Native Plant and Seed Production for High Elevation Restoration: Growing high elevation species in a northern plains desert

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Abstract

Producing high elevation plants under arid, low elevation conditions presents several challenges including heavy textured soils, desiccating winds and open winters. Methods of reducing soil crusting and improving seedling emergence include using vermiculite or rice hulls during seeding, rolling, and light, frequent irrigation with sprinklers during germination and establishment. Snow fence creates additional winter cover to protect seed production fields. Seed harvesting of small-stature and/or indeterminate species is maximized by hand harvesting, *cyclic* stripping or vacuuming, or windrowing, all followed by after-ripening. Summer cuttings are a viable alternative for container production.

Keywords

Bareroot, container, vegetative, cuttings

Introduction

The Plant Materials Center (PMC) at Bridger, Montana has been involved in high elevation restoration for over 25 years, working extensively with Glacier and Yellowstone National Parks. The work involves the restoration of linear disturbances created by highway reconstruction projects within both Parks. Although the total acres disturbed are relatively small, the length of the disturbance can be sig-

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nificant and may impact numerous sensitive habitats, including high elevation sites. Glacier and Yellowstone restoration policy mandates the use of native plants that are indigenous to each respective Park. Since most arable land is found in valley locations, the production of high elevation species often involves growing them under low elevation conditions. Despite the more favorable growing conditions characteristic of low elevation settings, problems arise when field growing alpine and sub-alpine species in a low elevation environment. This paper provides an overview of practical production considerations and techniques when attempting to grow high elevation plants. Small-scale production is emphasized, as well as the challenges that arise when growing high elevation species under low elevation conditions. Many of the techniques described reflect our local growing conditions, scale of production, equipment availability and staffing levels. Growers are encouraged to adjust their production methods to reflect their own situation, and to continuously experiment in order to improve propagation success.

Production Location

The Bridger PMC is located in south-central Montana in the Clark's Fork Valley at an elevation of 3,700 feet (1,100 m) in a 10- to 12-inch (254- to 305-mm) annual precipitation zone. Most precipitation occurs in April through June (-5 in) and September through October (2.5 in) (USDAlNRCS 1998). The site is in close proximity to a broad range of habitat types for adaptation testing, from desertic valley bottoms to alpine sites over 12,000 feet (3,700 m). The location is classified as Major Land Resource Area 32 — Northern Intermountain Desertic Basin (USDA/SCS 1981) and falls in USDA Winter Hardiness Zone 4b (-20 to –25°F [-29 to —32°C]). Temperatures have ranged from 10°F (43°C) to –38°F (-39°C). The area is characterized by frequent and high seasonal winds with an average daily wind velocity of —9 mph (--14 km/h), and the highest average monthly wind velocities occurring in March and October (II to 12 mph [18 to 19 km/h]). The annual relative humidity averages —63 percent. Winters in Bridger are open with little consistent snow cover. The growing season is relatively long (—135 days) with a high number of solar days (USDAlNRCS 1998). The alluvial soils are fertile, deep, and have few rocks. There is a large and consistent supply of inexpensive, high quality irrigation water originating in the Beartooth Mountains. Low annual precipitation and relative humidity result in a low incidence of fungal disease-an important factor in seed production. Limitations include heavy textured soils, desiccating winds, drought, chinook conditions, temperature extremes, open winters, frequent summer thunderstorms, and rarely, hail.

A main production challenge at Bridger is soil texture. The soils in our valley are primarily alluvial deposits containing a high percentage of silt and clay. As a result, the surface of the soil crusts as it dries, impeding seedling emergence, especially of small-seeded grasses and forbs. Planting depth (usually <0.25 in [<0.6 cm]) is critical; and facilitating emergence, while avoiding seedling desiccation, is often difficult. There are several techniques that reduce crusting and improve seedling emergence. Add vermiculite, potting mix or rice hulls to the seed during sowing in order to facilitate seedling emergence. Light rolling of the soil surface prior to germination breaks the crust and aids emergence as well. Use frequent, light sprinkler irrigation, in lieu of flood irrigation, during early establishment to keep delicate seedlings moist and prevent soil crusting. There are factors to consider when using stationary or fixed sprinkler systems including timing of application, water quality, non-target irrigation and soil crusting from the impact of water droplets. Soil crusting is also exacerbated by heavy rain and irrigation. Avoid over-watering and surface pounding by large water droplets-two conditions that contribute to crusting. Use in-line valves to control the frequency and distribution of irrigation water. Sprinklers that distribute water over broad areas have large nozzle openings that produce large drops. Smaller nozzles can be used, but decreasing orifice size results in increased nozzle clogging and decreased coverage. Select a sprinkler head that produces a relatively fine droplet with the operating pressure of the system. It may be necessary to install filters to prevent clogging, and to decrease the spacing of sprinklers in order to obtain thorough coverage. For hand-line, this may mean using shorter sections of pipe or alternating long and short sections to increase overlap. Increasing water pressure will also reduce droplet size. A combination of excelsior blanket (American Excelsior Co., Arlington, TX) and sprinkler irrigation protects bareroot beds from wind desiccation and reduces crusting.

Bareroot Production

There are several advantages to producing and using bareroot seedlings for restoration projects. The cost of production is low, the plants are well acclimated to field conditions, shipping is inexpensive, the size and weight of the seedlings lend themselves well to field planting, and the likelihood of weed contamination is low. On the other hand, bareroot plants require special handling and care that is unnecessary with containerized stock. Timing is critical in the lifting of bareroot plants because the stock must remain dormant until after field planting. In the northern Great Plains, chinook winds can create air temperatures in mid- to late winter that are conducive to premature bud break. If this warm period is followed by a rapid and large decrease in air temperature, plant mortality may occur in the nursery. Bareroot plants may break bud in the nursery in early spring before the soil is fully thawed. Avoid sowing bareroot beds in shaded areas that thaw slower than sunny areas. If necessary, remove mulches in late winter to early spring to allow complete thawing of the soil profile. It may be necessary to lift thawed stock, and to leave those plants frozen in the ground until a later date. At Bridger, all bareroot material is lifted by early to mid-March and then stored in a cooler until delivery. Untimely precipitation can cause lifting delays on slick clay soils. Deer and rabbit browsing of nursery stock in the winter can result in high plant damage, and growers should plan on installing tall (8-foot [2.4-m]), multi-wire, electric fences.

Given an acceptable growing environment, bareroot production depends largely on water quality and quantity, as well as soil type. Since bareroot plants are grown in high densities, frequent irrigation is needed to reduce competition and produce a healthy seedling. In the arid northern plains, access to an inexpensive supply of high quality water will be a critical production factor. Ground water may contain high levels of salt that reduce germination and plant growth, and the cost of filtering and pumping may prove prohibitive. Heavy-textured soils cause seedling emergence problems with some small-seeded woody species, but are generally not significant unless the clay content is quite high. High densities of rocks can impair sowing and lifting operations, and will need to be removed.

Bareroot production works well at Bridger for serviceberry *(Amelanchier alnifolia)*, kinnikinnick *(Arctostaphylos uva-ursi)*, silverberry *(Elaeaguus commutata)*, Oregongrape *(Mahonia repens)*, common chokecherry *(Prunus virginiana)*, Wood's rose *(Rosa woodsii)*, thimbleberry *(Rubus parviflorus)* and common snowberry *(Symphoricarpos albus)*. Site preparation, as it affects seed:soil contact and planting depth, has proven critical with our heavy-textured soils. Nursery beds are rototilled only when soil moisture is ideal. Excessive soil moisture during rototilling produces large clods, whereas dry soils become fluffed and require repeated rolling to firm. After rototilling the site is rolled with a lawn roller or culti-packer to firm the seedbed. Water is added to the roller until the rolled area is firm enough that foot prints leave less than a 0.25-inch (6 mm) depression. If a packer is used, a weighted board or pallet is pulled behind the packer or a tractor to eliminate ridges. We sow species needing just a cold, moist chilling in late fall, whereas we mid-summer sow plants requiring a warm, moist stratification prior to chilling. Our seeding rate depends on seed viability and purity, desired stock size, and anticipated germination percentage. We target production for 6 to 12 seedlings per linear foot (20 to 40 seedlings per meter) of row. Stocking densities greater than this tend to result in undersized, weak plants and an increase in damping-off diseases. Although our seeding rate varies, our rule of thumb is to sow approximately 25 to 50 viable seeds per linear foot (82 to 164 viable seeds per meter) of row. Our sowing depth is about two to three times the diameter of the seed. Three rows of fast growing species or four rows of slower growing species are sown on 12-inch (30-cm) centers within a 4-foot (1.2-m) bed. Five-foot (1.5-m) alleys are left between beds to facilitate weed maintenance. Each bed is covered with 4-foot (1.2-m) wide excelsior blanket to maintain soil moisture, reduce crusting, suppress weeds, and reduce seed loss to birds. Germination occurs the first or second spring after sowing. Two to three growing seasons are generally required, although Wood's rose is sometimes produced in one year. We use hand weeding and spot spraying to control weeds within the beds. At Bridger, the blankets are left in place and disintegrate before harvesting (usually 2 to 3 years). Harvesting is with a tractor-mounted "U" blade prior to bud break in the spring. It requires a 55-hp tractor to pull our 40-inch (102-cm) wide and 18-inch (46-cm) deep blade through our soils. Seedlings are stored at 34 to 37°F (1 to 3°C) and 75 to 90 percent relative humidity until shipping. Excessive moisture on our heavy textured soils has occasionally caused root rot diseases in serviceberry and seedling emergence problems with thimbleberry.

Container Production

Container production from seeds works well for most high elevation species since growing conditions are easily manipulated in a greenhouse environment. We overcome seed dormancy with one of two production techniques. Entire lots of dormant seed may be treated prior to sowing, or dormant seed may be sown and then the containers warm stratified and/or cold chilled to break dormancy. The later technique is used when greenhouse, hoop house and cooler space is plentiful. At Bridger we use standard production techniques, growing most plants in 7- or 10-cubic-inch (115- to 164-cubic-cm) Conetainers™ (Steuwe and Sons, Inc., Corvallis, OR) in a commercial soilless mix for I to 2 years, depending on the species. Plants are started in the greenhouse in February through April and then moved in mid- to late summer to a ventilated hoophouse covered with 50 percent shade. The containers overwinter in the hoophouse until spring when they are either shipped or grown for another season. Grasses and (orbs are sometimes started directly in the hoophouse in mid-March or April and remain there until the following year. Supplemental heat is provided periodically in early spring and winter to prevent freezing. Species that have been difficult to container produce from seeds include dogtooth lily *(Erythronium grandiflorum),* Hitchcock's smooth woodrush *(Luzula glabrata* var. *hitchcockii)* (Wick 2001) and beargrass *(Xerophyllum tenax).* Saprophytic water molds have been identified as the likely cause of seed degradation of beargrass during cold, moist chilling (Grey 2001). Seed treatment with Thiram™ (Gustafson, Inc., Plano, TX) prior to chilling effectively controls this problem. Culture remains difficult, and trials are ongoing to identify the proper growing media, fungicide treatment and environment. The best results to date have been with the use of coarse vermiculite as a propagation medium.

Vegetative propagation may be preferred to sexual propagation when seed is limited, inaccessible, of low viability, has lengthy dormancy breaking periods, or there is a critical or short restoration interval. Good results have been achieved at Bridger with dormant cuttings of mountain alder *(Abuts incana),* redosier dogwood *(Corpus sericea),* plains cottonwood *(Populus deltoides* spp. *monilifera)* and willow *(Salix* sp.). Dormant hardwood cuttings of mountain alder taken in late October in Yellowstone Park rooted very well after a 48-hour soak in water immediately after removal from the donor plants (Scianna 1996). Good success at Yellowstone Park has been achieved with kinnikinnick, narrowleaf cottonwood *(Populus august folia),* black cottonwood *(P. trichocarpa),* russet buffaloberry *(Shepherdia canadensis)* and snowberry (Reid 2001).

Although dormant, hardwood cuttings are easy to handle and store, access to donor plants, winter browsing, seasonal staffing, and reduced winter greenhouse operations may limit their use. Good success has been achieved with several species using summer cuttings. Correct donor plant selection and proper harvesting, transport and storage of these perishable cuttings is critical (Scianna et al. 1998). Vegetative propagation with summer cuttings has worked well at Glacier Park for arctic willow *(Salix arctica),* undergreen willow *(S. commutata),* Drummond's willow *(S. drummondiana),* rock willow *(S. vestita),* as well as broadpetal strawberry *(Fragaria virginiana)* from runners (\Vick 2001). Summer cutting propagation has proved successful at Yellowstone Park with redosier dogwood and snowberry (Reid 2001). Species successfully propagated at Bridger from summer cuttings (>50 percent rooting) include kinnikkinnick, common juniper *(Juniperus communis),* creeping juniper *(Juniperus horiontalis),* Western Labradortea *(Ledum glandulosum),* twinberry honeysuckle *(Lonicera involucrata),* Oregongrape, common chokecherry, Wood's rose, American red raspberry *(Rubus idaeus),* thimbleberry, mountain snowberry *(Symphoricarpos oreophilus)* and common snowberry (USDA/NRCS 1997). An often over-looked option with herbaceous plants is to use summer cuttings for asexual propagation. Although propagation of wildflowers by seeds is generally preferred, there are circumstances when seed production is impractical such as seed scarcity, low viability, long dormancy periods, unknown propagation protocols, or the need for rapid restoration of critical or high visibility sites. Vegetative propagation success has been achieved in small trials with yarrow *(Achillea millefolium),* smooth aster *(Aster laevis),* Pacific aster *(Aster chilensis),* fireweed *(Epilobium augustifolium),* and fuzzytongue penstemon *(Penstemon eriautherus).*

Seed Production

The low cost of production and ease of storage, shipping, transport and planting often favors using seed for high elevation restoration. In most cases the limited quantity and quality of wildland seed warrants production under cultivated conditions. At Bridger, we follow the same standards and production techniques with high elevation species that we use for low elevation plants (Smith and Smith 1997, Holzworth et al. 1990). A firm, granulated, weed-free seedbed is prepared as described in Bareroot Production. We sow 30 to 50 viable seed per linear feet (98 to 164 seed per meter) of row using a two-row drill, and space the rows 36 inches (0.9 m) apart. Our row spacing reflects the design and size of our tractors, cultivators and gated pipe, as well as access for hand weeding and harvesting. Seedling emergence through crusted soils is aided by rolling or sprinkler irrigation as previously described. Heavy sprinkler irrigation during anthesis is avoided at Bridger, although few adverse effects have been noted from untimely rains. This may be due, in part, to apomictic seed production or the presence of included anthers. Flood irrigation can be used after stand establishment to prevent pollen loss during irrigation. When multiple species are to be grown in close proximity, seed increase fields should be designed and zoned so that each species can be isolated during irrigation.

It may be necessary to container produce and then transplant species with poor seedling emergence. This technique is also useful when resource protection is critical, there is a short restoration schedule, or seed is limited. We start 7- to 10-cubic-inch (115 to 164-cubic-cm) Cone-TM in the greenhouse in mid- to late winter and then line them out in the field by hand or with a mechanical transplanter (Mechanical Transplanter Co., Holland, MI) in early summer. This technique is more economically viable if the species is long-lived and likely to produce seed for several years. We have used this technique successfully with smooth aster, slenderbeak sedge *(Carex athrostachya),* Dewey sedge (C. *deweyana),* chamisso sedge (C. *pachystachya)* (Husby and Lesica 2001), tufted hairgrass *(Deschampsia cespitosa),* fuzzytongue penstemon, silverleaf phacelia *(Phacelia hastata)* and alpine bluegrass.

As equally important as timely irrigation is proper weed control. Weeds reduce seed production and contaminate pristine high elevation habitats upon reintroduction. Weed maintenance practices vary with field size, production species, weed species, equipment availability and staffing levels. Small-scale seed production (<0.25 A [<0.1 ha]) is maintained by a combination of hand-rouging and spot spraying. Weed barrier can be used in small seed production fields of high value, prostrate forbs to control weeds and capture shattered seed. In larger production fields we use bromoxynil during the year of establishment to control broadleaf weeds without damaging grass seedlings.

Several 2,4-D products will remove broad-leaved weeds from mature grass fields (2 years or older); however, the control of grassy weeds in grass fields remains difficult. In studies conducted at Bridger, fall-applied metribuzin at 0.36 lb/A (0.4 kg/ha) and oxyfluorfen plus metribuzin at 0.98 plus 0.27 lb/A (1. I plus 0.3 kg/ha) controlled 98 and 95 percent of downy brome Bromus tectorum in perennial grass seed production fields (Whitson et al. 1997). This research led to a 24 C (EPA Special Local Needs Label) permit for use of these products in grass seed production in Montana and Wyoming. If seed germination is delayed and weed competition is high, we use 2 to 4 percent glyphosate to control weeds. It should be noted that relatively few herbicides are specifically labeled for use in grass seed production fields.

Although insect predation has historically been low at Bridger, a new pest emerged in seed production fields in 2001. Timothy billbug *(Sphenophorus zeae)* (Lanier 2001) infestations of alpine bluegrass and alpine timothy *(Phleum alpinum)* seed production fields caused premature ripening of seed heads in both species. Although the infestation did not appear to impact seed production, this species can cause serious seed losses in perennial grass production fields. Premature browning of seed heads in April is the first indication of a problem. Control of this insect is during the active adult stage, and applications of insecticides after infestation will not improve the current season's production.

Alpine plants grown at low elevation tend to mature early in the summer, and seed production and maturation appears more responsive to heat-units than day length. Although harvest occurs in late May or June in Bridger, stands are irrigated and maintained over the remaining growing season to assure seed production the following year. Depending on the weather, culture and species, stands may produce seed crops for one to three years before dying out. Seed harvesting of many high elevation species is labor intensive because of their low stature, indeterminate ripening and tendency to shatter. Many small stature species are hand harvested and allowed to dry and after-ripen on a tarp prior to processing. Indeterminate species can be harvested in several fashions. An estimate of maximum ripe seed can be made and the entire crop direct combined or hand harvested at one time. Another option is to windrow the fields and allow after-ripening for several days prior to combining. A similar technique is to hand-harvest the seed heads or collect them on a tarp fixed to the bottom of a swather, and then allow them to after-ripen on a tarp in a protected location. Cyclic stripping of seed heads by hand or machine is labor intensive, but has proven effective for indeterminate species. We have used a Flail-Vac' (Ag-Renewal, Inc., Weatherford, OK) seed stripper successfully on larger fields of blue wildrye *(Elymus glaucus),* although some shatter occurs at each operation. Smooth aster is also highly indeterminate and we have used swathing, hand clipping and vacuuming to harvest seed. Modification of a tractor-drawn leaf vacuum has proven successful for harvesting fluffy seeded species including Aster (Kujawski et al. 2001), and should prove successful with smooth aster as well.

Local weather patterns also play an important role in the seed production of high elevation species. As an example, limited winter snow cover at Bridger often results in winter desiccation of field grown alpines. We use 4-foot (1.2-m) high snow fence to capture enough snow cover to provide protection against extremes of temperature and desiccating winter winds. The fence is located at 20- to 30-foot (6- to 9-m) intervals and oriented perpendicular to alpine seed production fields in order to increase snow cover. Leaves are also used to mulch exposed areas between rows. High elevation species that lend themselves well to seed production appear in Table I.

One underutilized group of plants for high elevation restoration are the sedges *(Carex* sp.). Seed production of sedges began in 1998 at Bridger as a result of monitoring data from Glacier Park indicating good establishment, survival and persistence of several sedge species on roadside restoration projects. Numerous sedges grow at high altitude and some require less moisture for successful establishment than popularly believed. Sedges are easy to grow in containers, establish well in the nursery and produce abundant, viable seed - depending on

Table 1. High elevation species for seed production.

common yarrow	*Achillea millefolium*
smooth aster	*Aster laevis*
other aster	*Aster* spp.
golden sedge	*Carex aurea*[1]
slenderbeak sedge	*Carex athrostachya*
Dewey sedge	*Carex deweyana*
Hayden's sedge	*Carex haydeniana*[1]
smallwing sedge	*Carex microptera*[1]
black alpine sedge	*Carex nigricans*[1]
chamisso sedge	*Carex pachystachya*
Payson's sedge	*Carex paysonis*[1]
Ross' sedge	*Carex rossii*[1]
tufted hairgrass	*Deschampsia cespitosa*
blue wildrye	*Elymus glaucus*
slender wheatgrass	*Elymus trachycaulus*
alpine willowherb	*Epilobium anagallidifolium*[1]
fireweed	*Epilobium angustifolium*[1]
northern sweetvetch	*Hedysarum boreale*
fuzzytongue penstemon	*Penstemon eriantherus*
silverleaf phacelia	*Phacelia hastata*
alpine timothy	*Phleum alpinum*
alpine bluegrass	*Poa alpina*
slender bluegrass	*Poa gracillima*[1]
arrowleaf groundsel	*Senecio triangularis*[1]
other groundsels	*Senecio* spp.[1]
creeping sibbaldia	*Sibbaldia procumbens*[1]
alpine hairgrass	*Vahlodea atropurpurea*

[1] – Species not produced at Bridger, but production success likely.

the species. Direct seeding of seed production fields may be possible, but has not yet been attempted at Bridger. The plants are long-lived and continue to expand in size each year with what appears to be a commensurate increase in seed production. The PMC has achieved good success with sedges, especially slenderbeak sedge that produced over 350 lb/A (393 kglha) of bulk seed in 2001. Other high elevation sedges worth testing include golden sedge (Carex *aurea),* Hayden's sedge (C. *haydeniana),* smallwing sedge (C. *microptera),* black alpine sedge (C. *nigricans),* Payson's sedge (C. *paysonis),* dunhead sedge (C. *phaeocephala)* and Ross'sedge (C. *rossii).*

Summary

Small niche markets growing native plants for restoration and other end uses are emerging for beginning, as well as established growers. The lessons we have [earned growing native, high elevation species lend themselves well to other restoration and horticultural applications. Producing high elevation species in a low elevation environment poses unique challenges that can be overcome with proper planning and production methodologies. Land managers should anticipate and budget for the increased expense of producing local ecotypes for restoration work.

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