wheatgrass	7	10	2.2	0.7
Orchardgrass	2.5	15	4	0.4
Mountain brome	10	20	3.7	2
Big bluegrass	2	20	8.1	0.4
Thickspike wheatgrass	7	15	3.7	1.1
				6 PLS lb/ac

Table 7: Example seed mix containing native and introduced species suitable for eastern Montana grasslands. In general, warm season grasses are suitable to only the eastern third of Montana. Add forbs (e.g., alfalfa) only when herbicide residual is not a concern.

Common name	Full Stand Rate (PLS lbs/ac)	% Mixture	Seeds/ft^2	Total PLS lb/ac for drill seeding
Western wheatgrass	10	20	4.3	3
Slender wheatgrass	7	10	2.2	0.7
Pubescent wheatgrass	10	20	3.7	2
Sideoats grama	6	20	5.3	1.2
Sandberg bluegrass	2	20	8.3	0.4
Switchgrass	3	5	1.3	0.15
Alfalfa	5	5	1.3	0.25
				7.7 PLS lb/ac

STEP 2 Worksheet:

Determine Project Goals and Objectives

Set goals and objectives to determine if the revegetation project is working or if management practices should be adapted.

What is the goal of the revegetation project? Goal statements should describe the desired conditions to be developed based on how the land will be used and what the land can support. What do you want to accomplish on the land?

Project Goal Statement: _____

_____

_____

_____

_____

What are some objectives to help meet the goals? Objectives provide a measurable link between goal statements and revegetation actions. Use the acronym "SMART" to help understand how to formulate objectives. Objectives should be:

- Specific – concrete and detailed, with enough information to know when the objective has been met.
- Measurable – numbers and data can determine if objectives have been met.
- Achievable – consider site conditions, economics, accessibility to equipment, future land use, and other constraints to ensure objectives are possible to meet.
- Relevant – helpful in moving the project area closer to meeting the land use goal(s).
- Time-Bound – feasible to achieve within a set time frame.

Objective 1: _____

_____

_____

_____

Objective 2: _____

_____

_____

_____

Objective 3: _____

_____

_____

_____

STEP 4 Worksheet:

Planning a Seeding

When selecting species to use in the revegetation project, choose those most appropriate to the land use goals and the site's environmental conditions, including soil attributes, annual precipitation, temperature, and elevation. Considerations when selecting a species for a seed mix include:

- Species characteristics that meet site goals and objectives
- Species lifecycle (i.e., annual or perennial)
- Species origin (i.e., native or introduced)
- Species growth form (i.e., bunchgrass or sod-forming grass)
- Number of species in a mix

Create the seed mix

Practice making a seed mix here using information and ideas in Step 4: Planning a Seeding. Find species and full stand rates in Table 1.

Species	Recommended Full Stand Rate (PLS lbs/ac)	Desired % of Seed Mix	Calculate the PLS lbs/ac for each species in the mix*

*To calculate the pure live seed per acre needed for each species, use the calculation:
lbs PLS mix per acre = (desired % of seed mix) x (lbs PLS recommended/acre)

Based on the seed mix, what will be the appropriate time of year to seed? _____

STEP 6 Worksheet:

Monitor Establishment using Transects

Monitoring allows one to see if revegetation is on track to meet the management goals. This worksheet describes basic steps for quantitative monitoring using transects.

Below are step-by-step directions for establishing a transect and recording the abundance of seeded species and other vegetation. These directions can be modified to fit individual needs (e.g., using a 25-meter transect instead of a 30-meter transect), but it is important to monitor the same way every time (e.g., don't use a 25-meter transect one time and a 30-meter transect the next time).

1. Establish a permanent transect. The beginning of the transect should be at least 5 m (~16 ft) from the edge of the seeded area, and it should be representative (as similar as possible) to the entire area. Mark the starting location with a permanent location marker. Run a measuring tape 30 m (~98 ft) and mark the end with another permanent location marker. Additional markers are a good idea to facilitate relocation and to sample the same area each time.

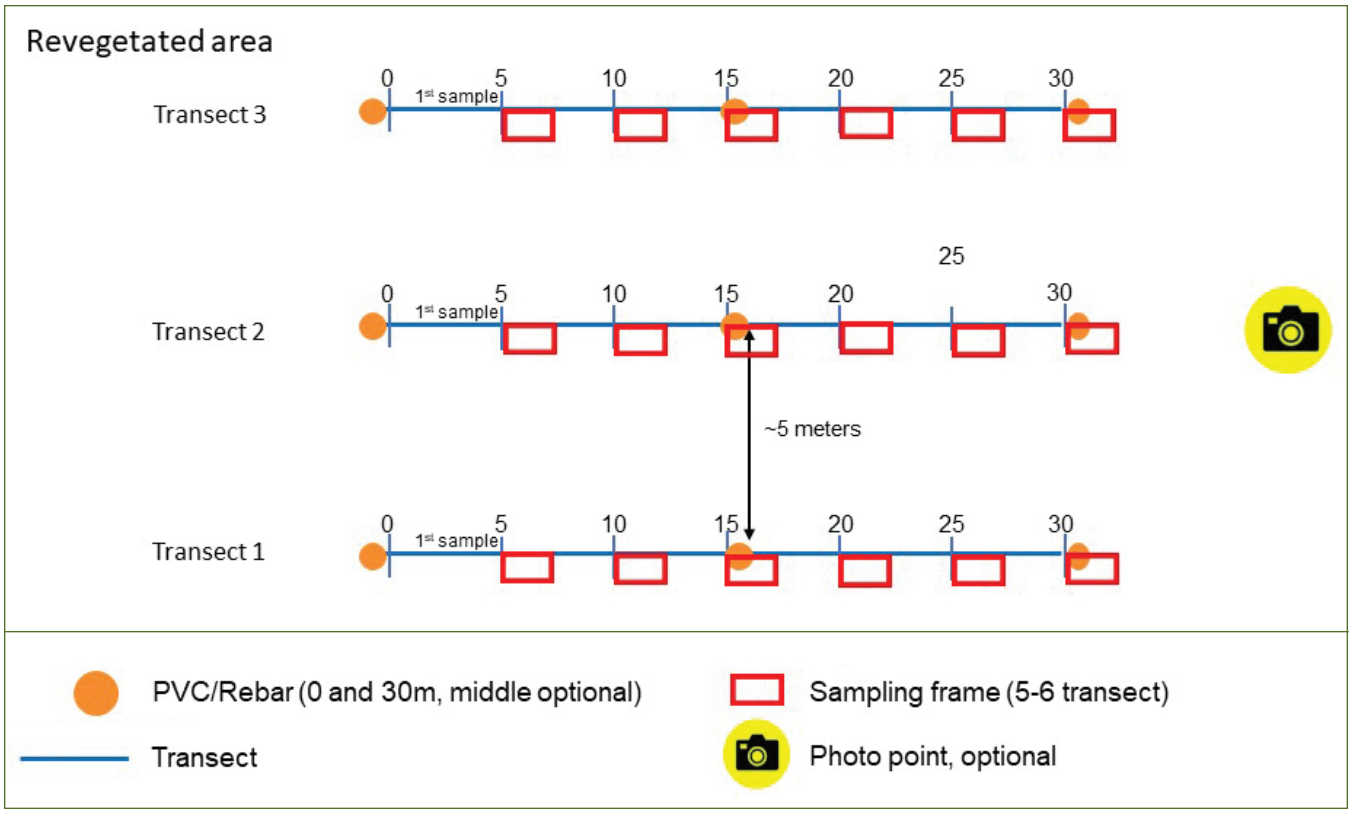
   Permanent markers could include PVC pipe around 33 cm (1ft) in length, driven partially into the ground. Spray paint the markers above ground with bright colors to help in relocation. Another option is to use survey whiskers on six-inch nails (note four-inch nails are too small as they tend to be moved more easily by animals). One can also mark beginning and end with a GPS, but depending on accuracy of the GPS, it may only reach the vicinity of the transect starting location and is not accurate enough to rely solely upon that for relocation.

2. Establish one or two more transects, with at least 5 meters (16 ft) in between transects. If the seeded area is too small to accommodate 5 meters, transects can be closer together or simply use a single transect. Transects should be parallel to each other but can be staggered.

3. Walk along the transect and place the first frame at 5 meters (16 ft). Record vegetation within the frame using the data sheet at the end of this section. Plant abundance can be measured in different ways. For the first year or two after seeding, it is best to count the number of seedlings/young plants of seeded species (i.e., seedling density) and estimate the canopy cover of any other vegetation. As seeded species mature, switch to estimating canopy cover of seeded species and other vegetation.

4. Record vegetation every 5 meters (16 ft) along the transect, aiming for 5 to 6 frames. Recommended frame size is 20 cm x 50 cm (~8" x 20"; inside perimeter). It is OK to use another frame size, but it should remain consistent from year to year. One easy way to build a frame is with PVC pipe and corners.

5. Repeat procedure for any additional transects.



Example of three, 30-meter transects with six sampling frames along each transect (Diagram: Jane Mangold).

Sampling frame laying along transect (Photo: Jane Mangold).

Use the area below to draw a map of transects.

Data Sheet for Monitoring Establishment using Transects

Date: _____ Observer's name: _____

Frame size: _____ Field or site name: _____

Transect #	Frame #	# seedlings	Canopy cover (%) other vegetation	Canopy cover (%) bare ground	Other	Notes
1	1					
1	2					
1	3					
1	4					
1	5					
1	6					
2	1					
2	2					
2	3					
2	4					
2	5					
2	6					
3	1					
3	2					
3	3					
3	4					
3	5					
3	6					
Average						

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