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SUCCESSFUL RESTORATION OF SEVERELY DISTURBED LANDS: NATIVE PLANTS AND ADAPTED SEEDS FOR RECLAMATION

This bulletin provides general information appropriate for all Wyoming ecological sites.

Part of a series by the University of Wyoming Extension Reclamation Issue Team and the Wyoming Reclamation and Restoration Center that describes strategies for restoring ecological functions to disturbed Wyoming lands. For this series, reclamation means restoration of components that support desired ecological functions, such as forage for livestock grazing, wildlife forage and cover, water supply, water quality protection, and aesthetic values.

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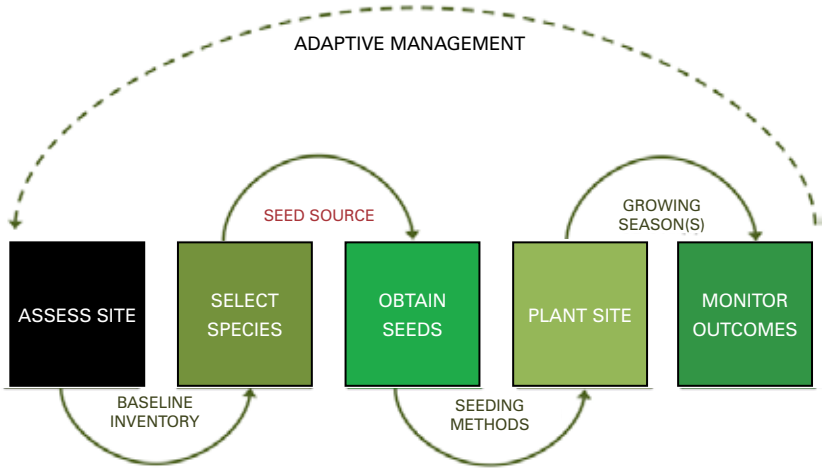
Summary

This bulletin addresses the use of native plants and adapted seed sources in reclamation of severely disturbed lands. Native plants represent key resources for restoration of ecosystem functions and wildland health. Selection of adapted seed sources may improve the short-term establishment of plants as well as the long-term sustainability of plant and animal communities at reclamation sites. Background information and practical guidelines are outlined to assist restoration practitioners and land managers when selecting plant materials for site revegetation.

Determine reclamation objectives

The goal for any reclamation project is to restore the important pre-disturbance ecological functions of a site altered by land use and development, such as mining, wildfire, or overgrazing. Important functions include rangeland forage production, wildlife habitat, and water quality and watershed protection among many others. The successful re-establishment of diverse, native plant communities will contribute significantly to the recovery of these functions.



Steps for the reclamation of native plant species: An initial site assessment will include a baseline inventory of native plants growing in remnants at the reclamation site or in nearby reference areas. Once species are selected for revegetation, seeds must be obtained for planting and their source will be determined at that time. When the seed mix is available, appropriate seeding methods are needed to plant the site, and monitoring over one or more growing seasons will determine the outcome of planting. If initial efforts fail or are incomplete, adaptive management would begin with a reassessment of the site conditions and species suitable for reclamation.

Introduction

Native Plants

Revegetating arid landscapes in the western United States can be challenging. Some risks are inevitable when critical periods for seed germination and seedling establishment depend on unpredictable seasonal snow and rainfall. Despite these limitations, questions arise about the elements of revegetation projects that we can control to improve outcomes.

In the early years of wildland reclamation, non-native plants were often introduced to prevent erosion and stabilize degraded landscapes. Reclamation goals of the period were primarily focused on soil conservation. The same qualities that made those non-native species so useful, however, also resulted in problems. Many introduced plant species, such as saltcedar and Russian olive (*Tamarix ramosissima* and *Elaeagnus angustifolia*), escaped cultivation and are now invasive, resulting in significant costs for their control (Nagler et al. 2011). Other exotic species such as cheatgrass (*Bromus tectorum*) were accidental introductions, but have similar negative consequences. Invasive exotic species outcompete native plants, reduce available habitat for wildlife, and alter the landscape through sheer numbers and increased risks and frequency of wildfire. For example, landscape dominance by cheatgrass alone has increased fire frequency from historical intervals of 50 or more years to intervals as small as 1 to 5 years (Pellant 1996).

In light of concerns about introduced species, state and federal policies for reclamation have shifted to emphasize the benefits of planting **native** (see Glossary) grasses, forbs, and shrubs. Native—or indigenous—species support native pollinators, provide high quality wildlife habitat, contribute to biological diversity and resilience to disturbance, and sustain ecosystem functions (Chapin et al. 2000). These species represent critical resources for the management of healthy forests and rangelands and are preferred plant materials for reclamation. However, not only the species but also the source of seeds may impact reclamation success and revegetation outcomes.

Common Gardens

Plants of the same species may look different when growing in different locations, but their appearance is a function of both the environment in which they grow and genetic variation. Common gardens are used to test for heritable differences among seed sources by planting them together in a common environment. If environmental conditions (rainfall, soils, etc.) are the same, then any observed variation among different seed sources likely represents heritable genetic variation. This heritable variation is useful for the development of seed zones.

Local Adaptation

Common plant species often have a wide geographic distribution. For example, Wyoming's state grass, western wheatgrass (*Pascopyrum smithii*), occurs from Canada to New Mexico over an elevational range from 1,000 to 9,000 feet (Tirmenstein 1999). Populations within a species grow in a variety of climate conditions and are in contact with diverse soil types and plant and animal communities throughout their range. Over time, those populations adapt to the growing season in their local environment including temperatures and rainfall, and are compatible with local soils and other resident species (Linhart and Grant 1996). As a result, populations growing in northern latitudes generally differ from populations of the same species growing in southern latitudes, and similar differences are seen at high and low elevations. This intraspecific (or within species) variation is common and is termed "local adaptation." When individuals diverge to adapt to different environments, those populations represent **ecotypes** within the species.

It is because of adaptation to local growing conditions that the selection of seed sources for planting may affect revegetation success (Knapp and Rice 1994). In Wyoming, plants need to be adapted to cold winters, low levels of precipitation, and nutrient-poor, saline or alkaline soils. Seeds selected from sites that do not have these features may not survive or have decreased vigor in Wyoming's arid landscape.

Seed Zones

Foresters were the first to notice that individuals of the same species, when replanted after harvest, had different fitness (or survival and reproduction) depending on the site of origin of the seeds. If seeds were collected within the same region and elevation in which they were planted, those saplings were more likely to survive not only the average climate conditions for that site, but also the uncommon extremes in factors such as temperature or rainfall. In contrast, if seeds were collected from long distances and/or very different environments, some plantations were wiped out when disease, a rare cold snap, or seasonal drought affected the planting site (Millar and Libby 1989). In response to these discoveries, seeds of most commercial forest tree species are now sourced within established planting or "seed transfer" zones. These seed zones represent regions within which we can expect the seeds to germinate and grow with low risk of mortality (Johnson et al. 2004).

Western wheatgrass population near Glenrock.

Seed zones are developed through field trials to examine the fitness of different seed sources planted in "common gardens" at multiple locations throughout a species range. These trials require a significant commitment of time and resources, and many species are not yet studied. In the absence of experimental data, provisional seed zones can be described using variation in climate, topography, soils, and other landscape features (e.g., Fig. 1, Cunningham 1975). However, seed zones—provisional or otherwise—are generally not yet available for native grasses, forbs, and shrubs. Work is underway to improve our knowledge of the geographic and environmental distances (or the degree of similarity of habitats) that define seed zones for common reclamation species. At the same time, restoration practitioners can improve present-day planning and increase the odds of revegetation success if they are aware of the different native seed sources available for planting and the recommendations for their use.

Seed Source

Many reclamation policies not only support the planting of native species, but also the use of "genetically appropriate and locally adapted" plant materials (Johnson et al. 2010; US Forest Service 2012). This recommendation is a result of considerable evidence of local adaptation among populations of large numbers of native plant species. There are two primary sources of native plant materials for reclamation: local seed collections and cultivated varieties.

Local seed sources represent wild plants and native genetic diversity—including traits such as disease resistance or cold hardiness—that promote the survival of those plants at sites where they grow. There has been considerable discussion about how to define "local" seed sources for reclamation and restoration of degraded lands (McKay et al. 2005; Johnson et al. 2010). Regardless, local seed sources are not genetically uniform, are locally or regionally collected, and originate from environments similar to conditions that existed at the project site prior to disturbance.

The availability of native species for reclamation has not kept up with the demand, particularly in years of high fire activity. As a result of this demand, native plants are often cultivated for seed production, and those cultivated varieties (or **cultivars**) are available for purchase through native seed suppliers. Cultivars of native species are valid resources for reclamation. However, they often have origins at long distances relative to the project site. In addition, cultivation often results in reduced genetic variability through unintentional or intentional selection of traits such as plant vigor during seed production (Burton and Burton 2002).

Cultivation greatly increases the supply of native plant materials for reclamation. Nevertheless, cultivated plants are unlikely to represent native, local genetic diversity,

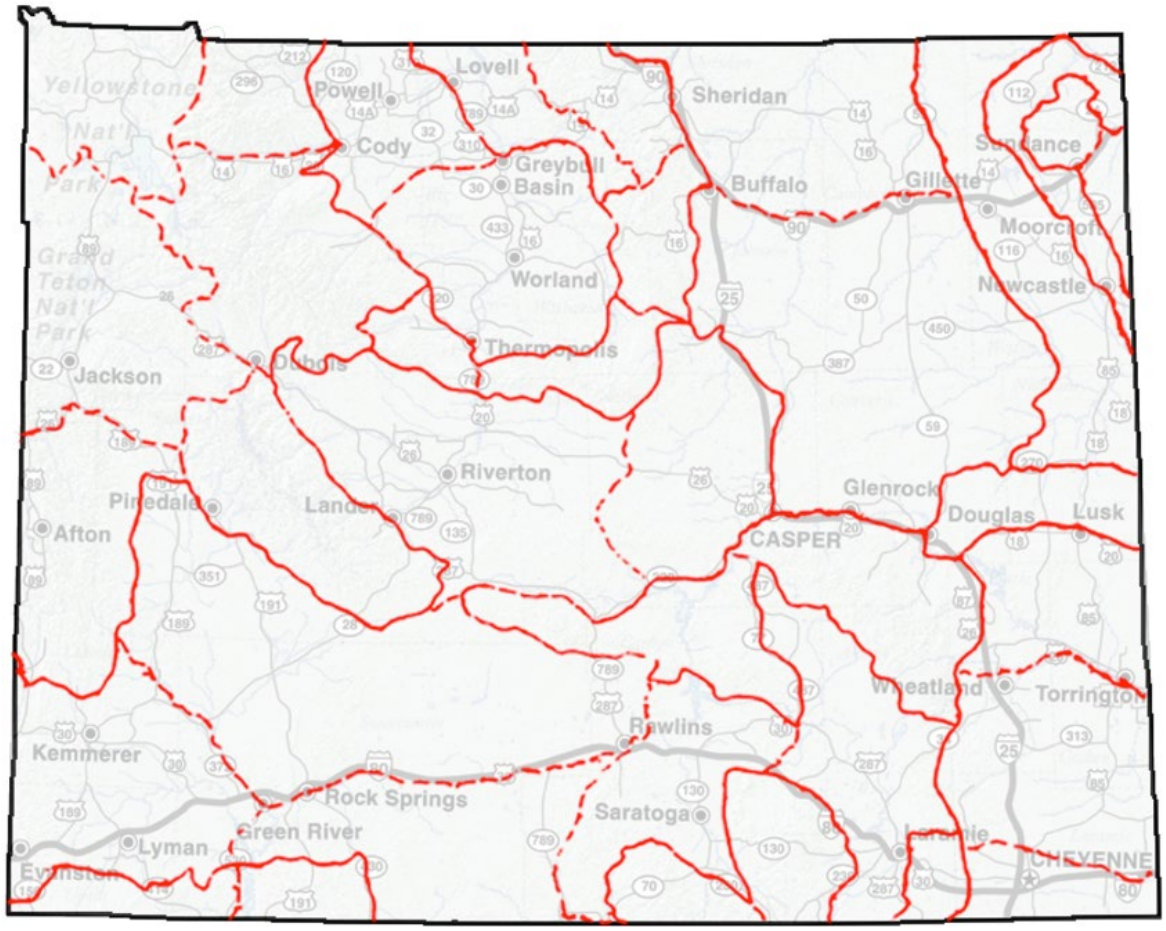


Fig.1. U.S. Forest Service provisional seed zones for the state of Wyoming. Seed zone boundaries are defined by superimposing climate data (dotted lines) on land resource regions (solid lines). Derived from Cunningham (1975).

and their use may have unforeseen consequences (Lesica and Allendorf 1999). If non-local cultivars are not adapted to site conditions, they may not persist in the landscape, and result in reclamation failure. Alternatively, if cultivars represent vigorous plants, they may **swamp** remnant populations of local plants (or local genotypes). The loss of adapted traits as a result of swamping can impact the ability of those populations to persist when environmental extremes such as drought or disease outbreaks occur (Hufford and Mazer 2003). These concerns should be considered in project development, and decision making will benefit from knowledge of the history and site of origin of commercial seed sources prior to purchase.

In summary, native plant species are key resources for reclamation and the choice of seed source is an important consideration in project planning. The use of adapted plant materials may contribute to: 1) short-term planting success, and 2) long-term sustainability of vegetation at the reclamation site. Below, we describe the resources and guidelines available when choosing native plant materials—from species to seeds—for revegetation.

Resources for the Selection of Native Plant Species and Appropriate Seed Sources

Choosing Appropriate Plant Species

There are many resources available to assist reclamation professionals and land managers with the selection of appropriate plant materials for revegetation. The best means to determine which species to plant is to visit both the reclamation site and nearby, undisturbed **reference sites**. If remnant stands of native species are present at the reclamation site, they are indicators of the minimum number of candidate species that might survive and grow when seeded in the disturbed area. At the same time, reference sites will provide a larger inventory of the different native species that may have once occurred at the project site. To develop an adequate sample of suitable species, a site visit should take place on one or more occasions during the growing season and, if possible, for more than one year. If needed, flowering specimens can be collected and pressed at that time so that identification of species may occur at a later date. When selecting reference sites to survey, it is important to match site characteristics such as soils, aspect (the direction faced

by a slope), elevation, and topography. Matching environmental conditions between the reference and reclamation areas will provide some insurance that native species growing at the reference site will also establish at the project site.

In the case of public lands, a list of native species recommended or required for planting may be available through your federal, state, or local regulatory agency office. A survey of the reclamation and reference sites is still recommended in these cases. Species lists derived from generic sources are unlikely to be comprehensive and/or will not anticipate factors in the landscape unique to your project area. In addition, native species noted during site surveys may be suitable substitutes for other species within the recommended seed mix that are either difficult to establish or unavailable for purchase. Knowledge of your reclamation site and species that grow in nearby reference areas will provide the opportunity to discuss these options with regulatory personnel.

If there is no list of recommended native species for planting, local authorities, such as agriculture extension educators and personnel at conservation districts or weed and pest districts, can often assist with selection of native species suitable for your region and the project site. If there is a nearby Natural Resources Conservation Service (NRCS) office, NRCS personnel can also provide information. Be sure to indicate the short- and long-term objectives of the reclamation project as well as the desired outcomes for revegetation.

Lastly, print and online resources are available to assist with identification of native plants that grow in your area. Plant identification guides are useful for site surveys and also provide initial lists of possible grasses, forbs, and shrubs that may be suitable for planting. Two important online resources are:

1. NRCS Ecological Site Information System (https://esis.sc.egov.usda.gov/Default.aspx)

   An ecological site description (ESD) provides information about site-specific soil characteristics, elevation, slope, aspect, landform, precipitation, growing season, and temperature range. These data can be particularly helpful in cases when the reclamation site occurs in an area where the surrounding landscape is so degraded that adequate reference sites are no longer available. To begin, locate the ESD for your area – this requires knowledge of the major land resource area and soil characteristics relevant for your site (see Web Soil Survey, http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm). Once you have the correct ESD, it will list the potential plant species and communities relevant for your location. Additional resources to select the ESD for your site are available through UW Extension (http://www.wyomingextension.org/agpubs/pubs/B1212.pdf).

2. U.S. Department of Agriculture PLANTS Database (http://plants.usda.gov)

   Another option is to create a list of potential species for planting using the USDA PLANTS database. To

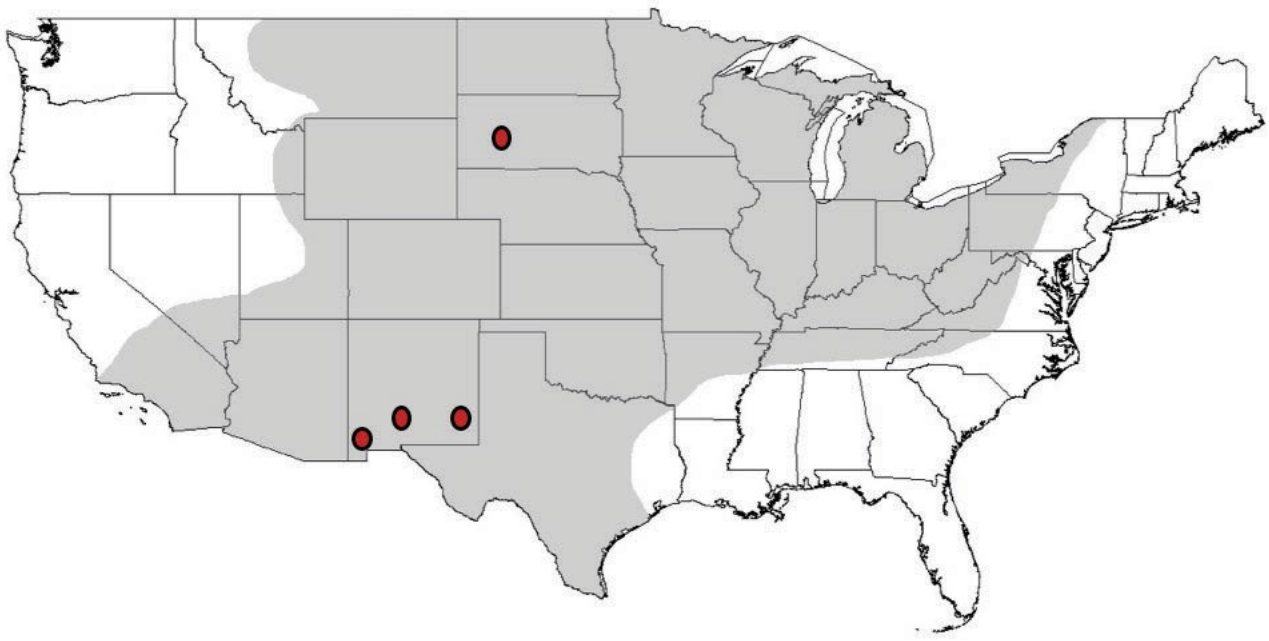


Fig. 2. Of the four available cultivars of blue grama, three were originally derived from sites in New Mexico, and the fourth had origins in South Dakota. It's useful to compare the sites of origin of these cultivars to their recommended planting range (in gray).

do this, choose the "Advanced Search" option and follow the form to indicate your location (1. Distribution) and interest in native species (3. Ecology, Native Status) before submitting the search. Many other options are also available to narrow the list of potential species resulting from your online search. For example, site conditions in Wyoming may require species that are salt-tolerant or drought-adapted. Once the search is completed, you will have a list of species that meet specified requirements. Clicking on the scientific name of any one of those species will open a Plant Profile that includes the species' common name (e.g., "Sandberg bluegrass" for *Poa secunda*) at the top of the page.

Each of these methods will assist with the selection of native plant species suitable for revegetation of your project site. Use of more than one of these options is recommended to provide comprehensive information about the native plant species relevant for reclamation. In all cases, familiarity with the reclamation site and the surrounding area will improve your ability to anticipate the species likely to establish when planted, and to determine the best methods and timeframes for planting (Majerus 2009). Additional resources to assist with planting are available through Wyoming Extension (http://www.wyomingextension.org/publications/Search_Details.asp?pubid=1281).

Selecting an Appropriate Seed Source: Commercial Seeds

Once a species list has been developed for your project, the first step for planting a reclamation site is to acquire the seeds needed for the seed mix (Fig. 3). Commercial suppliers are often the first choice for large projects. If commercial seeds will be purchased, there are several points to consider.

1. Are species of interest available for purchase?

   Many native plant species are not yet commercially available or demand for existing supplies may be high, and this will limit the number of species that are included in the seed mix.

2. What are your choices when selecting commercial seeds for planting?

   Some native seed companies supply wild-collected seeds as well as cultivars. This is particularly common in cases where long-lived species require many years of growth before they reproduce, such as in the case of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*). These species are not economically viable in production fields and instead are sourced from natural populations. If commercial collections are made within the same region or are derived from a similar latitude and elevation as your reclamation site, these seeds may be a good choice for purchase.

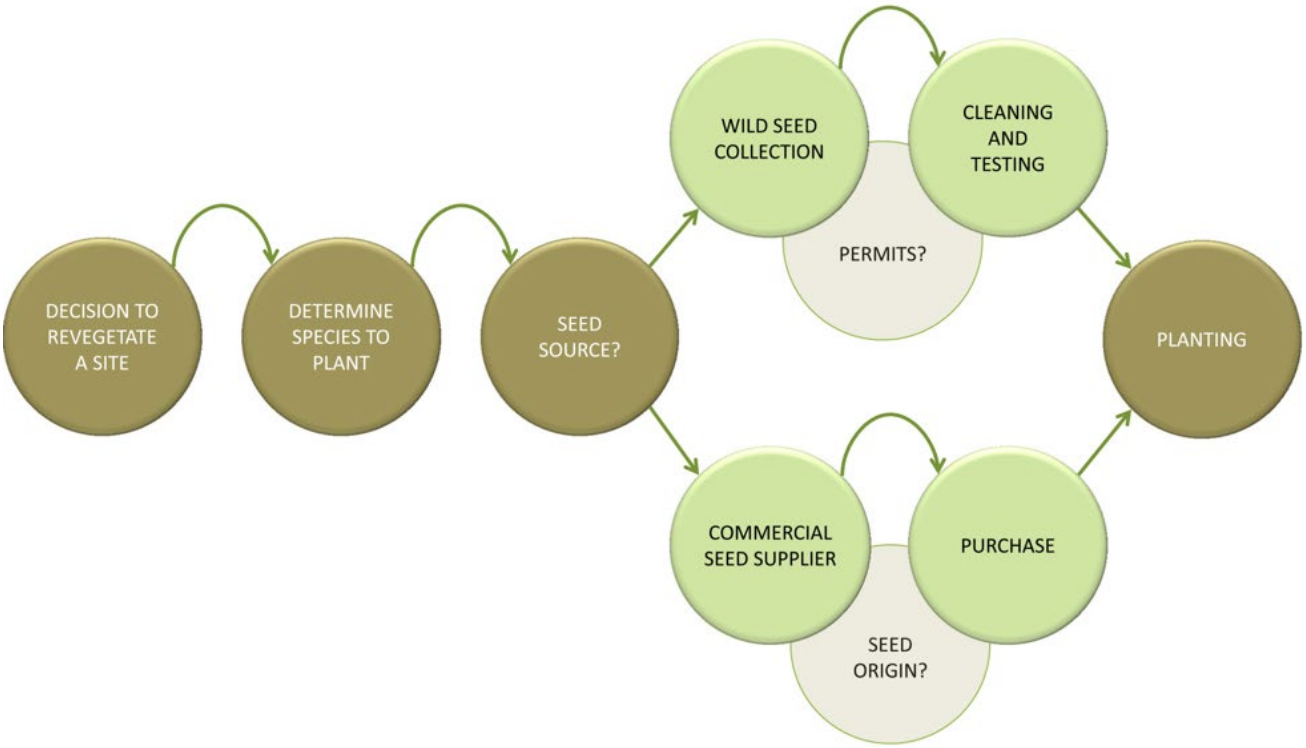


Fig. 3. The decision-making process for selection of native plant species and their seed sources when goals are to revegetate the project site during reclamation.

If available seed sources are cultivars, either the seed company or the NRCS will have data for their sites of origin. In the case of some species, more than one cultivar is available. Learning the background of each cultivated variety will assist selection of a seed source more likely to be suited for your reclamation site. Choices will often be limited, however. For example, of the four available blue grama (*Bouteloua gracilis*) cultivars, three have origins in New Mexico, and one was collected in South Dakota (Fig. 2). If you wanted to plant a site in Wyoming, the choice to minimize geographic distance between the site and the seed source would be the cultivar from South Dakota. However, the highest elevation where those plants originally grew is 2,840 feet (Wyoming's mean elevation is 6,700 feet). As an alternative, the New Mexico cultivars may be a closer match in elevation, but will unquestionably represent non-local genotypes if planted more than 500 miles north in latitude relative to their site of origin. Some risks are unavoidable, but the knowledge of those risks will improve decision making.

3. Do seed suppliers maintain records of seed origin and quality?

   A reputable supplier should be able to provide data for the site of origin and quality (e.g. germination percentage and **pure live seed** pounds per bulk sample) of each species available for sale. This information is required by state law.

Commercial (left) and local (right) winterfat seedlings with origins in New Mexico and Wyoming, respectively.
(note the NM winterfat is known to grow taller than plants with origins in Wyoming)

Selecting an Appropriate Seed Source: Wild Seeds

If reclamation projects are small or habitat quality is a high priority, there is potential for more control of the source of seeds used for revegetation. In these cases, field collections of seeds from wild populations would be desirable. This option also allows the inclusion in seed mixes of species that are not commercially available, improves the diversity of the seed mix and increases the potential for long-lived vegetation establishment at reclamation sites. As in the case of commercial seed sources, there are several points for consideration.

1. Do you have permission to collect seeds?

   If the plants do not grow at the project site, permits are likely required for seed collections. In many cases, permits can be obtained for public lands if you contact the appropriate land management agency. Planning ahead will be necessary to receive permission to make collections during the correct time of year. Private land may also serve as a source of wild seeds if the landowner is contacted and agrees to seed collections.

2. Can you identify the species for collection?

   Your team will need to include personnel who can identify native plant species. Many species are readily identified and located using plant keys and photo guides, but others can be very difficult to find and ID, and require the review of a specialist. It's important to note some plant species are threatened and endangered (or are agency species of concern) and those species should not be included in seed mixes for reclamation. Lastly, you will want to avoid contamination of reclamation seed sources with seeds from noxious or introduced weeds.

3. Are there suitable sites for seed collection?

   It is important to assess collection sites to find the desired species in populations that are large enough (usually a minimum of 100 plants) to support collection without negatively affecting the source populations, either by reducing the total number of seeds for the next generation or by reducing the genetic diversity at that site.

4. Are you aware of sampling protocols?

   Follow guidelines to improve the genetic diversity of your seed collections. Seeds should be collected from multiple plants across the collection site to represent a range of genetic diversity (and also adapted traits) of plants at that site. Genetic diversity of seed samples may be improved by collections of multiple sites near the project site and that represent similar environments.

5. Do you know your site and growing season?

   An understanding of site and seasonal climate conditions is important for successful collections. Collect seeds when ripe but before the seeds fall to the ground or disperse with wind and animals. Many land managers are aware of the appropriate timing for collection and can advise you of the best dates for site visits.

6. Storage conditions and seed quality are key.

   Seeds should be stored in paper or cloth bags in a cool, dry environment prior to cleaning and planting. This will prevent rotting and maintain seed quality. If desired, the Wyoming Seed Testing Laboratory in Powell can determine the germination rate of collected seeds, and those facilities might also clean the collections to remove debris (see http://www.uwyo.edu/seedlab/).

For more information regarding native seed collection protocols, we recommend the National Park Service "Seeds of Success" website (http://www.nps.gov/plants/sos/protocol/index.htm).

While local seed collections represent additional steps for reclamation, they are more likely to be suited to project site conditions and provide an important resource when desired species are not available via commercial production. These collections also support genetic diversity as well as native species diversity. Programs are now in place to improve the availability of native species and genetically appropriate seeds for reclamation (see box pg. 15). While not all native species are available commercially, and it takes time to match seeds to similar geographic locations and environmental conditions, knowledge of the different seed sources available for planting can improve decision making in reclamation. Land managers and reclamation practitioners can accomplish a great deal with a brief review of the site of origin of available seeds.

In all cases, we strongly recommend maintaining detailed records of seed sources and the location where they are planted. Each reclamation program represents an experiment in restoration. If we maintain records of seeding success and corresponding data for seed sources, site conditions, and seasonal variation, the potential exists for improving protocols to increase the establishment of plants at reclamation sites and beat the odds to achieve reclamation success. Within the greater context of weather patterns and soil conditions, native species and adapted seeds represent resources to help you achieve your goals.

Glossary

Cultivar – (Derived from cultivated variety). A named variety selected within a plant species distinguished by any morphological, physiological, cytological, or chemical characteristics. A variety of a plant species produced and maintained by cultivation that is genetically retained through subsequent generations.

Ecological Site Description (ESD) – A compilation of information known about a particular ecological site. ESDs characterize physical attributes that define the site (i.e. soil, elevation, slope, aspect, landform, precipitation pattern and amount, growing season, temperature) and are typically accessed in conjunction with published soil survey data.

Ecotype – A genetically differentiated subpopulation (race) that is restricted or adapted to a specific habitat. Note that: 1) most differences among ecotypes are observed only when different ecotypes are tested in a common environment and 2) ecotypes are generally subdivided into races, e.g. edaphic, climatic (termed cline), or geographic (termed variety).

Genotype – The genetic constitution (or makeup) of an individual organism.

Major land use resource area – MLRAs are geographically associated land resource units usually encompassing thousands of acres. A unit may be one continuous area or several separate nearby areas. MLRAs are characterized by particular patterns of soils, geology, climate, water resources, and land use (Natural Resources Conservation Service).

Native species – A species that is part of the original fauna or flora of the area in question. *Syn. Indigenous.* (compare to *introduced and resident species*)

Pure live seed – Purity and germination of seed expressed in percent; may be calculated by formula: P.L.S.= proportion germination x proportion purity x 100, e.g. (0.91 x 0.96) x 100 = 87.36%. Abbr., PLS or P.L.S. cf. seed purity.

Reference site – An ecosystem that serves as a model for restoring another ecosystem. This implies that: 1) the reference site has more intact, autogenic ecological processes, higher functionality, more complex structure, and greater diversity than the system to be restored, and 2) the biophysical site conditions of the reference site closely match those of the restoration site.

Swamping – In ecological restoration, swamping occurs when local plants are either outnumbered by introduced plants of the same species or cross pollination between introduced and local genotypes alters local genetic variation.

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Acknowledgments

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Programs to address the scarcity of suitable native plant materials for restoration are developing throughout the West. Some of these efforts include:

- **The Uncomphagre Plateau Native Plant Program in Colorado and Utah**
  http://www.upproject.org/up_project/current_nativeplant.htm

  The Uncomphagre Plateau Native Plant Program (UP) has the objective to "develop an adequate supply of a variety of seed species native to the Colorado Plateau for use in restoration activities." Now a partnership with the Bureau of Land Management (BLM) and Division of Wildlife in Colorado and Utah, this program aims to collect and increase native, local plant species for commercial production and sale. At this time, the UP program offers 13 different native species through commercial growers.

- **National Native Plant Material Development Program and Seeds of Success**
  http://www.blm.gov/wo/st/en/prog/more/fish__wildlife_and/plants/1.html

  Seeds of Success (SOS) was established by the BLM in cooperation with the Kew Botanical Gardens in 2000 to improve available plant materials for conservation and restoration. The SOS program has been very active in the West, and teams participate in annual efforts to improve wild seed collection with goals for archiving and increase of native plant materials available for land reclamation and restoration.

- **USDA Natural Resources Conservation Service (NRCS) Plant Materials Program**
  http://www.nrcs.usda.gov/wps/portal/nrcs/main/plantmaterials/about/

  The 27 Plant Materials Centers include nearby facilities in Meeker, Colorado, and Bridger, Montana. These centers "collect, evaluate, select and release plants which are intended for commercial production to solve resource conservation problems." The NRCS is a primary resource for the development of cultivated varieties of native plant species, and protocols have changed in recent years to improve the genetic diversity of selected plant materials.

We encourage you to learn more about each of these programs and how they work to improve the availability of native plants for restoration.

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