Production of Genetically Appropriate Native Grass and Forb Seed at the USDA Forest Service Coeur d'Alene Nursery

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Abstract

The U.S. Department of Agriculture, Forest Service, Coeur d'Alene Nursery is the tree seedling and native plant propagule production facility for the Northern Region of the Forest Service (Region 1). Although conifer seedling production is the nursery's primary focus, requests for native plant and seed production have risen over the last decade, partly in response to national efforts to use site-appropriate species and genetics for revegetation work on public lands. Region 1 botany staff and the Coeur d'Alene Nursery, in conjunction with partners, have worked for the past decade to establish empirical seed transfer zones for commonly used native forbs, shrubs, and grasses. This work is the primary component of the Region's effort to collect, increase, and furnish genetically appropriate native seed to revegetation practitioners. The nursery also provides seed increase services for individual projects and specialty native plant species from multiple ecosystems in the Western United States, with a focus on maintaining genetic integrity. This paper was presented at the Joint Annual Meeting of the Western Forest and Conservation Nursery Association and the Intermountain Container Seedling Growers Association (Coeur d'Alene, ID, October 25–26, 2018).

Region 1 Seed Transfer Zone Development

Wildland Seed Use and Genetics

Historically, the U.S. Department of Agriculture (USDA), Forest Service and other Federal agencies involved in land management have relied heavily on the use of cultivars (cultivated varieties) for grass and forb reseeding work in wildlands (Burton and Burton 2002). These cultivars were developed by Federal, State, or private entities for revegetation efforts or range forage production. Typically, traits such as ease of culture, high seed yield, high biomass yield, and speed of growth and establishment were preferred when developing cultivars. Breeding programs focusing on such characteristics helped create low-cost, high-yield strains of useful revegetation species, but have rarely considered the genetic implications for long-term wildland establishment, adaptation to planting site climate and soil conditions, or impacts on local population genetics (Lesica and Allendorf 1999). These cultivars are often available in large, commercially produced quantities, whereas locally adapted alternatives are typically rare outside of small, wildland collections. Due to this rarity, revegetation practitioners often resort to using cultivars, despite sometimes tremendous geographic and climatic distances between revegetation project areas and the cultivar's genetic origin.

Species Selection and Seed Zone Establishment

Recognizing these challenges, practitioners in the Northern Region of the USDA Forest Service (Region 1) have been working for the past decade to research and develop locally adapted, genetically appropriate seed stores for commonly used shrub, forb, and grass revegetation species. This work involves three major components: (1) collect small volumes of genetically representative native wildland seed from across Forest Service lands in Region 1 for commonly used revegetation species; (2) establish, monitor, and collect data from common gardens grown from that wildland seed to develop area-wide genetic groupings (seed transfer zones); and (3) collect larger volumes of wildland seed

from within each of the newly developed seed transfer zones to use as seed stock for commercial-scale seed production. Using this method, species with previously poorly known or unknown genetic distributions can be mapped, sampled, bulk-produced, and incorporated into revegetation work without many of the genetic and ecological risks inherent to cultivars of the same species (Johnson et al. 2010).

Implementation

Region 1 Forest Service botanists and revegetation practitioners have systematically selected and studied two shrub species, four forb species, and eight grass species. These species were chosen based on the ubiquity of their distribution within the Region, their ability as early seral species to colonize disturbed areas and compete well with weedy invaders, and their ease of cultivation in large-scale seed production facilities. Several species are still in the process of development, but to date, seed transfer zones have been published for 12 native shrubs, grasses, and forbs (such as those shown in figures 1 and 2). Many of the 12 species are now being collected and used for commercial-scale seed production. Three of the grass species, bluebunch wheatgrass (*Psuedoregneria spicata* Pursh), rough bentgrass (*Agrostis scabra* Willd.), and tufted hairgrass (*Deschampsia cespitosa* L.), are currently in production and yielding significant volumes of zone-identified seed (figure 3). That seed is being incorporated into wildland seed mixes throughout Region 1 for revegetation efforts such as post-fire seeding, forest

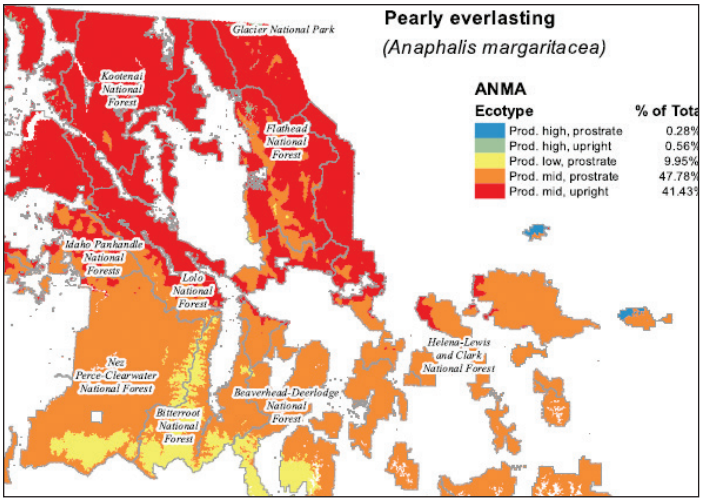

Figure 1. Seed transfer zone map for pearly everlasting (*Anaphilis margaritacea*, ANMA) showing seed zone distribution on USDA Forest Service Region 1 lands (Gibson et al. 2017a)

engineering projects, and wildlife/riparian restoration work. Some of the 12 species, such as pearly everlasting (*Anaphalis margaritacea* L.) and bluejoint reedgrass (*Calamagrostis canadensis* Michx.), are widely distributed across the Region and have high ecological value as native colonizers, but present cultural or seed processing challenges for large-scale seed production facilities (Flessner and Trindle 2003). In the future, some of these species may be bulk-produced by the USDA Forest Service Coeur d'Alene Nursery (CDAN). The primary avenue for Region 1 grass and forb seed production will, however, continue to be via contract growing with private-sector native seed production companies. Ideally, this scenario allows Forest Service revegetation projects to incorporate genetically

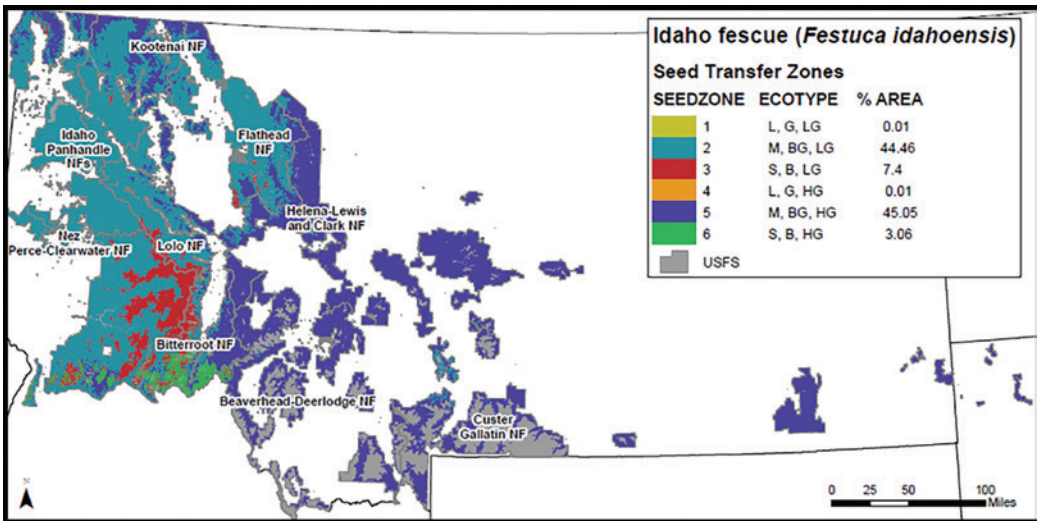

Figure 2. Seed transfer zone map for pearly everlasting (*Festuca idahoensis* Elmer, FEID) showing seed zone distribution on USDA Forest Service Region 1 lands (Gibson et al. 2017b)

Figure 3. Bags of source-identified bluebunch wheatgrass (*Pseudoroegneria spicata Pursh*) generated by a commercial grower for incorporation into Region 1 seed mixes. (Photo by Nathan Robertson, 2019)

appropriate seed in accordance with Federal guidelines, while simultaneously providing business opportunities for private-sector seed producers in lieu of cultivars of the same species.

Native Seed Production at the Coeur d'Alene Nursery

Historic Seed-Increase Production

Seed transfer zones have been used for decades to protect landscape-level genetic distributions in commercially valuable tree species. These zones have guided forest managers in the replanting of millions of acres of public and private forest lands. Adhering to seed transfer guidelines and sourcing genetically appropriate seed for tree species is now a well-accepted best practice, especially on publicly owned forest lands in the Western United States (Johnson et al. 2004). While the avenues for tree seed collection, processing, and storage, as well as orchard seed production, have been well studied, no such body of literature exists for most native grasses, shrubs, and forbs (USDA Forest Service 2012). This is especially true regarding native plant genetics (Bower et al. 2014). The Region 1 seed transfer zone establishment efforts described previously are an attempt to better understand and steward the use of native seed for commonly used revegetation species. The scope, extent, and cost of these studies, however, limits the number of species that can be practically evaluated. Practitioners often recognize that a particular native grass or forb has high value for restoration purposes, such as wildlife or pollinator habitat, rare or threatened status, or a specialized but important ecological niche (figure 4). Without the help of seed transfer zones to guide seed source selection, and a lack of availability of seed for some species, practitioners are left with few options for including such species in revegetation seed mixes. Often the best recourse in such cases is to collect propagules from undisturbed reference sites near the revegetation project area, then enlist a native plant nursery or seed producer to propagate and grow plants from that wildland collection (Hufford and Mealor 2014). Unlike trees, the typically short lifecycles of grasses and forbs allows large-scale harvest of seed from the original plants within a few years. Many private and some publicly owned nurseries and seed-increase facilities offer this service. Theoretically, the resulting seeds will be genetically appropriate to return to the revegetation project area (Shaw et al. 2005).

CDAN has been growing seed-increase plots of wildland-collected grasses, forbs, and shrubs for several decades. Over the last decade, CDAN has maintained an average of 140 different seed-increase plots per year. These plots average yields of more than 800 lbs (360 kg) of grass seed and more than 50 lbs (22 kg) of forb seed per year (figures 5 and 6). The bulk of seed weight yield comes from grass seed increase plots due to the typically larger and heavier nature of grass seed compared with forb seed. Additionally, grasses are often better colonizers of disturbed areas than more specialized native forbs. Forbs, however, represent a much greater diversity of species currently in seed production at CDAN (figure 7). Forbs typically produce smaller, lighter seeds than grasses, with some in excess of 9 million per lb (4.1 million per kg)

Figure 4. Source-identified showy milkweed (*Asclepias speciosa* Torr.), an important pollinator species, in flower at Coeur d'Alene Nursery. (Photo by Jasmine Drapeau, 2018)

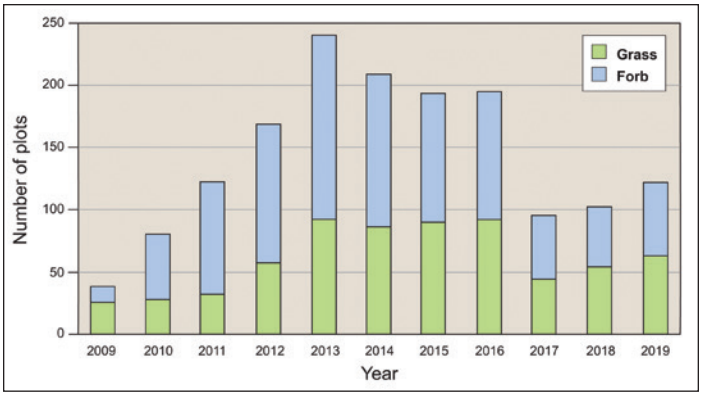

Figure 5. Number of seed increase plots over time at Coeur d'Alene Nursery. Each plot represents a distinct wildland collection of a single grass or forb species.

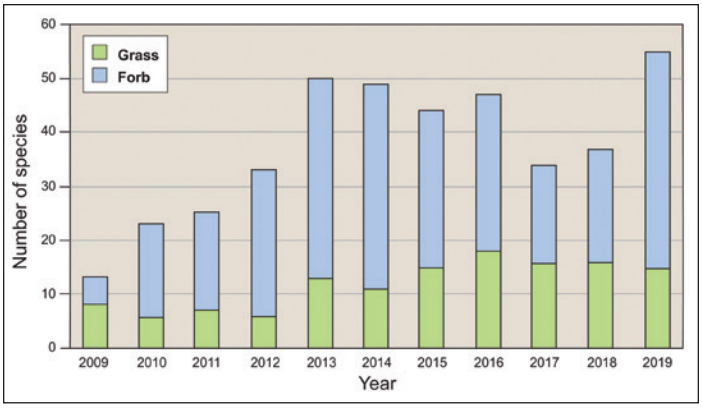

Figure 7. Species diversity in the seed increase program at Coeur d'Alene Nursery. Bars indicate the total number of distinct species in production during a given year.

(i.e., pearly everlasting). Although seed weight may be relatively small, actual seed yields can be impressive. Currently, CDAN has more than 60 forb seed-increase plots in production, an increasing trend over the last 3 years. Given the recent increased emphasis on using genetically appropriate wildland seed in the Forest Service and other public land management agencies, this upward trend is likely to continue, especially in Region 1 because of implementation of the newly developed seed transfer zones for wildland species.

Integration of Region 1 Seed Transfer Zones and Seed Increase

Private-industry seed growers are an invaluable resource for implementing wildland seed transfer zones

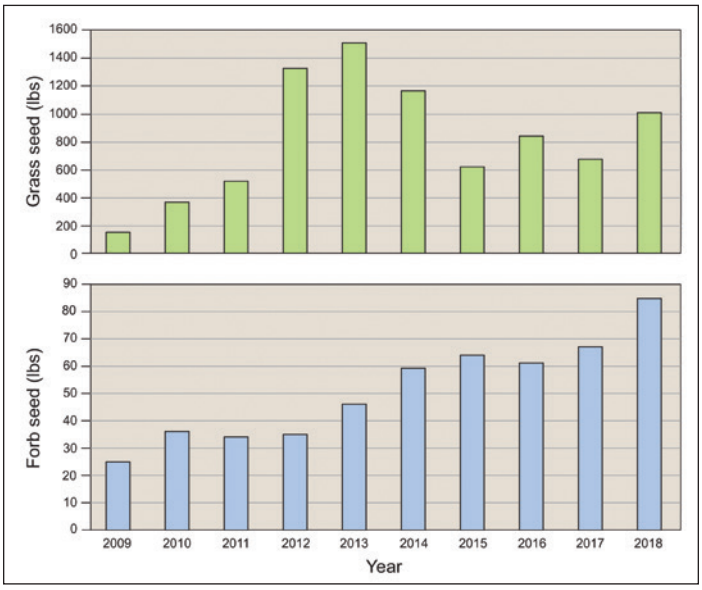

Figure 6. Volume of grass and forb seed production at Coeur d'Alene Nursery over time. Each year's yield represents cleaned seed volumes for all grass or forb species in production that year.

(Shaw et al. 2005). Because of their experience in plant culture and seed production on a commercial scale, these growers will be the primary avenue for zone seed production in Region 1. Contract growing allows for competitive pricing, quality control measures, and a decreased burden on Government agencies to generate seed in-house. Unfortunately, not all wildland seed production efforts are financially desirable for private growers. Some species are too labor-intensive to yield profitable returns, require specialized equipment or practices for establishment and seed harvesting/processing, or are needed on such a small scale as to make commercial seed increase impractical. In instances such as these, Region 1 Forest Service seed-increase efforts are typically undertaken by CDAN. Several of the species with newly established seed transfer zones fall into this category. Forbs such as pearly everlasting and white spirea (*Spirea betulifolia* Pall.), and grasses such as bluejoint reedgrass present challenges to commercial growers due to indeterminate seed ripening and complex seed morphology. Because of these cultural complications, CDAN is conducting bulk production of zone-identified seed for these species. Additionally, CDAN is increasing the smaller zones of other species with seed store requirements typically below the commercial threshold.

Whether produced commercially by private growers or increased at CDAN, native seed for Region 1 is typically housed at CDAN for storage and distribution. The nursery serves as a seed cache, seed mixing facility, and distributor for Region 1 of the Forest Service and some neighboring public land agencies. Through these functions, CDAN can provide custom wildland seed mixes, while maintaining a high level

of quality control with regard to both seed source genetics and seed quality (purity, viability, weed seed contamination) (Vankus 2018). Nursery personnel work with national forest or district botanists and revegetation practitioners to determine which zone-identified seed is appropriate for the project area, and in which concentrations. CDAN then mixes, bags, and distributes the seed to project managers. In cases where zone-identified seed is unavailable, commercially available cultivars are used. When purchasing cultivars, nursery personnel seek out high-quality seed free of noxious weeds, ideally from parent sources that are close in geography and elevation to the project area. Through a combination of these three sources (wildland collected/increased seed, Region 1 seed transfer zone seed, and cultivars when needed), CDAN can provide land managers with quality wildland seed and seed mixes with considerations for both genetics and purity.

Seed-Increase Management Considerations and Challenges

Considerations

Cultural practices for forest seedling nurseries have been, and continue to be, studied extensively. Unfortunately, this information is of limited utility when considering the cultural needs of wildland grasses and forbs. Some grasses and a few forbs have been researched specifically for the purpose of seed production, given those species' utility for revegetation work. Species such as bluebunch wheatgrass, Idaho fescue, and mountain brome have well-established cultural practices (Bartow 2015). These species, however, are exceptions to the general rule of limited cultural information for wildland plants, which complicates seed-increase efforts for CDAN and other native seed production facilities. Fortunately, growth failures or poor performance for seed-increase plots can often be avoided by considering several broad-stroke cultural factors.

Ecotypic groupings of grass and forb species are often found growing together across their ranges, presumably due to similarities in growing conditions associated with climate and temperature (Bower et al. 2014). For example, species growing in shortgrass prairies in eastern Washington contain many of the same species as shortgrass prairies in northern Utah or eastern Montana. Although climatic tolerances (and associated genotypes) may or may not be very different between these communities, as a general rule, these groupings can be strong indicators of general cultural conditions for seed-increase efforts. Because water is typically the major limiting factor for plant community development in the West, CDAN personnel apply supplemental irrigation carefully to mimic ideal growth and reproductive conditions for species in seed-increase plots. When laying out plots, species with similar water needs are grouped together. Species from xeric or dryland ecotypes are grouped and planted in areas of the nursery with higher soil drainage and are irrigated minimally (figure 8). Mesic or riparian species are planted in fields with more moisture-retentive soils and irrigated regularly. In this way, cultural needs at the nursery are scaled out from a single plot to a grouping of ectopically similar species, with the results being increased efficiency and decreased water use.

In addition to ecotypic groupings, it is very culturally advantageous to group seed-increase plots by lifeform. Weed control is a major expense and limitation to seed-increase work (Bartow 2015). Standards of cleanliness for wildland seed used on public land are high, and distributing wildland seed contaminated with weed seed is either illegal or highly undesirable, depending on the species and State. Weed control is a foremost consideration for seed-increase work at CDAN. Most post-emergent herbicides fall into two classes: non-selective (indiscriminately affecting all plants), and selective (affecting either grasses or broadleaf plants, but not both). Although non-selective herbicides are invaluable for weed control in bare-ground areas and around seed-increase plots, they are of little use in controlling weeds in established plots. A tremendous advantage of grouping grass and forb seed-increase plots separately is the ability to safely apply broadleaf-specific herbicides to grass fields, and grass-specific herbicides to forb fields. If grass and forb plots are grown in close proximity, the risk of plant injury from spray drift or other contact is high, as is the complexity of the task for the applicator. Only after selective herbicides have controlled their target weeds are labor-expensive hand-weeding crews used to pull grassy weeds in grass increase plots and broadleaf weeds in forb-increase plots. The ideal scenario for seed increase at CDAN is to plant suites of ecotypically similar grass plots in

Figure 8. Source-identified seed-increase plots in an ecotypic grouping at Coeur d'Alene Nursery, including slender wheatgrass (*Elymus trachychaulus* Link)(center) and sulphur-flower buckwheat *(Eriogonum umbellatum* Torr.) (lower right). Similar cultural requirements allow for cultural efficiency. (Photo by Jasmine Drapeau, USDA Forest Service, 2018)

one field (figure 9) and suites of ecotypically similar forbs in another (figure 10). This management approach helps reduce labor and cost and increase plant growth and yield.

Genetic Considerations

In addition to plant culture, one of the most important considerations for seed-increase work at CDAN is the preservation of source genetics during seed production. Cross-pollination between plots of the same species is a high risk when grown in close proximity (Young et al. 2006). Cross-pollination between plots may result in offspring that lack the genetic fitness to survive and thrive on revegetation project sites, thus eliminating the advantage of the seed-increase effort. Managers at CDAN plan seed-increase plots with this risk in mind, taking care to separate genetically distinct plots of the same species by as much distance as possible. The risk of interspecies hybridization further complicates seed-increase efforts and must be taken into consideration. Several genera of commonly used grasses (i.e., *Elymus* sp. and *Festuca* sp.) and forbs (i.e., *Erigeron* sp. and *Penstemon* sp.) are known to produce interspecies hybrids (Culumber et al. 2013, Wilson and Vanesuela 2002). Growth in close proximity can encourage such hybridization, so increase plots of known hybridizing species are kept separated at CDAN. Before undertaking to grow a new species for seed increase, managers at CDAN research the possibility for hybridization with any currently growing species, and plan accordingly to preserve genetic integrity.

Figure 9. Newly germinated source-identified Sandberg's bluegrass (*Poa secunda* J. Presl.) seed-increase plot at Coeur d'Alene Nursery. Grass species grouped together allow for efficient herbicidal control of broadleaf weeds. (Photo by Nathan Robertson 2018)

Special Challenges

CDAN periodically receives requests for seed increase of species not typically conducive to agricultural conditions or bulk seed harvest. Often the highly valuable ecological role of a species, or its classification as rare or threatened, prompts restoration practitioners to pursue seed-increase efforts regardless of the cultural difficulties. When possible, CDAN undertakes to cultivate such species. Success with these especially challenging species has often depended on research and the amount of information available. Some of the more challenging species encountered are those with indeterminate seed ripening, symbiotic or parasitic needs, and/or very long or short lifecycles.

One of the biggest challenges to seed harvesting on wildland plants occurs when seed does not ripen uniformly. Genera such as *Thermopsis* sp., *Lupinus* sp., and many members of the Asteraceae family

Figure 10. Source-identified seed-increase plots at Coeur d'Alene Nursery, including white sagebrush (*Artemisia ludoviciana* Nutt.)(upper left), silky lupine (*Lupinus sericeus* Pursch.)(center), and Canada goldenrod (*Solidago canadensis* L.)(right). Native forb groupings allow for herbicidal control of grassy weeds in production plots. (Photo by Nathan Robertson 2018)

Figure 11. Source-identified showy fleabane (*Erigeron speciosus* Lindl.) flowers at Coeur d'Alene Nursery. Pappas-borne seeds from such Asteraceous species require specialized seed-collection efforts. (Photo by Nathan Robertson, 2018)

(figure 11) ripen and disperse seed throughout the growing season. Culturists are forced to either destructively harvest (combine) at a single point, thereby losing any further harvest of existing unripe seed, or to non-destructively harvest (hand collect, vacuum, etc.) throughout the season, which is typically extremely labor intensive. Although periodic collection methods can be very effective, the time investment translates to high cost per pound of seed yield. At CDAN, some collection, especially for asteraceous plants with a windborne pappas, is expedited through the use of a leaf blower that has been reversed and used as a motorized vacuum with a collection bag.

Some species present complications with basic plant establishment and growth in a horticultural setting. For example, most of the species in the genus *Lupinus* do not thrive and produce appreciable seed unless favorable conditions exist for root establishment and, possibly, inoculation with a compatible mycorrhizal root fungi occurs (Jones et al. 2018). These conditions and inoculation can occur in a cultural setting, but until they are met, individual plants often languish. On a plot-wide scale, the effect can be very frustrating for seed producers. Other species present similar problems. Plants in the genus *Castilleja* (Indian paintbrushes) are typically hemi-parasitic and depend on the root system of a neighboring grass or forb to thrive (Kaye 2001). For seed-increase efforts, *Castilleja* species cannot be planted as a monoculture, but must be grown in association with a suitable host plant. At CDAN, ideal host plants for *Castilleja* have very different seed sizes, and/or different seed ripening timelines. This difference helps prevent cross-contamination when harvesting *Castilleja* seed pods.

Ideally, a species used for seed increase reaches reproductive maturity quickly (within 1 to 3 years), and yields seed for multiple seasons without needing to be reseeded. Unfortunately, some very desirable species

do not fit this description, and must be managed differently. Annuals, biennials, and very short-lived perennials such as *Agrostis* and *Ipomopsis* species can be excellent colonizers on disturbed areas, but often require a higher cultural investment due to reseeding costs. Conversely, long-lived species can require years of cultural investment prior to producing significant seed yields. At CDAN, clients are frequently informed that timelines and cultural costs for slow-maturing species such as basin wildrye (*Leymus cinera* Scrib. & Merr.) and balsamroots (*Balsamorhiza spp*. Nutt.) may extend 3 to 5 years before seed yield even begins. Each species CDAN undertakes for seed increase is researched extensively to determine lifecycle timelines, expected seed yields, and any special cultural considerations inherent to that particular species.

Conclusions

Reliable access to genetically appropriate, site-adapted native plant seed stores is a challenge for revegetation practitioners working with disturbed public lands in the Western United States. Through the development of empirical seed transfer zones, Region 1 of the Forest Service has made strides to facilitate the development and availability of seed stores for commonly used native plants. Creating these stores is accomplished by both private-sector seed production facilities and the Coeur d'Alene Nursery. Because of these increase efforts, zone-identified native seed is now becoming available for incorporation into native seed mixes across the Region. For species without established seed-transfer guidelines, the Coeur d'Alene Nursery provides services for source-identified seed production, storage, and mixing. The nursery's cultural management approach helps ensure the genetic integrity of seed crops, efficiency of production, and high seed quality. These approaches will help the nursery maintain viable seed production services in response to rising future demands for site-appropriate native seed.

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