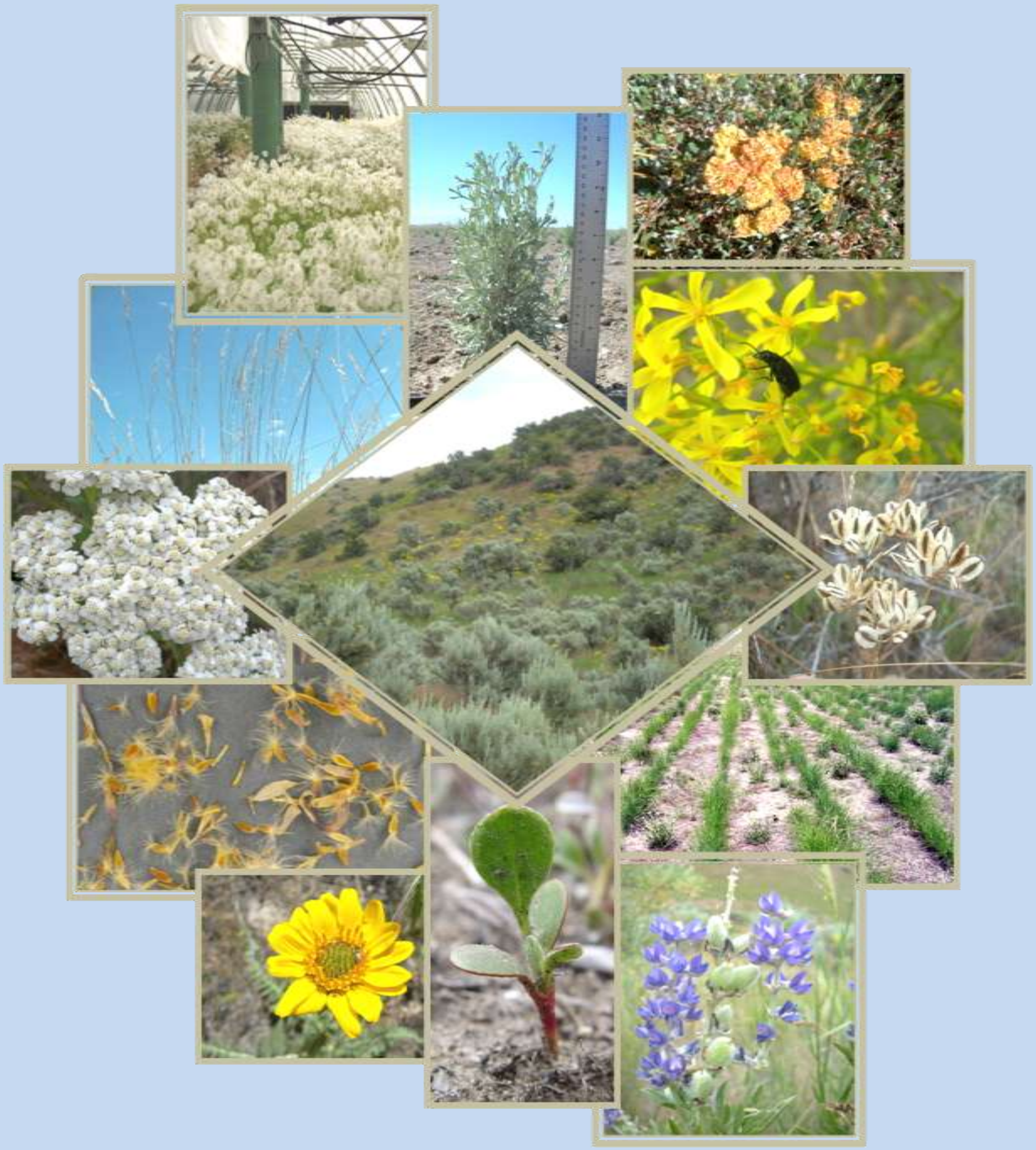
Great Basin Native Plant Selection and Increase Project



FY2010 Progress Report

GREAT BASIN NATIVE PLANT SELECTION AND INCREASE PROJECT

FY2010 PROGRESS REPORT

APRIL 2011

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Great Basin Native Plant Selection and Increase Project

2010 Annual Report

The Interagency native Plant Materials Development Program outlined in the 2002 Report to Congress (USDI and USDA 2002), USDI Bureau of Land Management programs and policies, and the Great Basin Restoration Initiative encourage the use of native species for rangeland rehabilitation and restoration where feasible. This project was initiated to foster the development of native plant materials for use in the Great Basin and to provide information that will be useful to managers when making decisions about selecting appropriate plant materials for seedings. A second major objective is to provide the equipment and techniques required for reestablishing diverse native communities.

Research priorities include: 1) increased understanding of genetic variability in native plant species under consideration for use in revegetation; 2) development of seed transfer zones to provide native plant materials adapted to major bio-geographic areas of the Great Basin; 3) improved availability of native plant seed; 4) development of seed technology and cultural practices required for agricultural seed increase of native forbs and grasses; 5) native pollinator management of native seed production and investigation of post-wildfire pollinator recovery; 6) provision for in situ and ex situ conservation of important populations; 7) management or re-establishment of wildland shrub stands to improve seed availability and conserve native populations; 8) evaluation of the potential for increasing native plant diversity in established crested wheatgrass stands in the Great Basin while minimizing weed invasion; 9) investigation of the biology of native forbs, emphasizing seed germination and seedling establishment; 10) assessment of interactions among restoration species and between restoration species and invasive exotics; 11) evaluation of rangeland drills and strategies for establishing diverse native communities; and 12) science delivery.

We thank our collaborators for their expertise and the in-kind contributions of their agencies that have made it possible to address many of the issues involved in native plant materials development and use. We especially thank Erin Denney and Matt Fisk for their assistance with the GBNPSIP annual meeting and Erin Denney for assisting with editing, formatting and assembling this report.

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http://www.fs.fed.us/rm/boise/research/shrub/greatbasin.shtml
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http://www.blm.gov/id/st/en/prog/gbri.html

NOTE: The results in this report should be considered preliminary in nature and should not be quoted or cited without the written consent of the Principal Investigator for the study.

Highlights from FY2010

GENETICS, COMMON GARDENS AND SEED ZONES

Genetic diversity and genecology of bluebunch wheatgrass (*Pseudoroegneria spicata*)
Brad St. Clair, Richard Johnson and Nancy Shaw

- Bluebunch wheatgrass populations differ substantially for traits of growth, reproduction, leaf morphology, and floral phenology.
- Moderate correlations of population means with the climates of bluebunch wheatgrass seed sources suggest that presence of adaptively significant genetic variation should be considered when moving populations in restoration projects.
- Geographic genetic variation in bluebunch wheatgrass is mapped based on the relationships between traits and climate, and seed zones are delineated that guide the choice of adapted populations for revegetation and restoration of grasslands in the interior Pacific Northwest and Great Basin.

Adapted Indian ricegrass (*Achnatherum hymenoides*) for the Great Basin
Richard Johnson, Mike Cashman and Ken Vance-Borland

- Indian ricegrass accessions representing the southern and eastern Central Basin and Range and Southwestern Tablelands ecoregions were planted in two common gardens in 2007.
- Seed zone maps for restoration of Indian ricegrass in the Great Basin have been developed based on links between genetic variation and climate. These maps allow informed decisions regarding the suitability of genetic resources for restoration in varying Great Basin and Southwestern environments.
- The recommended seed zone boundaries may be modified based on management resources and land manager experience without changing their basic form or links between genetic variation and climate.
- The maps should be considered as tools to guide restoration and management rather than rigid units. The aim is to strike a balance between generating so many seed zones that they would be unwieldy, but enough to promote sound restoration. With rangeland degradation and climate change, the scope for future selective adaption depends on the availability of genetic variation. We recommend utilization of multiple populations of Indian ricegrass within each seed zone to promote biodiveristy needed for sustainable restoration and genetic conservation.

Genetic diversity patterns of tapertip onion (*Allium acuminatum*) in the Great Basin
Richard Johnson, Barbara Hellier and Ken Vance-Borland

- Tapertip onion bulbs were collected from 55 populations throughout eastern Oregon, southern Idaho and northeastern Nevada (20 of the Level IV Omernik Ecoregions across the Great Basin) and planted in common gardens in 2006.
- Seed zones for restoration of tapertip onion in the Great Basin have been developed based on links between genetic variation and climate. The results suggest other herbaceous species to be amenable with similar seed zone mapping.
- Seed zone maps allow informed decisions regarding the suitability of genetic resources for restoration in varying Great Basin environments. The recommended seed zone boundaries may be modified based on management resources and land manager experience without changing their basic form and links between genetic variation and climate.

- We recommend collection of multiple populations of tapertip onion within each seed zone to promote the biodiveristy needed for sustainable restoration and genetic conservation.

Ecological genetics of big sagebrush (*Artemisia tridentata*): Genetic structure and climate based seed zone mapping
Bryce Richardson, Nancy Shaw and Joshua Udall

- Ninety-three seed sources of big sagebrush were collected in 11 western states in fall and winter 2009-2010. Up to 10 families from each of 56 seed sources were outplanted at three common gardens in spring 2010. First-year measurements included height, basal diameter and crown area. Preliminary growth patterns have met expectations. Subspecies *tridentata* yielded the greatest heights and diameters and also exhibited lower allocations of wood development to height compared to ssp. *vaseyana*.
- Transcriptomes were sequenced for all three subspecies. The DNA sequence data has been compiled and annotated with over 21,000 sequences identified with putative function. Out of approximately 1,000 SNPs (single-nucleotide polymorpisms) between ssp. *tridentata* and *vaseyana*, ssp. *wyomingensis* was heterozygous for over one-third. For the remaining SNPs the most, approximately 60%, match ssp. *vaseyana* compared to ssp. *tridentata* at approximately 40%.

Morphological and genetic variation among common Utah globemallows (*Sphaeralcea* spp.)
Heidi Kratsch and Chalita Sriladda

- To clarify taxonomic relationships among the species of globemallow we investigated morphological and genetic variation. Results indicate:
    - *S. coccinea* is a distinct species. The presence of a single flower per node is characteristic.
    - *S. munroana* may be an ecotype of *S. parvifolia*. These taxa can be differentiated from *S. coccinea* by having an almost entire rather than a dissected leaf shape.
    - *S. grossulariifolia* does not appear to be distinct, and may represent inter-specific hybridization among the other three species.
- A Great Basin native plant demonstration garden is planned in collaboration with Washoe County, Nevada pending approval of an MOU between University of Nevada Cooperative Extension and Washoe County Parks and Recreation.

SEED BIOLOGY AND TECHNOLOGY

Characterization of seed germination requirements and post germination seedling development for improved restoration success
Anthony Davis and Olga Kildisheva

- Submergence of *Sphaeralcea munroana* seed in boiling water can be a logistically feasible and effective method for breaking dormancy in large quantities of seed prior to use in restoration.

Development of germination protocols, seed weight, purity and seed conditioning/cleaning protocols for Great Basin grasses and forbs
Robert Karrfalt and Victor Vankus

- Storing Wyoming big sagebrush in sealed, moisture-proof containers gives land managers the potential to bank seed supplies for restoration for at least 4 years.
- Using the principles of equilibrium relative humidity, and measuring it using inexpensive

electronic hygrometers, seed moisture can be managed for maintaining the highest seed viabilities at all stages of seed handling, from harvest to long term storage.

Development of procedures to break dormancy in *Lomatium dissectum* seeds
Marcelo Serpe and Stephen Novak

- To investigate differences in stratification requirements among populations of two varieties of *L. dissectum*, *L. dissectum* var. *dissectum* and *L. dissectum* var. *multifidum*, the degree of genetic diversity and genetic differentiation among eight populations were characterized using enzyme electrophoresis.
- The populations of *L. dissectum* analyzed in this study contained relatively high amounts of genetic diversity. Management efforts should be designed to maintain this level of diversity. A relatively large number of individuals should be sampled from each population to avoid population bottlenecks.
- Genetic diversity in these populations is consistent with what has previously been reported for plants with a mixed mating system. Because high levels of heterozygosity are usually associated with higher fitness levels, management efforts should be designed to protect insect pollinator populations that contribute to outcrossing in this species.

SEED AND SEEDLING ECOLOGY

Modeling seedling root growth of Great Basin species
Bruce Roundy and Kert Young

- An important application of thermal accumulation modeling is to predict which seeded species are most likely to establish given site-specific soil temperature and moisture patterns and interspecies interference. Thermal accumulation models for seedling root growth were developed for forbs, grasses, and cheatgrass (*Bromus tectorum*).
- Cheatgrass roots grew fastest at cool temperatures. Crested wheatgrasses (*Agropyron cristatum*) and Anatone bluebunch wheatgrass grew well enough to compete with cheatgrass.
- Blue flax (*Linum perenne*) requires 700-800 degree days to reach 15 cm root depth, while Anatone bluebunch wheatgrass requires 250-350.

Diversity of mycorrhizal fungi associated with *Artemisia tridentata* ssp. *wyomingensis*
Marcelo Serpe

- Five arbuscular mycorrhizal fungi (AMF) species have been found to colonize Wyoming big sagebrush in southern Idaho based on DNA sequences and phylogenetic analyses. AM fungi help plants to capture nutrients such as phosphorus and micronutrients from the soil. The general goal of the project is to identify species that colonize Wyoming big sagebrush in sagebrush communities of southwestern Idaho.
- The two species *Glomus intraradices* and *G. microaggregatum* are cosmopolitan species found in many commercial inoculums. However, the strains present in sagebrush roots may be different from those in commercial inoculums. Thus, the use of commercial inoculum cannot be recommended without further research.

Developing protocols for maximizing establishment of two Great Basin legume species
Douglas Johnson and Shaun Bushman

- Scarification is essential for Western prairie clover (*Dalea ornata*) seed germination, but it is not as critical for basalt milkvetch (*Astragalus filipes*).
- Deeper depth of seeding may be beneficial for Western prairie clover seeding.

Native plant materials development and cultivation trials for native Great Basin forbs and grasses
Covy Jones and Alison Whittaker

- New common gardens of globemallow species (*Sphaeralcea* spp.) were established in 2009 in Nephi and at the Desert Experimental Range (DER), west of Milford, Utah, for further examination of plant characteristics and seed production.
- Arrowleaf balsamroot (*Balsamorhiza sagittata*) and Hooker's balsamroot (*Balsamorhiza hookeri*) have posed problems primarily because it requires 3-4 years of growth before flowering. To reduce the amount of space required during the first years of growth and the land investment for a grower, we seeded each species in plots with 6-inch row spacings. Dense stand of plants established in spring 2010. In 3 to 4 years, mature plants will be transplanted to a production field setting.
- Seed scarification requirements for lupine (*Lupinus* spp.) and globemallow species to facilitate stand establishment and reduce seed requirements: *L. arbustus* does not require scarification and is easily damaged if scarified. *L. argenteus* and *L. prunophilus* seed germination increase with both chemical and mechanical scarification, while *L. sericeus* seed germination increases with mechanical scarification. Globemallow seed germination is increased by scarifying the seed with a hot water bath.
- The use of N-Sulate fabric appears to be a potential option to help establish native forbs in a wildland setting. This could be used to establish forbs in selected areas or "islands" within a planting site. Additional study will examine whether other row covers may be more cost effective.

Selecting and growing Great Basin natives
Scott Jensen

- Equipment development (collaborative with the Utah Division of Wildlife Resources):
    - Design and fabrication of a hooded row cover for herbicide spraying on high-density nursery beds.
    - Design and fabrication of wheel extenders to permit a compact Kubota tractor to straddle nursery beds.
    - Modification of a fabric roller to roll both 6' and 12' materials.
- Herbarium searches (30 species): Vouchers with precise source location information are logged into a database. This data has proven useful in viewing distributions across provisional seed zones. We anticipate extracting data from various GIS layers to aid in understanding species distribution limitations and making recommendations for revegetation plantings.
- Annual agoseris *(Agoseris heterophylla)*: This annual species responds well to cultivation by producing a robust canopy of flowering stems in response to irrigation and fertilizer. The dramatic increase in seed production places this species among the best candidates from the genus for commercial production.
- Transplanting slow-to-mature forbs: Several often requested species, hawksbeards (*Crepis*

spp.), arrowleaf balsamroot and some biscuitroots (*Lomatium* spp.), require 3 to 5 years to produce the first seed crop. Rootsocks of Gray's biscuitroot (*L. grayi*) and nineleaf biscuitroot (*L. triternatum*) were planted with a tree transplanter to determine if rootstocks could be grown in high-density plots, and then transplanted into seed production fields to reduce the space required during the non-productive years. Survival and seed yield will be tracked in 2011.

- Seeds of Success Interns: Four employees of the Chicago Botanic Garden funded through the 2009 American Recovery and Reinvestment Act made over 400 seed collections from 81 species. This provided a tremendous boost of stock seed for research, inclusion into long-term germplasm storage through the ARS GRIN system, distribution to cooperators, seed increase plantings, and distribution to growers.
- Stock seed production: Stock seed was harvested from plots of seven forb species. In addition, 93 sources of 21 species were planted into seed increase beds.
- The USDA FS Missoula Technology and Development Center selected two project proposals for development in 2011:
  - Development of a specialized seed harvester for species with indeterminate ripening and seed shatter characteristics.
  - Development of a propane fired weed control service pack for thermal weed control in nursery beds and seed production fields.

Cooperative work between the Great Basin Native Plant Selection and Increase Project and the Aberdeen Plant Materials Center

Loren St. John and Dan Ogle

- Seeding trials were planted near Bruneau, ID in cooperation with the USDA FS RMRS and Southfork, NV in cooperation with the University of Nevada Cooperative Extension. Modifications were made to a Truax RoughRider minimum-till drill and a Kemmerer rangeland drill to broadcast and drill seed in alternate rows during the same pass. The Truax RoughRider drill performs well in seeding studies and should be used for large-scale seedings.
- Certified seed stock of Anatone germplasm bluebunch wheatgrass (*Pseudoroegneria spicata*), produced by the PMC is available though the University of Idaho Foundation Seed Program and Utah Crop Improvement Association.
- Sulphur-flower buckwheat, hotrock penstemon, sagebrush penstemon and sharpleaf penstemon can be commercially grown, at least with the use of weed barrier fabric. *Lomatium* species appear to require a number of years (3-4) to mature to reproductive stage under the climatic conditions at Aberdeen, Idaho.

Pollinators and seed predators

Jim Cane

- In burns of even degraded sage-steppe plant communities across the northern Basin and Range province, samples show that bee communities are clearly emerging well within the fire perimeter the spring after the fire. In the weeks following a massive fire, they continued to forage and nest wherever their host plants continue to flower, even miles into the burn where they are clearly resident. Blooms will be needed by resident bee faunas in the year following wildfire, either those belonging to recovering resident species or newly seeded populations.
- Wild *Diadasia* bees, which are specialists and effective pollinators of *Sphaeralcea,* proved to be indiscriminate foragers among mixed arrays of four host species in our common garden.

Seed growers must expect that even specialist bees will hybridize plants along edges of neighboring fields. However, I expect that standard spatial isolation distances will prove satisfactory. Since I have seen these bees colonizing cultivated plantings, they will be useful for pollinating any of the globemallows that growers plant.

- We are able to increase species of cavity-nesting *Osmia* bees that pollinate wild members of the Asteraceae and Fabaceae where they are grown, even on farm.

Tapertip onion (*Allium acuminatum*) seed production: Cultural parameters
Barbara Hellier and Richard Johnson

- As a component of Greater Sage-Grouse and Southern Idaho Ground Squirrel habitat, tapertip onion has been targeted for use in restoration projects. Mechanically planting mature bulbs in an agricultural setting is an efficient planting method for seed and bulb production. Bulbs can be spaced 1 inch apart for maximum seed production but a wider between bulb spacing is needed for maximum diameter (7-15 mm) bulb production. Harvesting as the lower capsules opened resulted in greater seed yields than a later harvesting when the upper capsules opened.

Cultural thinning of native sagebrush stands to increase seed yields
Brad Geary

- There is a crucial need for large volumes of sagebrush seed of higher quality for the use in rehabilitation projects. This study is designed to expand previous research by determining if thinning stands can improve seed yields in established native populations of Wyoming big sagebrush. Two sites in Utah were chosen for this study based on area (50 acres or larger), sagebrush stand uniformity, and sagebrush density. All thinning treatments, mechanical and chemical, were established during the summer of 2010.
- Seed production in 2010 within treatment areas was minimal due to the chemical and mechanical disturbances that occurred from the treatments, therefore data for 2010 is not usable. The first seed collection to determine treatment difference will occur in 2011.

Evaluation of imazapic rates and grass and forb planting times on native forb establishment
Corey Ransom

- Spring and fall herbicide treatments included imazapic at various rates compared to propozycarbazone (Olympus), sulfosulfuron (Outrider), rimsulfuron (Matrix), and sulfometuron (Oust).
- Utah sweetvetch (*Hedysarum boreale*) densities were highest when 0.0625 lb ai/A imazapic was applied in the spring or 0.0313 lb ai/A applied in the fall.
- Bluebunch wheatgrass (*Pseudoroegneria spicata*) established best with spring applied imazapic at 0.0625 lb ai/A.
- A list of grass and forb species and their reported sensitivity to imazapic was prepared. Most information was from the Plateau label. Very little information is available on forbs.

Identification of herbicides for use in native forb seed production
Corey Ransom and Kim Edvarchuk

- Weed control is essential for the commercial production of native forb seed. Herbicide trials were established at two locations, Washington and Utah, to evaluate effective applications for controlling weeds in basalt milkvetch (*Astragalus filipes)*, Western prairie clover (*Dalea ornata*), and Searls' prairie clover (*Dalea searlsiae*). Most of the herbicide applications will be made in spring of 2011 and evaluated through the summer of 2011.

Seed production of Great Basin native forbs—subsurface drip irrigation (SDI) for stable, efficient native forb seed production using small amounts of supplemental irrigation water; weed control; and seeding practices
Clint Shock, Erik Feibert, Lamont Saunders, Cheryl Parris, Nancy Shaw and Ram Sampangi
Irrigation

- Results of a multi-year study provide optimal irrigation amounts for maximum seed yield, years to first seed set and life span for 12 forbs.

Weed Control

- Prowl and Outlook herbicides were found to not harm growth and seed production of some forb species when applied post emergence. These results can support a potential future registration process for these herbicides. In addition, activated charcoal was found to have the potential of allowing the use of soil active herbicides applied pre-emergence. These results can support a potential future registration process for the use of activated charcoal in forb seed production.

Stand Establishment

- Row cover improved emergence for all species except *Penstemon acuminatus*.
- Sawdust did not improve emergence with the probable exception of *Balsamorhiza sagittata*.
- Seed treatment with fungicides reduced emergence of six species. Seed treatment might be beneficial for *Dalea ornata*.
- Sand improved the early emergence of *Penstemon acuminatus* and *Crepis intermedia*.

Etiology, epidemiology and management of diseases of native wildflower seed production
Ram Sampangi, Krishna Mohan, and Clint Shock

- Diseases of economic crops are well known and studied but not the diseases affecting native plants. Plant materials should be prescreened for natural resistance to pests and diseases.
- Several diseases (leaf spots, blights, rusts, and powdery mildews) and several new plant pathogens/diseases were recorded on native forbs.

SEED INCREASE

Stock seed production of native plants for the Great Basin
Stanford Young and Michael Bouck

- Accessions consisting of limited quantities of seed obtained from defined wildland stands, or pooled from defined geographic areas, must be increased in commercial fields or nurseries in order to be available in the marketplace in sufficient quantities to supply reclamation projects of the scope called for in the Great Basin.
- The UCIA Buy-Back project provides a bridge between small-quantity initial accessions and commercial marketplace production. By working with specialized growers who are willing to provide land, time, and expertise to produce increased amounts of stock seed from the former, and with UCIA facilitation, makes it available for the latter.
- This program encourages and allows seed growers to benefit economically in a timely manner as an incentive to participate in the UCIA Stock Seed Buy-back Program. The program helps accelerate the increase in stock seed supplies and ultimately increases seed supplies on the open market for commercial revegetation use.

Coordination of GBNPSIP plant materials development, seed increase and use
Berta Youtie

- Native seed farms growing forbs for the GBNPSIP in the Columbia Basin and Treasure Valley were visited and fields were monitored. Six native seed growers from Oregon, Washington and Idaho were contracted to grow twelve forb species.
- Nevada locations for research collections of Thurber's needlegrass (*Achnatherum thurberianum*) and bottlebrush squirreltail (*Elymus elymoides*) were identified.
- Seed was collected in southern Oregon and northern Nevada for the GBNBSIP, ARS, OSU Malheur Experiment Station, USDA-FS, native seed growers, and the USDI BLM Seeds of Success programs.
- EOSS co-sponsored and helped organize a workshop: Seed production of native grasses and forbs in Ontario, OR. Over 120 participants, mostly from private industry, heard from 14 GBNPSIP collaborators about new restoration species entering the market, genetics and seed zones, seeding rates, stand establishment, irrigation requirements, weed control, pollinators and seed predators, and native seed certification and contracting.

SPECIES INTERACTIONS

The role of native annual forbs in the restoration of invaded rangelands
Tara Forbis, Beth Leger, and Erin Goergen

- In Western rangelands, invasion by the exotic annual grass *Bromus tectorum* is altering fire regimes, community composition, and ecosystem function. Greater restoration success may be achieved with seed mixes that mimic natural succession in Great Basin systems, which includes native annuals as a key component of the post-disturbance community.
- Some native forbs such as *Amsinckia tessellata* and *A. intermedia*, show promise as good competitors against *Bromus tectorum*.
- The presence of certain native annual forbs, such as *Mentzelia veatchiana*, can enhance the establishment and restoration of native perennial grasses, such as *Elymus multisetus,* in *B. tectorum* invaded rangelands.

Evolution of native plants in cheatgrass invaded systems
Beth Leger, Erin Goergen, and Erin Espeland

- Native species and populations differ in their ability to tolerate and compete with *Bromus tectorum.*
- *Poa secunda* (Sandberg bluegrass) was consistently the best suppressor of *B. tectorum* biomass, and one population of *Elymus multisetus* (big squirreltail) was very good at both tolerating and competing with *B. tectorum.*
- Remnant native populations growing in invaded areas may be an important source of genotypes for restoration of invaded communities, but not all remnant populations will harbor more competitive individuals than neighboring uninvaded areas.
- Native populations should be screened for their ability to both tolerate and compete with *B. tectorum*, and restoration material selected based on these two measures of field performance.

Crested Wheatgrass Diversification

Evaluating strategies for increasing plant diversity in crested wheatgrass seedings
Kent McAdoo

- The following strategies are being tested at a site 15 miles southeast of Elko, NV: (1) untreated crested wheatgrass; (2) partially controlled crested wheatgrass; and (3) completely controlled crested wheatgrass. Sub-plots of each crested wheatgrass control treatment were seeded. Seeded native grasses germinated on plots both with and without crested wheatgrass control, but were much taller and more robust in plots where crested wheatgrass was suppressed.

Effect of herbicide application timing on crested wheatgrass control and subsequent native plant reestablishment success
Corey Moffet

- Crested wheatgrass stands in much of the western United States are stable in near monocultures that are resistant to native plant reestablishment. Experiments were initiated in spring 2008 to determine whether herbicide efficacy differs among timing of application and disturbance and establishment of seeded native plants is improved when crested wheatgrass is controlled.
- Irrespective of control treatment, year effects explained most of the variability in crested wheatgrass control and reseeding success.
- Spring disking and herbicide application may be more efficacious in controlling crested wheatgrass when followed by a dry summer.
- With the exception of grasses in 2009, reseeding success was poor.
- Herbicide application had no effect on seeded species density and disking reduced seeded grass density, primarily due to reductions in Sandberg bluegrass and needlegrass density.

Recruitment of native vegetation into crested wheatgrass seedings and the influence of crested wheatgrass on native vegetation
Kirk Davies and Aleta Nafus

- Monitoring of experimental plots with known, even densities of crested wheatgrass and seven native perennial bunchgrasses over a 12-yr period indicated that crested wheatgrass density increased 40-fold while native bunchgrass density remained the same or decreased. The ability of crested wheatgrass to increase, while native bunchgrass densities remained the same or decreased should be considered before co-planting crested wheatgrass and native bunchgrasses.

Restoration Strategies and Equipment

Revegetation Equipment Catalog
Robert Cox

- The Revegetation Equipment Catalog is an online repository of descriptions, photos, and company information for equipment that is used for revegetation efforts in the United States.
- During 2010, the Texas Tech University-hosted site was fully updated, and revised. All links were checked and corrected, if necessary, and the site was converted to a more “modern” format utilizing frames.

GPS datalogger for rangeland drills

Damian Hoffman

- A durable GPS datalogger to provide quality control for monitoring rangeland drill operation and contracts is undergoing testing. The device provides a record of operating time, drill speed, distance traveled, site coverage, elevation changes and avoidance of archaeological sites and other leave areas

Rangeland drill calibration videos

Lisa Outka-Perkins

- The DVD "Calibrating Your Rangeland Drill" describes the history of rangeland drill development, the essential features of rangeland drills, the basic seed and seed testing terminology, the calculation of seeding rates and three methods of drill calibration. It also demonstrates how the output of seed boxes can be adjusted. Proper calibration can improve efficiency of seed use.

Modifications to the minimum-till drill

Jim Truax

- Changes have been made to the telescoping seed delivery tubes and boot casing of the RoughRider minimum-till drill to reduce plugging experienced when the drill is used in snow. Testing will occur in 2011.

Establishment of native forbs following mechanical soil disturbance in Wyoming big sagebrush communities in the Great Basin

Alison Whittaker and Danny Summers

- Establishment of native forbs in Wyoming big sagebrush communities using four different mechanical planting methods at two locations (north and south) in Toole Co., Utah is being evaluated. The treatments include a control, broadcast seeding followed by a Lawson aerator, broadcast seeding followed by a Dixie harrow, broadcast seeding followed by an Ely chain, and a rangeland drill seeding using a Truax Rough Rider minimum-till drill. The seed mix consisted of native forbs.
- The greatest germination success was seen on the north site on the plots treated with the Ely chain, followed by the Dixie harrow and Lawson aerator.
- Differences between treatments were smaller on plots treated in 2009 when precipitation was greater, particularly during the growing period.
- Blue flax (*Linum perenne*), Utah sweetvetch (*Hedysarum boreale*), Utah milkvetch (*Astragalus utahensis*), and silvery lupine (*Lupinus argenteus*) had the highest germination success in the first growing season. Palmer penstemon (*Penstemon palmeri*) and firecracker penstemon (*P. eatonii*) germinated better the second growing season.

Post-fire seeding strategies and native plant materials for the Northern Great Basin

Nancy Shaw, Robert Cox, Matthew Fisk, Erin Denney and Jan Gurr

- Seed collections and distribution: Eighty-one collections were made with the assistance of a Seeds of Success intern employed by the Chicago Botanic Garden. Samples of all 81 collections are being provided to the Western Regional Plant Introduction Station for germplasm conservation. Seed of 11 species was provided to seven growers through the Buy-back program or for seed increase. Stock seed of fernleaf biscuitroot (*Lomatium dissectum*) and Gray's biscuitroot (*Lomatium grayi*) from the Snake River Plain seed zone was provided to the Utah Crop Improvement Association for distribution to growers. Seventy-nine collections were distributed to cooperators and other users.

- Reestablishing diverse native Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis*) communities, a comparison of seeding equipment (rangeland drill and minimum-till drill) and seeding rates: Plots were installed post-fire at two locations near Elko, NV. Results indicated the two drills were similarly effective at establishing grasses through the drill drops. Initial establishment of small-seeded species broadcast by each drill was greater with the minimum-till drill. However, this advantage was lost by the second year, perhaps due to unusually dry conditions.
- Equipment and strategies to enhance the post-wildfire establishment and persistence of Great Basin native plants: The ability of the standard rangeland drill and the minimum-till drill to plant grass, forb, and shrub seeds at different rates and depths are compared. Methods and dates for planting small seeded species are compared and seeding rates for Wyoming big sagebrush examined. A fourth replication of the study was installed near the Mountain Home Air Force Base Training Range. Second year data collected at the Utah site indicated that drill seeded species biomass was similar among all seeded treatments and reduced invasive species (primarily cheatgrass, Russian thistle (*Salsloa kali*) and halogeton (*Halogeton glomeratus*) by more than 80%.

EX SITU GERMPLASM CONSERVATION

Richard Johnson and Mike Cashman

- Cooperation between the National Plant Germplasm System (NPGS), the Western Regional Plant Introduction Station, Pullman, WA, and the BLM involving native seed collection and conservation through the “Seeds of Success” program: Through 2010, a total 1,648 SOS accessions were distributed for research and utilization. The native plant collection in the NPGS also provides a security back-up for native populations that may be lost as a result of climate change and disturbances such as fire and invasive weeds.

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Project Title: Genetic Diversity and Genecology of Bluebunch Wheatgrass (*Pseudoroegneria spicata*)

Project Location: USDA Forest Service Pacific Northwest Research Station, Corvallis, Oregon; USDA-ARS Western Regional Plant Introduction Station (WRPIS), Pullman, Washington; USDA Forest Service Rocky Mountain Research Station, Boise, Idaho

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Project Description:
Bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] Á. Löve) is a cool-season, long-lived, self-incompatible, perennial bunchgrass of semi-arid regions of western North America. It is found in a wide variety of habitats, and is a dominant species of many grasslands of the inland Northwest. The wide distribution across a diverse range of climates suggests that bluebunch wheatgrass is genetically variable, and much of that variation may be adaptive. Nevertheless, many restoration projects using bluebunch wheatgrass rely upon a few cultivars that have proven to be useful over a wide area (although with less experience in the Great Basin). Few studies have been done, however, to evaluate genetic variation in relation to climatic factors across the Great Basin or the greater range of the species in a large set of diverse populations, and to compare the mean and variation of cultivars with that of the species as a whole. Determining the extent to which adaptive genetic variation is related to climatic variation is needed to ensure that the proper germplasm is chosen for revegetation and restoration. Furthermore, comparisons of cultivars with the natural range of variation will address questions of the suitability of cultivars over larger areas.

Objectives

1. Using common gardens, determine the magnitude and patterns of genetic variation among bluebunch wheatgrass populations from a wide range of source environments in the Great Basin, Columbia Plateau, and adjacent areas.
2. Relate genetic variation to environmental variation at collection locations.
3. Compare common cultivars of bluebunch wheatgrass to native sources.
4. Develop seed transfer guidelines.

Progress

In 2005, seed was collected from eight western states including many locations in the Great Basin. In fall 2006, 125 diverse populations, each represented by two families, along with five cultivars, were established in common gardens at Pullman and Central Ferry, WA, and at the USFS Lucky Peak Nursery near Boise, ID. Data was collected for 20 traits of growth, phenology and morphology at each of the three contrasting test sites during years 2007 and 2008. Seed was collected from the common gardens in 2008 and germination tests conducted in 2009 to evaluate population variation in germination. Analyses have been done to evaluate differences among test sites, years, populations, and families within populations, as well as their interactions, and to look at the relationship between population variation and climatic variation at source locations. Maps of genetic variation across the landscape have been produced, and preliminary seed zones have been delineated based on the results.

Preliminary Results

Differences among test sites and between years for traits of growth and phenology were generally large. Plants grown at the warmest and driest site, Central Ferry, were largest, whereas plants grown at the coolest, wettest site, Pullman, were smallest. Reproductive phenology was delayed at the coolest site, Pullman, as indicated by later dates of heading, anthesis, and seed maturation. Plants were larger in 2007 compared to 2008, indicating that plants were better established during the second year. Reproductive phenology was later in 2008. Despite large differences among test sites and between years, correlations of population means between test sites were generally large for the same traits measured at different sites. Correlations of population means between years were also generally large for many traits. Thus, population performance was generally consistent between sites and between years.

Considerable variation was found between populations evaluated at each test site. Many traits showed greater than 30% of the variation of individual plants could be attributed to differences among populations. Variation among families within populations was small.

Principal component analysis was done to simplify the analysis by reducing the considerable number of traits measured at different sites in different years down to a few uncorrelated linear combinations that may be considered as independent traits. The first three principal components (PC) explained 53% of the variation in all traits. The first PC explained 30% of the variation and was related to larger size and more inflorescences. The second PC was related to later phenology. The third PC was related to narrower leaves.

Correlations of populations means with climates at the seed sources were moderate to relatively strong with many correlations greater than 0.30. Larger plants were generally from areas with greater precipitation and warmer temperatures. Plants with later phenology were from cooler, less arid climates. Plants with narrow leaves were from hotter and drier climates. These relationships make sense from an adaptation perspective. Large population differences consistently correlated with environmental variables in ways that make sense suggests adaptively significant genetic variation that should be considered when moving populations in restoration projects.

Regressions between traits, including PCs, and climatic and geographic variables were done and the resulting models were used in GIS to produce maps of genetic variation in adaptive traits. Seed zones were delineated by dividing the first PC into three homogeneous areas, and the second and third PCs into two areas, then overlapping them to indicate areas that were of similar values for the three independent multivariate traits that account for the most of the variation in all traits that were evaluated. The trait maps and seed zones largely reflect differences among Level III ecoregions, but with variation within ecoregions corresponding to temperature, precipitation and aridity.

Future Plans

The project is close to being completed. In the next few months, we will make some final decisions as to the best way to present and classify the suggested seed zones, and complete the manuscript for publication in a peer-reviewed journal.

Publications:

St.Clair, J.B.; Johnson, R.C.; Shaw, N. 2010. Genetic diversity and genecology of Bluebunch wheatgrass (*Pseudoroegnaria spicata*). Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 55-59.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

St.Clair, J.B., R.C. Johnson, and N.L. Shaw. 2010. Seed transfer guidelines for Bluebunch wheatgrass. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2010 January 26-27; Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Management Applications:

This study will help ensure that adapted and appropriate sources of bluebunch wheatgrass will be used for revegetation and restoration in the Great Basin and adjacent areas. Results indicate that sources may be consolidated over fairly broad areas of similar climate, and thus may be shared between districts, forests, and different ownerships. Managers inclined to take less risk may want to restrict long-distance transfers between similar climates in widely-separated ecoregions.

Products:

This study will provide seed zones and seed transfer guidelines for developing adapted plant materials for revegetation and restoration in the Great Basin and adjacent areas, and provide guidelines for conservation of germplasm within the National Plant Germplasm System. Results will be reported in appropriate peer-reviewed journals and disseminated through symposia, field tours, training sessions, or workshops.

Project Title: Adapted Indian Ricegrass for the Great Basin

Project Location: Plant Germplasm Introduction and Research, Western Regional Plant Introduction Station (WRPIS), Pullman, Washington

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Project Description:
Indian ricegrass (*Achnatherum hymenoides* [Roem. & Schult.] Barkworth) is a key species for wildlife habitat, livestock grazing, and soil stabilization in the Great Basin and most of the Western U.S. Current releases of Indian ricegrass are useful but we know of no germplasm derived specifically from and for the Great Basin extending east across the Southwest. Information on how Indian ricegrass germplasm varies across the landscape and which populations may be best adapted is lacking. Considering the importance of Indian ricegrass in the Great Basin, germplasm specifically adapted to Great Basin climatic and environmental factors is critically needed.

Our objectives are:

1. Based on the current collections representing the southern and eastern Great Basin, establish common garden studies and measure numerous plant factors associated with growth and development.
2. Analyze plant traits among Indian ricegrass populations, select traits for multivariate analysis to develop composite plants traits, and link plant traits to climatic variables at source locations.
3. Develop regression models and map seed transfer zones.

Germplasm and Common Gardens

In spring 2007, a diverse set of Indian ricegrass accessions from the USDA germplasm collection was planted in two common gardens at Central Ferry, WA, one under dryland and the other with irrigation at panicle emergence and blooming, forming two growing environments. Each garden was randomized into 5 complete blocks with 600 plants each. This germplasm represented the southern and eastern Central Basin and Range across to the Southwestern Tablelands ecoregions (figs. 1 and 3). Evaluation of key growth and developmental traits was completed in 2007 and 2008 on numerous growth and development traits on each plant (table 1).

The analyses of variance showed that source locations within years differed significantly, indicating genetic variation in all plant traits ($P<0.01$) (table 1). In most cases the environment; that is, the irrigation treatment, did not strongly affect plant morphology or production, but in 2007 it did affect panicle emergence and maturity, and to a lesser extent, blooming (table 1). The irrigated garden had earlier phenology in 2007 ranging from 13 days for panicle emergence, 11 days for blooming, and 12 days for maturity (table 1). In general the irrigation environment x location source interactions were not significant. The exceptions were leaf roll and leaf abundance in 2007, and maturity in 2008 ($P<0.01$). In those cases the interaction was found to be more of magnitude than direction. As a result, the data for irrigated and non-irrigated gardens was averaged for multivariate analysis.

There were substantive differences between years in phenology and production traits. Panicle emergence, seed numbers, dry weight and regrowth were much larger in 2008 than in 2007, the establishment year (table 1). For phenology attributes, plants in 2008 were more than a month more advanced than in 2007.

Canonical Correlation and Composite Plant Traits

The purpose of the multivariate analysis was to obtain a smaller set of composite plants traits that represented a large fraction of the overall variation to facilitate regression modeling and mapping of seed zones (Johnson et al. 2010). Plant traits for the phenology, production, and morphology categories were used with climatic variables (temperature and precipitation) at source locations to obtain sets of phenology, production, and morphology composite traits that correlated with the set of climatic variables (St Clair et al. 2005). For phenology, out of five possible canonical variables, only the first, phenology 1, was significant; for production, only variables 1 and 2 were significant, and for morphology variables 1, 2, and 3 were significant (table 2).

Phenology 1 explained almost half the variation, production 1 and 2 a total of 55% of the variation, and significant morphology traits a total of 54% of the variation (table 2). Correlation of composite plant traits with precipitation were always significant, and temperate correlations were significant for all but production 2 and morphology 2.

As a way to represent all significant plant categories, canonical correlation was completed on the five significant composite plant traits in table 2, defined as extracted traits. For cancorr extracted 1, 44% of the variation was explained, and 22% for cancorr extracted 2.

Table 1. Summary of analyses of variance of plant traits for Indian ricegrass (*Achnatherum hymenoides*) grown in common gardens at Central Ferry WA, 2007 and 2008 (n=106).

Plant trait†	2007 Mean	2007 Env (E)‡	2007 Source (S)	2007 E x S	2008 Mean	2008 Env (E)	2008 Source (S)	2008 E x S
Phenology		------------P-values----------				-------------P-values----------		
Panicle emergence, doy	191.3	0.0087	<.0001	0.8217	148.1	0.7141	<.0001	0.2093
Blooming, doy	179.7	0.0115	<.0001	0.0566	138.8	0.5014	<.0001	0.8715
Maturity, doy	205.1	0.0008	<.0001	0.1285	166.4	0.0014	<.0001	<.0001
Blooming to maturity	25.44	0.6285	0.0073	0.7612	27.60	0.0222	<.0001	0.1886
Production								
Leaf abundance, 1(low) to 9(high)	4.810	0.0370	0.0001	0.0076	3.752	0.0242	<.0001	0.6676
Panicle number per plant	13.19	0.019	<.0001	0.3323	105.8	0.2830	<.0001	0.7563
Seeds per panicle	48.02	0.0963	<.0001	0.4535	43.59	0.2698	<.0001	0.7041
Dry weight, g	22.17	0.0265	<.0001	0.1797	45.96	0.7055	<.0001	0.5229
Crown diameter area, (length x width)/2	25.73	0.0071	<.0001	0.1540	34.33	0.9130	<.0001	0.6350
Regrowth weight, g	3.578	0.5322	<.0001	0.4160	11.054	0.0371	<.0001	0.1501
Morphology								
Habit, 1(prostrate) to 9(upright)	5.541	0.1807	<.0001	0.4093	6.018	0.1771	<.0001	0.7828
Leaf roll, 1(flat) to 9(cylindrical)	4.544	0.0975	<.0001	0.0105	6.854	0.6338	<.0001	0.8734
Leaf texture, 1(coarse) to 9(fine)	5.237	0.0407	<.0001	0.3761	5.635	0.9885	<.0001	0.5725
Leaf width, cm	0.184	0.0557	<.0001	0.5135	0.1551	0.8942	<.0001	0.3380
Leaf length, cm	14.57	0.9388	<.0001	0.8779	13.11	0.4156	<.0001	0.2985
Lf length x Lf width, cm^2	2.832	0.3468	<.0001	0.9163	2.128	0.7312	<.0001	0.5189
Culm length, cm	25.12	0.3058	<.0001	0.1262	27.01	0.8575	<.0001	0.0963
Panicle length, cm	14.90	0.3145	<.0001	0.6343	12.86	0.1564	<.0001	0.2347

† See Table 1 for description of each trait
‡Environments were irrigated and dryland common gardens at Central Ferry, WA

Table 2. Significant (P<0.01) composite plant traits derived from canonical correlation analysis of phenology, production and morphological traits in common gardens.

	Phenology 1	Production1	Production2	Morphology 1	Morphology 2	Morphology 3
Explained variance %	49	35	20	25	18	11
Canonical correlation	0.75	0.78	0.69	0.83	0.79	0.71
F-value	1.51	1.62	1.33	1.66	1.46	1.29
P-value	0.002	<0.001	0.010	<0.001	<0.001	0.004
Correlation, ave. temp.	0.48**	-0.48**	0.21*	0.31**	0.25**	0.22*
Correlation, ave. precip.	-0.33**	0.33**	-0.21*	-0.24*	-0.26**	-0.38**

*,**Correlation with source location climate significant at P<0.05 and 0.01, respectively (n=106).

Those extracted traits were also correlated with temperature and precipitation (fig. 1), but the significance and strength depended on the month. For example, for cancorr extract 1, average monthly temperature was always significantly correlated but tended to be less strongly correlated in the winter than other seasons. Cancorr extract 2 showed a similar pattern with temperature, but correlations were weaker, and not significant (P<0.01) for late fall and winter (fig. 1).

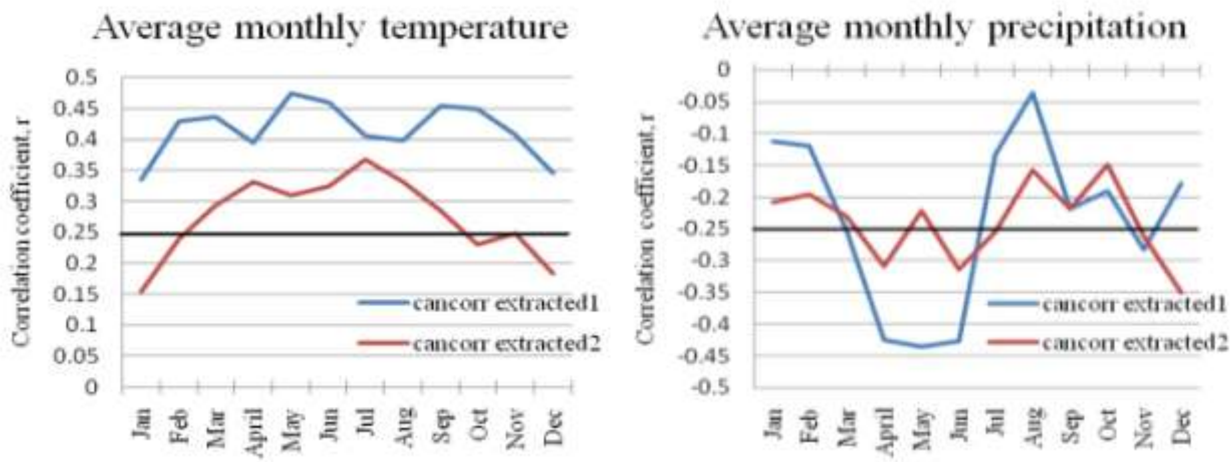

Figure 1. Correlation coefficients between extracted plant traits and monthly temperature and precipitation at seed source locations. The P=0.01 value at ±0.25 is represented by the black bar (n=106).

Precipitation correlations were even more dependent on month with strong, negative correlations for extract 1 during the spring.

Scores for each source location of cancorr extract 1 and 2 were regressed on monthly and annual average precipitation to produce models for mapping seed zones. The resulting regression models were strong; the model for extract 1 explained 72% of the variation and the extract 2 model explained 59%. When mapped over the landscape cancorr extract 1 showed a pattern very similar to temperature and precipitation patterns (fig 2). For example, areas mapped in blue were generally the hot and dry areas corresponding to the Mojave Basin and Range and parts of the Arizona and New Mexico Plateau and the Southwestern Tablelands. The cooler deserts to the north mapped more to the light green to orange hues (fig. 2). The pattern for cancorr extract 2 was not as easy to interpret as cancorr extract 1 as the north-south distinction between the cold and warm deserts was not evident. There was a trend toward the western areas to map more to yellow and orange hues and the central areas to more green to blue hues.

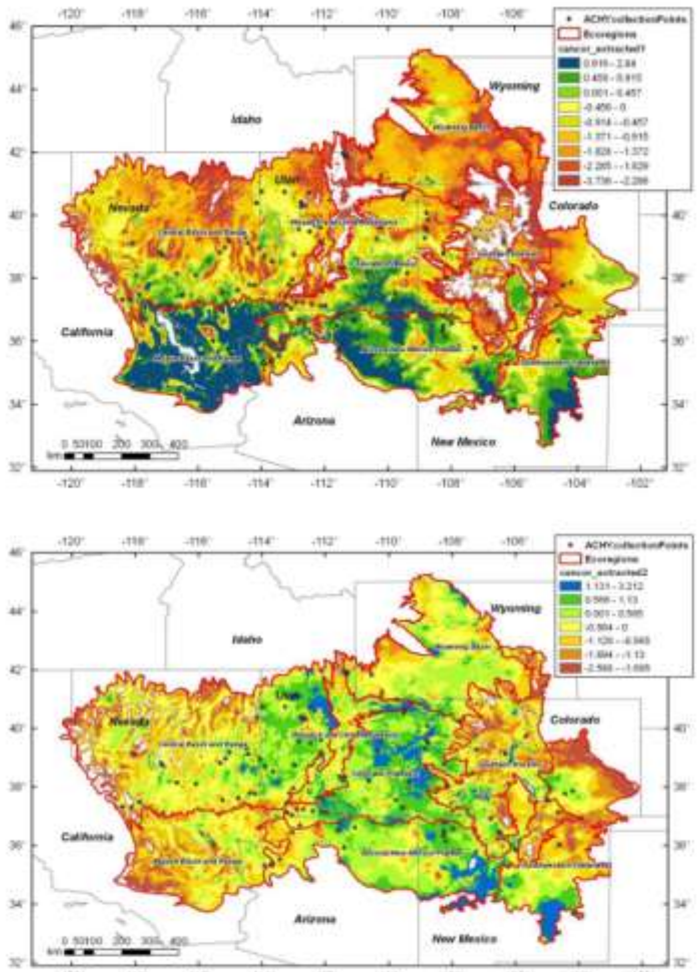

Figure 2. Maps showing the relationship between cancorr extract plant traits and temperature and precipitation variables over level III Omernik ecoregions. The circles show collection locations. Mapping was confined to the range of observed values for plant traits with unmapped areas shown in white. The contours were the ± 2 x P=0.05 confidence interval based on the regression model error.

Cancorr extract 1 and 2 contour intervals were divided into high, mid, and low sections and the two maps overlain to produce nine seed zones (Fig. 3). The separation of seed zones was generally representative of regional temperature and precipitation gradients that distinguished the cooler from warmer deserts. Within the Central Basin and Range four zones represented almost the entire ecoregion (fig 3). The seed zone represented as tan on the map (zone 22, fig. 3) represented 40% of the mapped area.

We recommend that the seed zones in fig. 3 be used to guide seed sources and transfer for Indian ricegrass restoration in the Southwest. However, the maps should be considered as tools to guide restoration and management rather than rigid units. The aim was to strike a balance between generating so many seed zones that they would be unwieldy, but enough to promote sound restoration. Restoration practitioners may consider modifications to our zones based on management considerations and experience. Problems with seed dormancy and seed retention in Indian ricegrass, for example, may limit seed production on a commercial basis of wildland collections (Ogle, 2006). However, within these large seed zones the prospect for variation in seed dormancy or seed retention of populations should be explored.

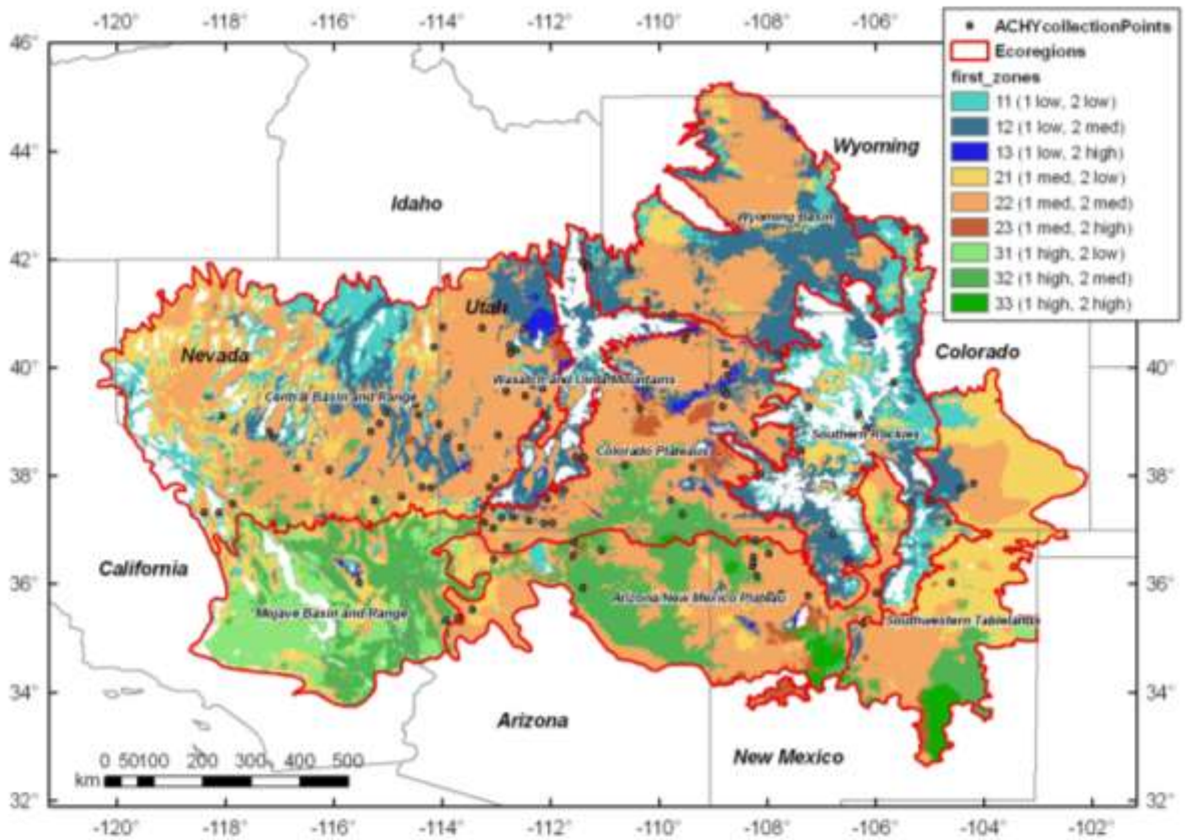

Figure 3. Proposed seed zones for Indian ricegrass over level III Omernik ecoregions based on overlays of cancorr extract 1 and 2 regression models. The circles show collection locations. The range of cancorr scores were divided by thirds into high, middle and low categories and overlain to give nine seed zones. Mapping was confined to the range of observed cancorr scores with unmapped areas shown in white. The contours were the ± 2 x P=0.05 confidence interval based on the regression model error.

Although selected germplasm or cultivars have been widely used (Jones and Young 2005), and may display wide adaptation, potential drawbacks include genetic swamping (Hufford and Mazer 2003, Johnson et al. 2010), outbreeding depression (Kramer and Havens 2009), and hybridization that lead to the loss of co-adapted gene complexes (Montalvo and Ellstrand 2001). With rangeland degradation and climate change, the scope for future selective adaption depends on the availability of genetic variation. To promote the conservation of biodiversity across the landscape, multiple populations should be combined and utilized within seed zones whenever possible.

Publications:

Johnson, R.C.; Cashman, M. 2010. Adapted Indian ricegrass for the Great Basin. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 39-46. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Johnson, R.C.; Hellier, B. 2010. Genetic diversity patterns of *Allium accuminatum* in the Great Basin. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 47-54. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Johnson, R. C.; Hellier, Barbara; Vance-Borland, Ken. Mapping genetic variability with climate for ecological restoration: the case of *Allium acuminatum* in the U.S. Great Basin. Restoration Ecology (submitted).

Presentations:

Johnson, R. C. Creating seed zones for native plants: examples for mountain brome and tapertip onion. Society for Ecological Restoration Pacific Northwest Chapter, 2010 February 18, Tulalip WA. (invited)

Johnson, R. C. Developing seed zones for native forbs and grasses. Workshop on Seed Production of Native Grasses and Forbs, 2010 February 23, Ontario OR. (invited) http://www.fs.fed.us/rm/boise/research/shrub/projects/Ontario2010.html

Johnson, R. C. Workshop: genecology and seed zones for native grasses and forbs. Workshop: genecology and seed zones for native grasses and forbs, National Native Seed Conference, 2010 May 18, Snowbird, UT.

Johnson, R.C.; Hellier, B. Cashman, M. 2010. Seed zones for tapertip onion and indian ricegrass. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Management Applications and Seed Production Guidelines:

- Maps visualizing the interaction of genetic variability and climate for Indian ricegrass allow informed decisions regarding the suitability of genetic resources for restoration in varying Great Basin and Southwestern environments.
- The recommended seed zone boundaries may be modified based on management resources and land manager experience without changing their basic form or links between genetic variation and climate.
- We recommend utilization of multiple populations of Indian ricegrass within each seed zone to promote biodiveristy needed for sustainable restoration and genetic conservation.

Products:

- Seed zones for restoration of Indian ricegrass in the Great Basin have been developed based on links between genetic variation and climate.
- Cooperation between the National Plant Germplasm System (NPGS), the Western Regional Plant Introduction Station, Pullman, WA, and the BLM involving native seed collection and conservation through the "Seeds of Success" program: Through 2010, a total 1,648 SOS accessions were distributed for research and utilization (table 3). The native plant collection in the NPGS also provides a security back-up for native populations that may be lost as a result of climate change and disturbances such as fire and invasive weeds.

Table 3. Seeds of Success (SOS) native germplasm sample distributions from National Plant Germplasm System (NPGS) repositories between 2005-2010.

Year and Repository*	2005 W6	2006 W6	2007 W6	2008 W6	2009 W6	2009 COR	2009 NC7	2010 W6	2010 NC7	Total†
Taxon Distributed	1	21	135	315	321	12	5	339	20	736
Accessions Distributed	1	23	161	438	448	14	5	530	28	1648
Non-U.S. Orders	0	0	7	25	21	1	0	20	7	270
Countries Receiving	1	1	6	18	12	1	1	14	6	26
Cooperator Orders	1	3	51	104	91	1	3	81	21	303
State Affiliated Orders	1	0	17	38	34	0	1	5	34	106
USDA-ARS Orders	0	1	2	5	5	0	0	1	7	16
Other Federal Orders	0	2	3	3	3	0	1	4	3	15
U.S. Non-profit	0	0	1	3	3	0	1	1	2	8
U.S. Individuals	0	0	13	12	10	0	0	7	1	43
Foreign Commercial Orders	0	0	0	6	3	0	0	3	2	12
Foreign Gene Bank Orders	0	0	0	2	2	1	0	0	1	6
Foreign Non-Commercial Orders	0	0	7	16	15	0	0	16	4	55
Foreign Individual Orders	0	0	0	1	1	0	0	1	0	3
Total Orders†	1	3	54	129	114	1	3	95	21	421

*NPGS repositories, W6 (Western Regional Station, Pullman, WA), COR (Clonal Germplasm Repository, Corvallis, OR), NC7 (North Central Regional Station, Ames, IA)
†Some rows do not tally as a single cooperator may have placed multiple orders

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Project Title: Genetic Diversity Patterns of *Allium acuminatum* in the Great Basin

Project Location: Plant Germplasm Introduction and Research, USDA-ARS Western Regional Plant Introduction Station (WRPIS), Pullman, Washington

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Project Description:
Genetic information to identify locally adapted seed sources for restoration and reclamation is generally lacking. An understanding of the geographic and ecological distance that plant material should be transferred from original source populations is critically needed. *Allium acuminatum* Hook. (Tapertip onion) is an important Great Basin forb associated with healthy rangeland and good sage-grouse habitat yet seed transfer zones to enhance restoration in-situ have not been determined. In addition, ex-situ gene bank conservation is being carried out at the Western Regional Plant Introduction Station, Pullman, WA, to provide readily available, source-identified genetic resources for utilization and security back-up for in-situ source locations.

<u>Objectives</u>

1. Collect and maintain native *Allium acuminatum* (Tapertip onion) for use in restoration and reclamation in the Great Basin.
2. Establish common gardens to determine variability in plant traits from the Great Basin
3. Link genetic variation in plant traits of Tapertip onion with environmental variables and develop regression models for seed zones.
4. Map seed zones for use in revegetation and restoration in the Great Basin.

Project Status

Collections. In 2005, Tapertip onion bulbs were collected from 55 populations throughout eastern Oregon, southern Idaho and northeastern Nevada (figs. 1 and 2) as described by Adair et al. (2006). Each team followed the same collection protocol. Forty to 50 bulbs per population were collected from across the given source location. Only populations with 250 or more individuals were collected so in situ population integrity was not compromised. Collections were made from June 17 to July 2, 2005 and covered approximately 620 km (385 mi.) east-west and 445 km (277 mi.) north-south, between N 39° to 44° latitude and W 114° to 119° longitude. Tapertip onion was collected in 20 of the Level IV Omernik Ecoregions across the Great Basin.

Common Gardens. Bulbs were planted in the greenhouse and vernalized at 4°C. Plants were transplanted to the field in the spring of 2006. Common gardens were established at Pullman, WA (780 m elevation; 46° 43' 28.05" N and 117 08' 07.94" W) and Central Ferry, WA (206 m elevation; 46° 41' 52.78" N and 117° 39' 52.55" W). Four plants from each of the 55 collection sites were randomized in five complete blocks at both locations. Thus there were 1,100 plants established at each site. The plant traits measured were categorized into morphology, phenology, and production traits, and all had significant source location effects (table 1). Most plant traits responded consistently over garden sites as shown by the absence of a significant site x location interaction in most cases (P<0.01). As a result, trait means were averaged over the common garden sites in most cases.

Table 1. Summary of source location (Loc) effects from analyses of variance of plant traits from 53 Tapertip onion collections measured in common garden sites in 2007 at Central Ferry (CF) and Pullman (PU) WA, USA.

Trait	Mean	Mean square		F-value (P-value)†	
		Loc	Loc x site	Loc	Loc x site
Morphology					
Leaf length (mm)	127	1365	386	3.54(<0.001)	1.19(0.188)
Leaf width (mm)	2.65	0.696	0.163	4.27(<0.001)	0.75(0.901)
Leaf length to leaf width	49.6	132	59.5	2.23(0.002)	0.95(0.582)
Scape length (mm)	150	2783	555	5.01(<0.001)	0.98(0.525)
Scape diameter (mm)	2.58	0.533	0.184	2.90(<0.001)	0.83(0.788)
Scape length to diameter	60.7	492	154	3.20(<0.001)	0.91(0.652)
Umbel diameter (mm)	52.2	108	35.9	3.01(<0.001)	1.08(0.339)
Flower color	7.07	16.3	1.03	15.92(<0.001)	2.45(<0.001)
Phenology					
Bolting date	108	98.4	10.3	9.59(<0.001)	1.25(0.123)
Flowering date	147	24.7	5.08	4.86(<0.001)	1.11(0.293)
Days to seed maturity	175	42.5	12.3	3.45(<0.001)	1.34(0.067)
Days bolting to flowering	39	40.4	11.1	3.65(<0.001)	1.68(0.004)
Days flowering to seed maturity	28	33.5	19.5	1.72(0.027)	1.48(0.022)
Days bolting to maturity	57	1909	1333	1.43 (0.099)	1.32 (0.073)
Production					
Emergence	0.60	0.281	0.104	2.69(<0.001)	1.46(0.024)
Leaf number	2.56	0.693	0.321	2.16(0.003)	1.14(0.252)
Flowers per umbel	28.3	82.4	20.0	4.13(<0.001)	0.60(0.986)
Seeds per plant	65.6	1906	589	3.24(<0.001)	0.99(0.494)

†For testing source location the location x site term was used as the error term; for testing site x location the residual error term was used.

Correlations between phenological and production traits and precipitation and temperature variables were frequent (table 2). For phenology, days to bolting and days from bolting to flowering were most frequently correlated with precipitation and temperature. For production traits, emergence and seeds per plant were correlated with annual precipitation and all temperature variables (table 2). For PC 1 phenology and PC 1 production, there were generally strong correlations with climatic variables and elevation.

Table 2. Summary of environmental variables at source locations and their correlations with plant traits measured in common gardens for Tapertip onion collected in the Great Basin (n=53).

Variable or Plant Trait	Elev.	Annual precip.	Annual max. T	Annual min. T	Annual ave. T	Frost free days
	(m)	(mm)	-----------------------°C---------------------			
Mean	1697	385	14.6	-0.5	7.1	95
Minimum	814	252	11.2	-6.3	2.5	41
Maximum	2244	792	17.1	2.7	9.4	131
Morphology						
Leaf width	0.27*	0.11	-0.07	0.16	0.06	0.06
Leaf length	-0.03	-0.02	0.06	0.17	0.13	0.07
Leaf length to width	-0.37**	-0.14	0.14	-0.03	0.05	0.01
Scape length	-0.05	-0.22	0.10	-0.06	0.01	-0.04
Scape diameter	0.33*	0.17	-0.21	0.05	-0.07	-0.17
Scape length to dia.	-0.35**	-0.28*	0.23	-0.08	0.07	0.13
Umbel dia.	0.25	-0.01	-0.08	0.04	-0.02	-0.03
Flower color CF	0.32*	-0.01	-0.08	-0.04	-0.07	-0.14
PC 1 morphology	0.27*	0.05	-0.09	0.09	0.01	-0.04
PC 2 morphology	0.37**	-0.21	0.20	-0.02	0.09	0.10
Phenology						
Bolting date	0.33*	0.31*	-0.44**	-0.43**	-0.48**	-0.48**
Flowering date	-0.02	0.03	-0.12	-0.28*	-0.23	-0.28*
Days bolt to flower PU	-0.46**	-0.37**	0.43**	0.20	0.33*	0.32*
Days bolt to flower CF	-0.42**	-0.41**	0.49**	0.39**	0.48**	0.48**
Days to seed maturity	0.05	-0.12	0.00	-0.16	-0.10	-0.20
PC 1 phenology	0.33*	0.28*	-0.40**	-0.40**	-0.44**	-0.47**
PC 2 phenology	-0.34*	-0.36**	0.33*	0.04	0.19	0.11
Production						
Emergence	0.31*	0.33*	-0.46**	-0.36**	-0.45**	-0.40**
Leaf number	0.12	0.56**	-0.36**	-0.30*	-0.36**	-0.19
Flowers per umbel	0.34*	0.09	-0.25	-0.17	-0.22	-0.37**
Seeds per plant	0.12	0.42**	-0.30*	-0.27*	-0.31*	-0.38**
PC 1 production	0.27*	0.43**	-0.42**	-0.34*	-0.41**	-0.42**
PC 2 production	-0.12	0.38**	-0.15	-0.15	-0.17	0.12

*,**Pearson correlation coefficients significant at $P<0.05$ and $P<0.01$, respectively

The source locations represented a wide range of environments (table 2). For example, there was a 1430 m range in elevation, a 540 mm range in annual average precipitation, and a 90 day range in the average frost free period. For certain morphological traits there were correlations between latitude and elevation but no significant correlation between temperature variables, and only one significant correlation between annual precipitation and morphological traits (table 2). Correlation of environmental variables and PC 1 and PC 2 morphology followed the same general pattern as seen with individual morphological plant traits; significant correlation was only observed for latitude and elevation but there was no correlation with temperature and precipitation (table 2).

Since there were strong links observed among climatic variables, phenology, and production, but weak or absent links between morphology and climate, the regression modeling and mapping of traits with environmental variables was confined to phenology and production traits. Given that correlations of climatic variables with PC 2 phenology and PC 2 production were less frequent than for PC 1 phenology and production (table 2), and explained much less of the total variation, regression models for composite phenology and production traits were completed only on PC 1 phenology and PC 1 production.

<u>Regression Models and Mapping Plant Traits to Landscape Environments</u>. Regression of environmental variables with bolting, a key phenology trait, and seeds per plant, a key production trait, produced models that explained 60% and 46% of the variation, respectively. These models produced landscape maps showing the relationship between genetic diversity observed in common gardens and environmental variation from source collection locations (fig. 1).

The range for bolting in common gardens was about 14 days (fig. 1) with later bolting observed on plants originating from locations with generally lower temperatures, usually associated with higher elevation (blue to green hues). Bolting was more advanced in areas with generally warmer climates, and these were usually in areas of lower precipitation shown in yellow to orange hues (fig. 1).

Seed production ranged from 32 to 110 seeds per plant and was generally higher for collections from lower temperature, higher precipitation areas (green to blue hues) (fig. 1). The correlation between bolting and seeds per plant was significant and positive ($r=0.31$, $P=0.025$, $n=53$) showing that later bolting and more seed production were associated. Even so, much of the variation remained unexplained. There were some areas where seeds per plants trended lower (yellow to orange hues) even as bolting was later than average (lighter to darker green hues). For example, in the eastern Snake River Plain, the central area of the Northern Basin and Range (centered near 42° north and -116.5° west), and in the Central Basin and Range (centered near 39.5° north and -116° west), relatively low temperatures and low precipitation were combined, suggesting that seed production capacity was limited by low precipitation in those collection locations even with the trend toward later bolting. The implication was that high seed production potential in those areas, with the associated resource investment, did not appear to provide a selective advantage.

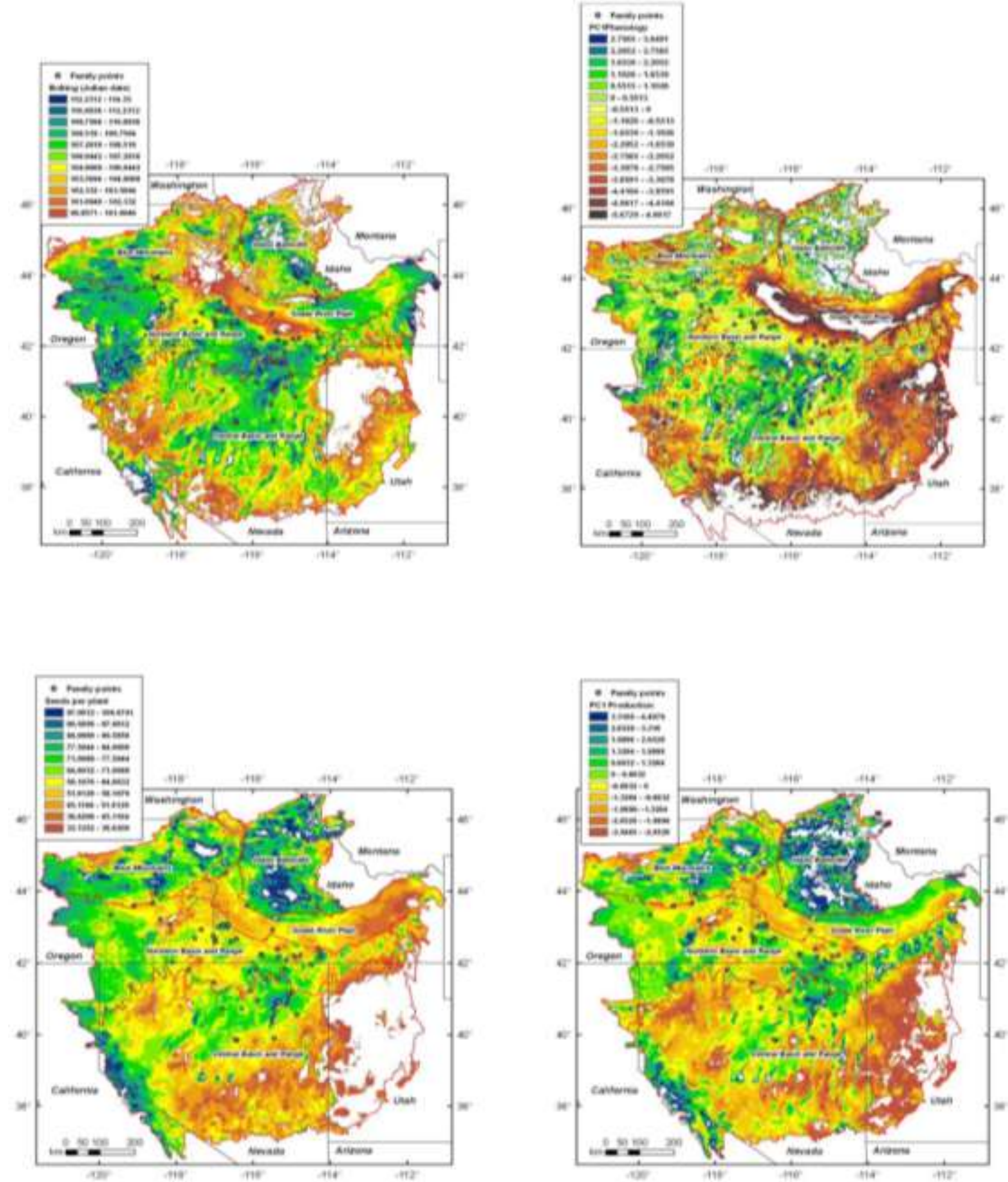

Figure 1. *Allium acuminatum* maps of bolting, seeds per plant, principal component (PC) 1 for phenology, and PC 1 for production in relation to environmental variables over level III Omernik ecoregions. The circles show collection locations. Mapping was confined to the range of observed values for plant traits with unmapped areas shown in white. The contours were the ± P=0.05 confidence interval based on the regression model error.

For PC1 phenology, the regression model with environment explained 59% of the variation. Regression models for PC 1 phenology mapped to largely green hues in the center of the Central Basin and Range extending to the south-central Northern Basin and Range (fig. 1). The eastern Northern Basin and Range also mapped to green hues that represented relatively cooler, wetter climates than in the eastern, southern and western Basin and Range (fig. 1). The PC 1 phenology map was similar in form to the bolting map (fig. 1), although compared to bolting more area was mapped as more area was within the PC scores data range (fig. 1).

For PC 1 production, then regression model with environment explained 62% of the variation. As might be expected, the PC 1 production map (fig. 1) had many similarities to the seeds per plant map (fig. 1). It did allow for additional mapped area, especially in areas in eastern Utah. High production occurred in the higher precipitation, lower temperature areas (blue to green hues). Except for the northern and eastern portions, the Snake River Plain was dominated by yellow to orange hues associated with limited precipitation and relatively warm temperatures (fig. 1). Lower production for much of the Northern Basin and Range and the Central Basin and Range also corresponded to areas with historically higher temperature and lower precipitation (fig. 1).

The overlay of PC 1 for phenology and PC 1 for production based on high, middle and low PC categories, resulted in nine proposed seed zones (fig. 2). The light to darker blue areas represented a relatively small fraction of the mapped area and corresponded to generally lower temperature areas. The great majority of the mapped area was represented by green and brown hues representing six seed zones (fig. 2). In general the green hues represented areas with lower temperature and precipitation than brown hues. For example, most of the brown hues in the northwest part of the Central Basin and Range had average maximum summer temperatures between 24 and 30°C and precipitation less than 250 mm per year. Most green hues represented areas with summer maximum temperatures averaging between 18 and 24°C and average annual precipitation between 250 and 600 mm. Although ecoregions have been suggested for use as provisional seed zones when genecology studies are not available (Erickson et al. 2004; Johnson et al. 2004), our results showed that Omernik level III ecoregions did not correspond with seed zones for tapertip onion based on genetic variability and source location climate. Nevertheless, a conservative approach to seed transfer would be to confine seed movement to adjacent level III ecoregions within a given seed zone.

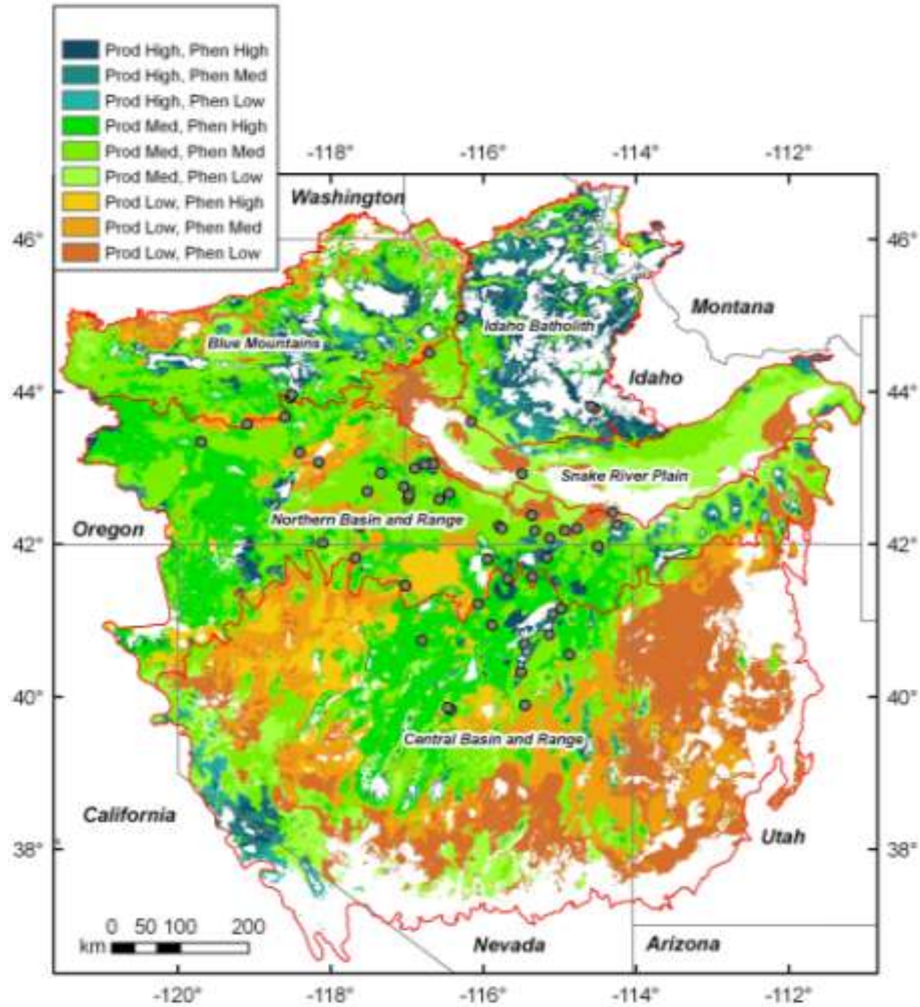

Figure 2. Proposed seed zones for *Allium acuminatum* over level III Omernik ecoregions based on overlays of PC1 phenology and PC1 production regression models. The circles show collection locations. The range of PC scores were divided by thirds into high, middle and low categories and overlain to give nine seed zones. Mapping was confined to the range of observed PCs scores with unmapped areas shown in white. The contours were the ± P=0.05 confidence interval based on the regression model error.

<u>Discussion</u>

In the presence of genetic variation, differences in climate often drive natural selection (Endler 1986). With the common garden approach to genecology we assume that "locally" derived genetic resources are best adapted, which is generally the case (Montalvo and Ellstrad 2000, Hufford and Mazer 2003, Rice and Knapp 2008, Leimu and Fisher 2008). With the strong links between temperature and precipitation and phenology and production, differences in those plant traits appeared to have adaptive value. The genetic variation in morphological traits, however, was not linked to climate, even though there were numerous correlations between elevation and morphological traits. This could result from non-climatic factors, perhaps edaphic. Yet most collections were made on similar, typically rocky or gravelly substrates, so the importance of edaphic factors to differences in morphological traits was uncertain. Given the expectation that temperature and precipitation would be important forces in natural selection, much of the variation in morphological traits appeared more the result of genetic drift than adaptation.

Plants from cooler source locations with shorter frost free periods were genetically predisposed to bolt later than those from warmer locations. Delayed bolting at cooler, higher elevation locations would likely improve the chances for avoidance of late spring frosts. Yet development from bolting to flowering tended to be more rapid at cooler source locations. Thus, the delayed bolting was coupled with more rapid post bolting development, accommodating the overall shorter frost free period expected at cooler, higher elevation locations. In addition, plants from cooler, higher precipitation locations produced more seeds per plant in common gardens than those from warmer, dryer locations. Thus, plants from higher precipitation, lower temperature areas had, overall, the highest potential for sexual reproduction. Thus, much of the genetic variation had a logical basis for adaptation to source locations climates.

The ±P=0.05 confidence interval, a frequently used statistical benchmark, was employed as the contour for delineating maps of plant traits with source location environments. The results were maps showing major areas of apparent plant adaptation. Since areas that fell outside the range of data were not mapped there was some fragmentation in certain areas. This was most prominent in the Snake River Plain and the western and southern fringe of the Central Basin and Range. Yet most of the Great Basin was mapped providing guidance for selecting seed sources for restoration.

The maps should be considered as tools to guide restoration and management rather than rigid units. The aim was to strike a balance between generating so many seed zones that they would be unwieldy but enough to promote sound restoration. Restoration practitioners may consider modifications to our zones based on management considerations and experience. In such cases the regression models developed herein could still be applied with either larger (smaller P values) or narrower (larger P values) contours; the basic form of the relationship between genetic variability and climate would remain intact.

Selected germplasm or cultivars have been widely used on western rangelands including the Great Basin (Jones and Young 2005). Although wide adaptation may be possible, potential drawbacks include genetic swamping (Hufford and Mazer 2003, Johnson et al. 2010), outbreeding depression (Kramer and Havens 2009), and hybridization that could lead to the loss of co-adapted gene complexes (Montalvo and Ellstrand 2001). We recommend wild populations be collected and used for restoration within seed zones to obviate those concerns. With rangeland degradation and climate change, the scope for future selective adaption depends on the availability of genetic variation. To promote the conservation of biodiversity across the landscape, multiple populations should be collected and combined within seed zones. We expect other species to show patterns of genetic variation linked to climatic variables, and similar genecology studies on other key species are needed to help conserve and utilize genetic variation now and into the future.

Publications:

Hellier, B.; Johnson, R.C. 2010. *Allium acuminatum* seed production: First look at cultural parameters. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p.88-90.
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Presentations:

Johnson, R. C. 2010. Creating seed ones for native plants: examples for mountain brome and tapertip onion. Society for Ecological Restoration Pacific Northwest Chapter Workshop, 2010 February 18, Tulalip,WA. (Invited)

Johnson, R. C. Developing seed zones for native forbs and grasses. Workshop on Seed Production of Native Grasses and Forbs, 2010 February 23, Ontario, OR. (Invited)
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Johnson, R. C. 2010. Genecology and seed zones for native grasses and forbs, National Native Seed Conference, 2010 May 18, Snowbird, UT. (Invited)

Johnson, R.C.; Hellier, B.; Cashman, M. 2010. Seed zones for Tapertip onion and Indian ricegrass. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

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Management Applications and Seed Production Guidelines:

- Maps visualizing the interaction of genetic variability and climate for Tapertip onion allow informed decisions regarding the suitability of genetic resources for restoration in varying Great Basin environments.

- The recommended seed zone boundaries may be modified based on management resources and land manager experience without changing their basic form and links between genetic variation and climate.

- We recommend collection of multiple populations of Tapertip onion within each seed zone to promote biodiversity needed for sustainable restoration and genetic conservation.

Products:

- Seed zones for restoration of Tapertip onion in the Great Basin have been developed based on links between genetic variation and climate. The results suggest other herbaceous species to be amenable to similar seed zone mapping.
- Cooperation between the National Plant Germplasm System (NPGS), the Western Regional Plant Introduction Station, Pullman, WA, and the BLM involving native seed collection and conservation through the "Seeds of Success" program: Through 2010, a total 1,648 SOS accessions were distributed for research and utilization (Table 3). The native plant collection in the NPGS also provides a security back-up for native populations that may be lost as a result of climate change and disturbances such as fire and invasive weeds.

Table 3. Seeds of success (SOS) native germplasm sample distributions from National Plant Germplasm System (NPGS) repositories between 2005-2010.

Year and Repository*	2005 W6	2006 W6	2007 W6	2008 W6	2009 W6	2009 COR	2009 NC7	2010 W6	2010 NC7	Total†
Taxon Distributed	1	21	135	315	321	12	5	339	20	736
Accessions Distributed	1	23	161	438	448	14	5	530	28	1648
Non-U.S. Orders	0	0	7	25	21	1	0	20	7	270
Countries Receiving	1	1	6	18	12	1	1	14	6	26
Cooperator Orders	1	3	51	104	91	1	3	81	21	303
State Affiliated Orders	1	0	17	38	34	0	1	5	34	106
USDA-ARS Orders	0	1	2	5	5	0	0	1	7	16
Other Federal Orders	0	2	3	3	3	0	1	4	3	15
U.S. Non-profit	0	0	1	3	3	0	1	1	2	8
U.S. Individuals	0	0	13	12	10	0	0	7	1	43
Foreign Commercial Orders	0	0	0	6	3	0	0	3	2	12
Foreign Gene Bank Orders	0	0	0	2	2	1	0	0	1	6
Foreign Non-Commercial Orders	0	0	7	16	15	0	0	16	4	55
Foreign Individual Orders	0	0	0	1	1	0	0	1	0	3
Total Orders†	1	3	54	129	114	1	3	95	21	421

*NPGS repositories, W6 (Western Regional Station, Pullman, WA), COR (Clonal Germplasm Repository, Corvallis, OR), NC7 (North Central Regional Station, Ames, IA)

†Some rows do not tally as a single cooperator may have placed multiple orders

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Project Title: Ecological Genetics of Big Sagebrush (*Artemisia tridentata*): Genetic structure and climate-based seed zone mapping

Project Location: RMRS, Shrub Sciences Laboratory, Provo, Utah

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Project Description:
Big sagebrush (*Artemisia tridentata*) is one of the most ecologically important and landscape dominant plant species in western North America. This species is a major focus for ecosystem restoration after disturbances because of its importance in wildlife forage, invasive weed exclusion (e.g., cheatgrass), snow catchment and nutrient cycling. Big sagebrush is divided into three major subspecies; *tridentata*, *vaseyana* and *wyomingenesis*, that typically occupy distinct ecological niches. However, subspecies are known to form hybrid zones in some areas (Freeman et al. 1991, McArthur et al. 1998). Maladaptation is a serious problem in restoration and becomes more complex with climate change. Planting big sagebrush seed sources outside its adaptive breadth will lead to continued ecosystem degradation and encroachment of invasive species. Successful restoration of big sagebrush requires understanding the climatic factors involved in defining subspecies and populations.

<u>Objectives</u>
1. Establish common gardens from collected seed sources across the range of big sagebrush.
2. Develop molecular markers from transcriptome data of subspecies *vaseyana* and *tridentata*.
3. Elucidate genetic structure using molecular markers and adaptive traits.
4. Determine climatic factors important to adaptation within and among big sagebrush ecological races.
5. Develop climate-based seed zone maps across the range of big sagebrush.

Common garden study

Collection of seed and plant tissue began in autumn of 2009. A total of 93 seed sources were collected, largely by collaborators, in 11 western states (fig. 1). In January 2010, seeds were planted in greenhouse containers. Up to 10 families from each of 56 seed sources were outplanted at each of the common gardens (table 1). Outplanting of seedlings occurred in May and June of 2010. First-year measurements were conducted in October and November of 2010. Measurements included height, diameter at the ground and overhead photos to calculate crown area. Plants were supplemented with water until August and mortality was minimal for the first year at < 2%. No supplemental water will be added in the future. Overall, the subspecies preliminary growth patterns have met expectations. Subspecies *tridentata* yielded the greatest heights and diameters and the Ephraim plot produced the highest yields among all subspecies (fig. 2). The preliminary data also indicated different allocations of wood development to height. Subspecies *tridentata* had lower ratios (i.e., greater height to wood development) compared to ssp. *vaseyana* (data not shown).

Table 1. Location information of three sagebrush common garden sites

Site Name	Latitude	Longitude	Elevation (m)
Orchard, Idaho	43.328	-116.003	976
Ephraim, Utah	39.369	-111.580	1,686
Majors Flat, Utah	39.337	-111.521	2,088

Figure 1. The location of 56 seed collection sites for *Artemisia tridentata*. The symbols identify subspecies *wyomingenesis*, *tridentata* and *vaseyana*.

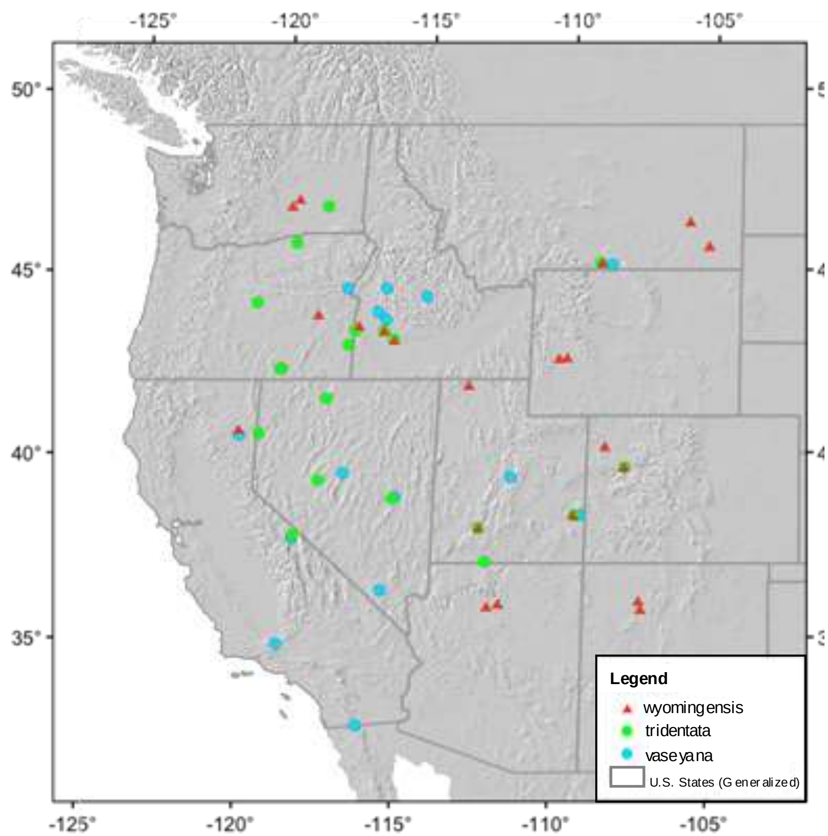
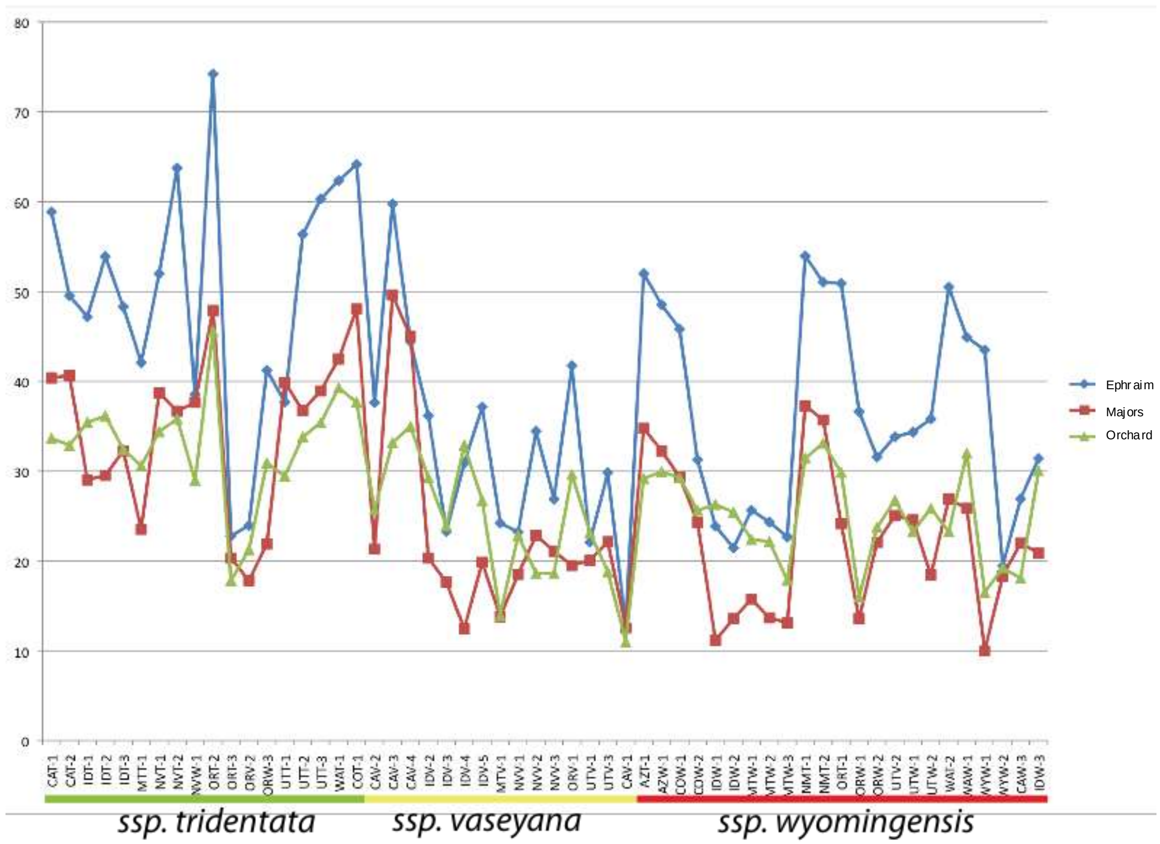


Figure 2. Average heights (cm) of 56 seed sources during first (2010) season growth. Colored lines within the graph represent heights in the three common gardens: Ephraim, Majors and Orchard. Putative subspecies designations based upon ploidy and coumarin fluorescence of ssp. *tridentata*, *vaseyana* and *wyomingensis* are provided below.



Molecular genetics

In September of 2009, leaf tissue was collected from two big sagebrush specimens (subspecies *tridentata* and *vaseyana*) growing in Provo, Utah. Total RNA was extracted and the transcriptomes were sequenced for both subspecies using a Roche 454 FLX Genome Sequencer. The DNA sequence data has been compiled and annotated with over 21,000 sequences identified with putative function. This data includes over 20,000 SNPs (single-nucleotide polymorphisms) and 119 polymorphic microsatellite markers that will be a resource for downstream projects such as the development of molecular markers for population genetic and phylogenetics studies. In September of 2010 further RNA sequencing was completed on two ssp. *wyomingensis*, from Utah (UTW-1) and Montana (MTW-1). After aligning DNA sequence reads from the *wyomingensis* samples with the previous reference sequence developed from the ssp. *tridentata* and *vaseyana* samples, it was found that some interesting SNP patterns emerged. Out of approximately 1,000 SNPs between ssp. *tridentata* and *vaseyana*, ssp. *wyomingensis* was heterozygous for over one-third. For the remaining SNPs the most, approximately 60%, match ssp. *vaseyana* compared to ssp. *tridentata* at approximately 40% (Bajgain et al. in review).

Future plans

Common gardens. Continued measurements of common garden plants will occur on a monthly basis during the growing season of 2011. Weather data will be collected at each common garden site. Such data can be used in the development of genecological models for delineation of seed zones. Progress is being made to take physiological measurements (e.g., carbon isotopes) at these gardens during the 2011 season.

Molecular genetics. Molecular marker development from transcriptome sequencing will lead to a range-wide population genetic and phylogenetic assessment of big sagebrush. An approach has been developed where selected RNA probes, designed from previously assembled sequences, will capture fragmented genomic DNA. Several hundred of these fragments will be sequenced and the data can be used to compare phylogenetic relationships and gene frequencies for population genetic analyses.

Literature cited:
Freeman, D. C., et al. 1991. Characterization of a narrow hybrid zone between two subspecies of big sagebrush (*Artemisia tridentata*: Asteraceae). Amererican Journal of Botany. 78: 805-815.

McArthur, E. Durant, et al. 1998. Narrow hybrid zone between two subspecies of big sagebrush (*Artemisia tridentata:* Asteraceae). Canadian Journal of Botany. 76: 567-574.

Publications:

Bajgain, P., Richardson, B. A., Price, J. C., Cronn, R.C., Udall, J.A. [In review]. Transcriptome characterization and polymorphism detection between *Artemisia tridentata* subspecies.

Richardson, B. A.; Shaw, N. L. 2010. Ecological genetics of big sagebrush (*Artemisia tridentata*): Genetic structure and climate based seed zone mapping. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 68-70. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

Richardson, B. A.; Klopfenstein, N. B; Kim, M. S.; Shaw, N. L; Warwell, M. V. 2010. Combined molecular and quantitative genetic approaches to assess climatic adaptation at multiple biological and spatial scales. All Scientists Meeting. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Richardson, B. A., Shaw, N. L., Udall, J. A. Bajgain, P. 2010. Studies to assess ecological genetics and evolutionary relationships in *Artemisia tridentata*. Great Basin Native Plant Selection and Increase Project Annual meeting; 2010 January 26-27; Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Shaw, N. L.; Jensen, S; Richardson, B. 2010. A collaborative science-based program to provide native plant materials and restoration technology for the Great Basin. All Scientists Meeting. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Products:
Development of molecular markers and annotated genes in big sagebrush for use in future studies. Data deposited into Genbank (completed).
Elucidate evolutionary relationships between and within big sagebrush subspecies (ongoing).

Evaluate quantitative traits for adaptive responses to climate, develop seed zones for big sagebrush subspecies (ongoing).

Leveraged funding:
National Fire Plan
Western Transcriptome Survey

Project Title: Morphological and Genetic Variation among Common Utah Globemallows

Project: Utah State University, Logan, Utah

Principal Investigators and Contact Information:

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Project Description:
We study variation and diversity among Intermountain West native plant species to 1) assure their stability and performance in home and commercial landscapes and 2) assess their useful range for growers to establish a market for their stock. *Sphaeralcea* (globemallow) species are a diverse group of forbs in the family Malvaceae. Their drought tolerance and bright orange flowers make them attractive for xeriscape gardening. They are early seral species and palatable to livestock, making them useful in rangeland restoration. They are also obligate outcrossers, and inter-specific hybridization among *Sphaeralcea* is common. The fact that they readily hybridize makes field identification difficult and brings into question the identity of species distributed or sold for rangeland restoration and home garden use. Four species are common to Utah: *S. coccinea*, *S. grossulariifolia*, *S. munroana* and *S. parvifolia*. Gooseberryleaf globemallow (*S. grossulariifolia*) is promoted as an attractive, drought-tolerant native species for northern intermountain western markets.

<u>Objective</u>
To clarify taxonomic relationships among the four species by investigating morphological and genetic variation.

<u>Taxonomy</u>
The main taxonomic characters used to distinguish among *Sphaeralcea* include leaf shape, pubescence and degree of dissection; length and plane of starlike leaf hairs, number of flowers per node; and shape of the fruit (schizocarp). For practical field identification, leaf shape and degree of dissection are the most commonly used characters. However, our work has shown these characters to be quite variable within species and not reliable as the sole indentifying characters. We noticed that *Sphaeralcea* obtained from a variety of sources labeled as a particular species are not consistent in their appearance. We also observed that *Sphaeralcea* grown from seed obtained from different sources produce plants with highly variable characters.

Further, we found that plants transplanted from the wild into a common garden respond to a common soil environment and irrigation regime by modifying their leaf lobe size and degree of dissection.

Approach

We studied differences in a variety of morphological characters using a statistical approach called principal components analysis (PCA). PCA is a multivariate analysis which reveals the internal structure of large quantities of data in a way that best explains the variation. This stepwise mathematical procedure transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components. Second, we used a molecular marker technique, Amplified Fragment Length Polymorphism (AFLP), to see if we could detect variation at the DNA level among the four species.

Morphological Variation

A type specimen is the original plant specimen from which the description of a new species is made. We obtained type specimens for the four *Sphaeralcea* from herbaria across the U.S. and Great Britain. We compared ten morphometric characters of herbarium samples (table 1) and our own field-collected specimens with those of the type specimens. Using PCA to create a predictive model, we were able to check the identity of local herbarium specimens, and to assign field-collected specimens to one of the four species by their similarity to type specimens.

Table 1. Means of ten morphometric characters obtained from type specimens of the four *Sphaeralcea* species. No one character accounts for differences among species.

Character (mm)	*S. coccinea* (n = 8)	*S. grossulariifolia* (n = 5)	*S. munroana* (n = 3)	*S. parvifolia* (n = 17)
Petiole length	10.6	14.7	8.7	14.0
Mid-lobe length	20.0	25.5	22.4	20.6
Mid-lobe width	3.3	4.7	3.7	10.6
Secondary lobe length	13.1	17.5	14.3	14.1
Secondary lobe width	2.6	3.6	2.8	8.3
Lobe depth	1.0	0.8	0.5	0.2
Pedicel length	3.1	2.9	2.9	3.0
Calyx length	6.7	5.7	5.9	6.5
Petal length	12.3	11.7	11.0	11.6
Flowers/node (no.)	1	5	4	6

Based on our model, we found that while 94% and 100% of *S. coccinea* and *S. parvifolia* herbarium samples, respectively, correlated with their respective type specimens, only 12% of *S. grossulariifolia* samples grouped with *S. grossulariifolia* type specimens (table 2). None of the *S. munroana* herbarium samples were true to type; all *S. munroana* herbarium specimens grouped with *S. parvifolia* type specimens (table 2).

Table 2. Proportion of herbarium samples assigned to the corresponding type specimen using a multivariate analysis model of ten morphometric characters.

	Type specimen			
	S. coccinea	*S. grossulariifolia*	*S. munroana*	*S. parvifolia*
Herbarium specimen				
S. coccinea	93.75%	6.25%	-	-
S. grossulariifolia	75.00%	12.50%	12.50%	-
S. munroana	-	-	-	100.00%
S. parvifolia	-	-	-	100.00%

Genetic Variation

We used Amplified Fragment Length Polymorphism (AFLP) to resolve differences among the four species. Genomic DNA from leaf samples from 20 populations (10-12 plants per population) was extracted and subjected to the AFLP technique. The resulting amplified DNA fragments were separated on a gel matrix to compare the band patterns. These were scored and subjected to cluster analysis. The resulting groups were consistent with those resolved using morphometric characters. These data support the existence of two main groups rather than four within the *Sphaeralcea* species included in the study.

Correlation of geographic with genetic and morphological distances

We used Mantel's test of morphological, genetic and geographic distances among *Sphaeralcea* to investigate the possibility of relationships with geographic occurrences of the species. Both morphological and genetic distances correlated with geographic distances among populations of *S. parvifolia* and *S. munroana*. The groups could be separated on the basis of ecoregions, *S. munroana* (and related *S. parvifolia*) associated with the Great Basin region, and a distinct subset of *S. parvifolia* associated with the Colorado Plateau region. These differences were supported by morphological and genetic data. *Sphaeralcea parvifolia* associated with the Colorado Plateau had leaves that were more densely pubescent and only shallowly lobed, as compared with the Great Basin *S. parvifolia*.

Conclusions

- *Sphaeralcea coccinea* is a distinct species. The presence of a single flower per node is characteristic.
- *Sphaeralcea munroana* may be an ecotype of *S. parvifolia*. These taxa can be differentiated from *S. coccinea* by having an almost entire rather than a dissected leaf shape.
- *Sphaeralcea grossulariifolia* does not appear to be distinct, and may represent inter-specific hybridization among the other three species.

Publications:

Kratsch, H.A.; Johnson, D.; Connors, K. 2010. Demonstration, education and outreach activities related to GBNPSIP plant materials. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 24-32.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:
Kratsch, H.A.; Johnson, D. 2010. Adaptability of selected Great Basin native plants to Utah markets. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Management Applications and Seed Production Guidelines:
These results will enable seed collectors, growers and land managers to make informed decisions about which *Sphaeralcea* is most appropriate for a given land restoration application. If *S. munroana* or *S. parvifolia* is specified or desired, seed source location will be of great importance to successful planting establishment. These two taxa appear to have adapted morphological characters that have allowed them to survive within unique climatic parameters.

Products:
- The importance Great Basin native plants in xeriscape plantings and rangeland restoration has been incorporated into master gardener and other consumer training programs.
- A list of intermountain regional native plant growers has been assembled and added to the WERA 1013 website (http://www.uwyo.edu/wera1013/).
- A report of native plant trial garden data was presented at the Idaho Nursery and Landscape Association meeting in Boise on January 21, 2011.
- A Great Basin native plant demonstration garden is planned in collaboration with Washoe County, Nevada pending approval of a Memorandum of Understanding between University of Nevada Cooperative Extension and Washoe County Parks and Recreation.

Project Title: Characterization of Seed Germination Requirements and Post Germination Seedling Development for Improved Restoration Success

Project: University of Idaho, Moscow, Idaho

Principal Investigators and Contact Information:

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Project Description:
The objectives of this study are to increase our understanding of the germination requirements of Munro's globemallow and to monitor post-germination response to environmental stress for Munro's globemallow and Wyoming big sagebrush.

Project status
Emily Overton, an M.S. student, started in August 2009 and conducted a literature review to determine specific current needs. Seedlings were grown from five seed sources in the current range of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) in order to evaluate phenotypic variation within a subspecies. Physiological and morphological data will be gathered; and this information could be used to gain an understanding of trait variation and subspecies distribution. Information on the physiological variation of seed sources could help to establish seed transfer guidelines for *Artemisia tridentata* ssp. *wyomingensis*, which may improve restoration plantings. Olga Kildisheva (M.S. Student), working with the *Sphaeralcea munroana* component of this project, has completed two studies: a first investigating seed dormancy and germination success across a suite of different treatment regimes, the second being a controlled environment study investigating early seedling development.

Publications:

Davis, A. S. 2010. Characterization of seed germination requirements for improved direct-seeding success in a changing climate. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 112.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Pavek, P. L. S.; Kildisheva, O. A.; Davis, A. S. [In press]. Plant guide for Munro's globemallow (*Sphaeralcea munroana*). Pullman, WA: USDA Natural Resources Conservation Service, Pullman Plant Materials Center.

Presentations:

Davis, A. S.; Overton, E. C.; Kildisheva, O. A. 2010. Germination trials of, and evaluation of post-germination stress in, Wyoming big sagebrush and Munro's Globemallow. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Kildisheva, O. A.; Davis, A.S.; Keefe, R. F. 2010. Mimicking nature: understanding seed ecology as a means of native plant restoration. Ecological Society of America, 2010 August 1-6, Pittsburgh, PA. (poster)

Kildisheva, O. A.; Davis, A. S.; Keefe, R. F. *Sphaeralcea munroana*: strategies for improving seed germination. International Seed Science Meeting on Seeds and the Environment, 2010 June 20-24, Salt Lake City, UT. (poster)

Management Applications and Seed Production Guidelines:

Improved germination success will result in higher yields for seed increase programs.

Products:

Funding from the Idaho Transportation Department is covering a graduate student stipend to conduct half of the research described in the scope of this project; the University of Idaho also awarded an additional $12,000 towards the research focused on Munro's globemallow.

Project Title: Development of Germination Protocols, Seed Weight, Purity and Seed Conditioning/Cleaning Protocols for Great Basin Grasses and Forbs

Project location: USDA Forest Service National Tree Seed Laboratory, Dry Branch, Georgia

Principal Investigators and Contact Information:

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Project Description:
The National Tree Seed Laboratory is developing seed cleaning, testing and storage protocols for the species selected for the Great Basin Native Plant Selection and Increase Project. The NSL has a complete range of seed cleaning equipment so that manipulations of raw seed of almost any species can be performed in order to produce clean seed of high viability. Germination is tested over a range of temperatures and the data analyzed by response surface analysis to find the optimum combination of light and temperatures for optimum germination. Seed storage studies are done using the new technology of equilibrium relative humidity (ERH) to assess seed moisture conditions. Training and information is also offered in workshops and conference presentations.

Publications:
Karrfalt, B.; Vankus, V. 2010. Development of germination protocols, seed weight, purity and seed conditioning/cleaning protocols for Great Basin grasses and forbs. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 113-115.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:
Karrfalt, R. P. 2010. Twenty-nine month seed storage data for *Artemisia tridentata* var. w*yomingensis*. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2010 January 26-27, Salt Lake City, Utah.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Products:

Seed germination protocols

Work continued on *Achnatherum hymenoides*, *Penstemon acuminatus, P. deustus* and *P. speciosus*. Seeds of the three penstemons were found to give little or no germination with up to 90 days of chilling at 3^{o}C. Longer chilling periods will be tested. *Achnatherum hymenoides* chilled for 100 days germinated well in the chilling room at 3^{o}C in the dark. Therefore, extended chilling will be done with this species also. Seed moisture levels will be reduced in prechill slightly from full imbibitions to prevent germination at prechill and hopefully obtain a controlled germination in the germination chambers.

Wyoming big sagebrush seed storage

Storage of Wyoming big sagebrush *Artemisia tridentata* ssp. *wyomingensis* in sealed moisture proof containers has proven to maintain high germination for 41 months if the seed is cleaned to high purity and dried to an equilibrium relative humidity between 30% and 40%. The methods and materials of this study have been reported in the 2009 report of the GBNPSIP. The bar graph below summarizes the 41 month data. The second graph shows how equilibrium relative humidity relates to seed moisture content.

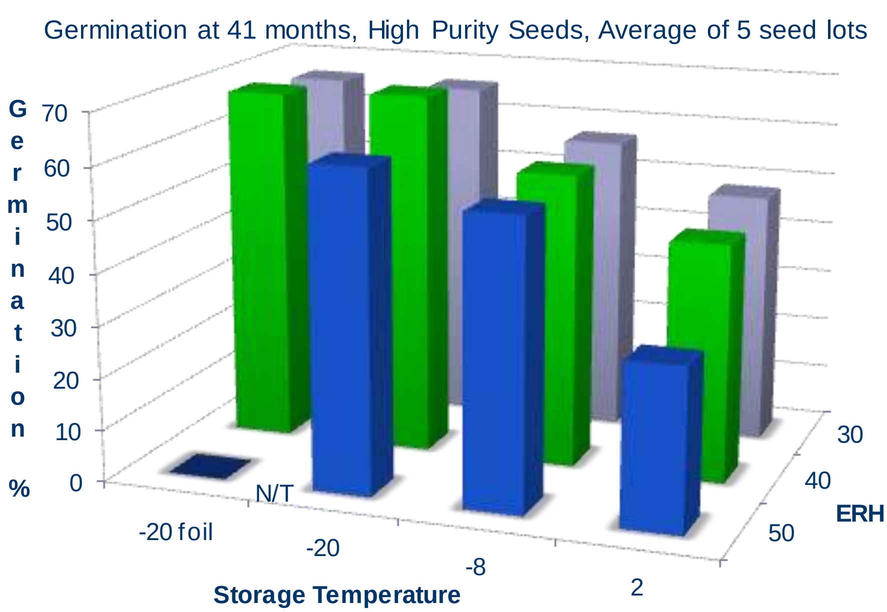

Figure 1. The effect of equilibrium relative humidity and storage temperature on the germination of Wyoming big sagebrush seeds sealed in moisture-proof bags.

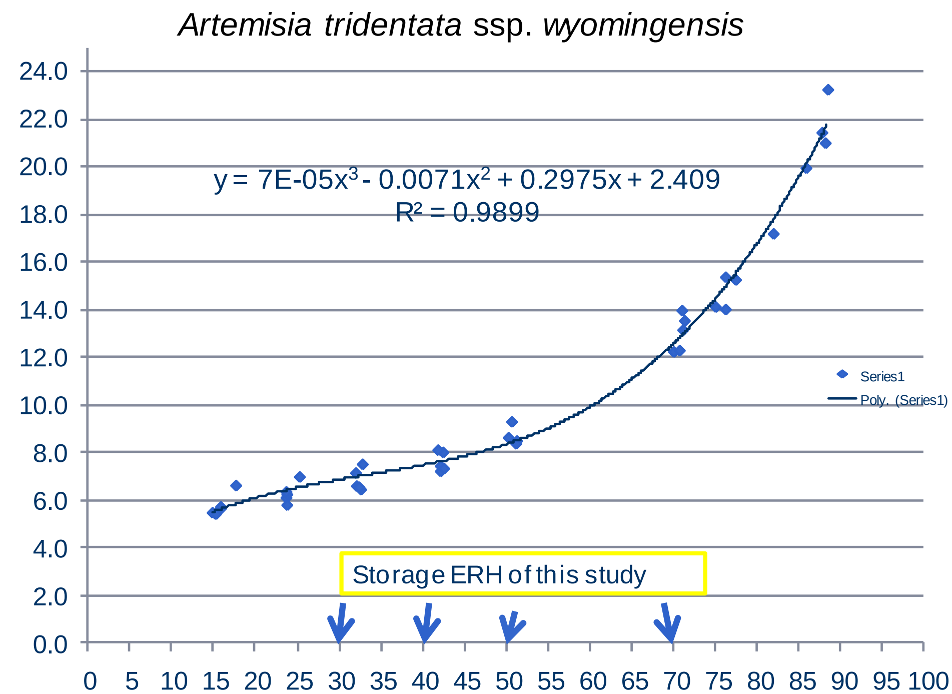

Figure 2. The relationship of seed moisture for Wyoming big sagebrush to equilibrium relative humidity (ERH).

Management Applications:
Land managers need not always make current year seed collections of Wyoming big sagebrush to meet current regeneration needs.

Seed collectors and users can easily, quickly, inexpensively, and effectively monitor seed moisture in order to manage seed lots to maintain highest quality seed germination.

Project Title: Development of Procedures to Break Dormancy in *Lomatium dissectum* Seeds

Project: Boise State University, Boise, Idaho

Principal Investigators and Contact Information:

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Project Description:
The aims of the project were to identify environmental conditions that break dormancy of *Lomatium dissectum* seeds and to characterize differences in stratification requirements among various populations.

Specific Objectives
Working under this project, in previous years we determined differences in cold stratification requirements among various populations of *L. dissectum*. These differences can be attributed to dissimilarities in environmental conditions during seed development or genetic differences among the populations (Bauer et al. 1998; Bentsink and Koornneef 2002). To begin to investigate this issue, during the past year, we have analyzed the degree of genetic diversity and genetic differentiation among eight populations of *L. dissectum* using enzyme electrophoresis.

Methods
Population sampling. In this study, we analyzed samples from two varieties of *L. dissectum*, *L. dissectum* var. *dissectum* and *L. dissectum* var. *multifidum* (Nutt.) Mathias & Constance (USDA NRCS 2011). *Lomatium dissectum* var. *dissectum* is more common west of the Cascade Mountains in areas with a mesic climate and average annual precipitation of more than 1000 mm. In contrast, *L. dissectum* var. *multifidum* is more frequent east of the Cascade Mountains in semiarid habitats, where it is found at elevations ranging from 800 to 2200 m. Seeds were collected from three populations of var. *dissectum* and five populations of var. *multifidum*. Seeds of var. *dissectum* were harvested within the Willamette Valley, Oregon at:

Adair 1 (44° 48'N, 123° 14'W; 81 m elevation)
Buell 1 (45° 2'N, 123° 28'W; 117 m)
Buell 2 (45° 1'N, 123° 24'W; 178 m)

Seeds of var. *multifidum* were collected at:

Prairie, Oregon (43° 31'N, 115° 58'W; 1287 m elevation)
Harper, Oregon (43° 33'N, 117° 47'W; 1347 m)
Bitner, Idaho (43° 37'N, 116° 49'W, 785 m)
Fairfield, Idaho (43° 10'N, 114° 40'W, 1700 m)
Moore's Mountain, Idaho (43° 47'N, 116° 5'W; 2200 m)

At each site, we collected seeds from 8 to 22 plants of var. *dissectum* and from at least 30 plants of var. *multifidum*. Seeds from each plant were stratified separately and after germination seedlings were transplanted to jiffy pots, keeping records of the site and plant origin of each seed. The first true leaves of the seedlings were used for extraction of proteins and subsequent allozyme analysis.

<u>Enzyme electrophoresis</u>. After the expansion of the first true leaves, leaf tissue from each *L. dissectum* plant was harvested and macerated in a tris-HCl grinding buffer-PVP solution. Starch concentration in the gels was 12% (w/v). Enzyme electrophoresis procedures generally followed Soltis et al. (1983), with modifications described by Novak et al. (1991). The 16 enzymes employed here were visualized using the following buffer systems: isocitrate dehydrogenase (IDH), glyceraldehyde-3-phosphate dehydrogenase (G3PDH) and 6-phosphogluconate dehydrogenase (6PGD) using system 1 of Soltis et al. (1983); colorimetric esterase (CE), glutamate dehydrogenase (GDH), glutamate oxalacetate transaminase (GOT) and malic enzyme (ME) using system 6; aldolase (ALD), leucine aminopeptidase (LAP), phosphoglucoisomerase (PGI), superoxide dismutase (SOD) and triosephosphate isomerase (TPI) using system 8; and malate dehydrogenase (MDH), phosphoglucomutase (PGM) and shikimate dehydrogenase (SKDH) using system 9.

Because *L. dissectum* is a diploid, the genetic basis of all allozyme variation observed was easily inferred based on the known subunit structure and compartmentalization of these enzymes (Weeden and Weendel 1989). When more than one locus was observed for an enzyme, the loci were numbered sequentially, with the most anodally migrating isozyme designated *1*. Different alleles at a locus were identified using letters, with the most anodal allele designated *a*, the next *b*, and so on.

<u>Data Analysis</u>
Allozyme data were analyzed using BIOSYS-1 (Swofford and Selander 1981) in order to determine the level and structure of genetic diversity within and among populations of *L. dissectum*. Allozyme data were entered into BIOSYS-1 as genotype frequencies with populations arranged hierarchically based on the two varietal designations. Genetic diversity was expressed as the mean number of alleles per locus (A), the percentage polymorphic loci per population (%P), expected mean heterozygosity (H_{exp}) and the mean observed heterozygosity (H_{obs}). Expected mean heterozygosity was computed using the unbiased estimate method of Nei (1978). Mean observed heterozygosity was determined by the direct count method. Means of these genetic diversity parameters were used to describe the overall diversity within populations from the Central U.S.

Wright's F-statistics (Wright 1965) are used to analyze subdivisions in a group of populations. The quantity F_{IT} is the overall fixation index and measures the reduction in heterozygosity of individuals relative to the total sample (across all populations). The value of F_{IT} can be partitioned into two components: reduction in heterozygosity within populations F_{IS}, and F_{ST} the measure of genetic differentiation among populations. F_{ST} is also described as the proportion of the genetic diversity that is partitioned among populations. Nei's (1978) unbiased genetic identity coefficients (I) were calculated for all possible pair-wise comparisons among all *L. dissectum* populations using BIOSYS-1. Based on all pair-wise comparisons, we calculated the mean values of I for each variety and among the two varieties. The unweighted pair-group method with arithmetic averaging (UPGMA) algorithm in BIOSYS-1 was used to generate a phenogram for these populations of *L. dissectum*, based on genetic identity (I) values.

Results

Genetic diversity across populations and varieties. The results in this report are preliminary because herein we present data from the analysis of only 81 individuals. Data collection and analysis are continuing. The 16 enzymes we used were encoded by 32 putative loci. Across all populations, 21 loci (65.6%) were found to be polymorphic, and the other 11 loci (34.4%) were monomorphic. Additionally, a total of 86 alleles was observed at the 32 loci (2.69 alleles per locus). At the 21 polymorpic loci, a total of 71 alleles was observed (3.38 alleles per polymorphic locus). This level of allozyme diversity is relatively high compared with other diploid seed plants, and is consistent with what has been reported for plants with a mixed mating system (equal amounts of outcrossing and self-pollination, Hamrick and Godt 1989).

Across populations, we detected higher allozyme diversity in var. *multifidum*, compared with var. *dissectum*. For instance, the five populations of var. *multifidum* possessed 20 polymorphic loci and 82 alleles; whereas the three populations of var. *dissectum* had 14 polymorhic loci and 62 alleles. These results should however be viewed cautiously because they are undoubtedly confounded by differences in sample size of both populations and individuals.

Genetic diversity within populations. Allozyme diversity was generally higher, on average, within populations of var. *multifidum* (mean values for A = 1.76, %P = 41.26, H_{obs} = 0.097, H_{exp} = 0.153), compared within populations of var. *dissectum* (A = 1.53, %P = 33.33, H_{obs} = 0.106, H_{exp} = 0.140). The one exception to this pattern was the value for H_{obs}, which was higher for var. *dissectum* populations (data not shown). Among populations of var. *multifidum*, the highest values for these allozyme diversity parameters were observed in the population from Fairfield, ID; whereas all three populations of var. *dissectum* had fairly similar values, with the values for the population from Adair, OR being only marginally larger (table 1). For the parameters A and %P, the level of diversity detected across all eight populations appears to be related to the number of individuals analyzed (N). Therefore, these values should also be viewed cautiously.

The values of H_{obs} reported for these populations are relatively high, but except for the Buell-1 population, do not equal the values for H_{exp} (table 1). Values for these two heterozygosity parameters suggest that these populations of *L. dissectum* possess a mixed (or random) mating system; that is, these plants engage in equal amounts of outcrossing and self-pollination. The value of F_{IS} (0.218) calculated across all polymorphic loci (table 2), is also consistent with a mixed mating system (Wright 1965).

Table 1. Allozyme diversity at 32 loci in all populations (SE in parentheses). A is mean number of alleles per locus, %P is the percentage polymorphic loci per population, H_{exp} is the expected mean heterozygosity and H_{obs} is the mean observed heterozygosity.

Population	N	A	%P*	Mean heterozygosity	
				H_{obs}	H_{exp**}
Fairfield, ID	15	2.1 (0.2)	56.3	0.140 (0.033)	0.211 (0.044)
Moore's, ID	7	1.6 (0.1)	37.5	0.103 (0.030)	0.152 (0.039)
Marsing, ID	13	1.8 (0.2)	37.5	0.084 (0.024)	0.140 (0.038)
Harper, ID	5	1.3 (0.1)	21.9	0.050 (0.020)	0.082 (0.030)
Prairie, ID	18	2.0 (0.2)	53.1	0.108 (0.026)	0.179 (0.039)
Adar, OR	7	1.6 (0.1)	37.5	0.094 (0.029)	0.137 (0.037)
Buell-1, OR	5	1.5 (0.2)	34.4	0.163 (0.043)	0.163 (0.044)
Buell-2, OR	11	1.5 (0.2)	28.1	0.063 (0.028)	0.119 (0.042)

*A locus is considered polymorphic if more than one allele is detected
**Unbiased estimate (Nei, 1978)

Table 2. Summary of F-statistics at all loci

Locus	F(IS)	F(IT)	F(ST)
CE1	.313	.413	.145
CE2	.207	.273	.084
CE3	.247	.298	.067
CE4	.211	.364	.194
GDH	1.000	1.000	.179
IDH	-.088	-.020	.062
LAP1	.376	.528	.245
LAP2	.547	.688	.311
MDH1	-.022	.152	.170
MDH2	.820	.909	.492
MDH3	.066	.216	.160
ME	.617	.727	.287
PGI1	1.000	1.000	.127
PGI2	-.145	-.002	.125
PGM1	.067	.347	.300
PGM2	-.024	.098	.119
PGM3	.313	.399	.126
6PGD1	.689	.702	.044
SKDH1	.242	.278	.048
SKDH2	.427	.453	.045
TPI1	-.015	.126	.138
Mean	.281	.429	.206

Genetic differentiation among populations and varieties. Values of F_{ST} vary among the 21 polymorphic loci; these values range from 0.044 for 6PGD1 to 0.492 for MDH2 (table 2). The mean value of F_{ST} for all polymorphic loci was 0.206. This value indicated that 20.6% of the total allelic diversity of *L. dissectum* is partitioned among populations, and 79.4% of the total allelic diversity is partitioned within populations. These parameters suggest moderate to low genetic structure among these populations.

The unbiased genetic identity (I) coefficient of Nei (1978) ranges from 0.0 to 1.0, where a genetic identity value of 1.0 indicates that a population pair is genetically identical. The highest mean genetic identity values occur for the inter-variety comparison for var. *dissectum* (0.985), and the lowest value occurs for var. *multifidum* (0.954) (table 3). The mean genetic identity comparison for the two varieties was intermediate (0.962) to the values reported for each of the two varieties alone. These data suggest little genetic differentiation among populations of the two varieties.

Table 3. Matrix of Nei's (1978) unbiased genetic identity coefficients averaged within and among varieties.

Variety	No. of populations	1	2
1 *multifidum*	5	.954 (.926-.972)	
2 *dissectum*	3	.962 (.941-.992)	.985 (.981-.990)

Figure 1. Cluster Diagram of genetic identity of different *Lomatium dissectum* populations

```
Similarity
.90       .92       .93       .95       .97       .98      1.00
+----+----+----+----+----+----+----+----+----+----+----+----+

                               ******************************  Fairfield, ID
                             ***
                             * ******************************  Moore's Mtn, ID
                             *
                             *            *******************  Marsing, ID
                             *            *
                             *          ***            ******  Prairie, ID
                             *          * *   **********
                             *          * *   *        ******  Adair-1, OR
                             *          * *****
                             ************     *       *******  Buell 1, OR
                                        *     *********
                                        *             *******  Buell 2, OR
                                        *
                                        *********************  Harper, OR

+----+----+----+----+----+----+----+----+----+----+----+----+
.90       .92       .93       .95       .97       .98      1.00
```

The UPGMA cluster diagram provides graphic representation of the overall genetic similarity among these eight populations of *L. dissectum* (Fig. 1). The populations from Fairfield, ID, and Moore's Mtn, ID are differentiated from the other six populations. The cluster with these other six populations contains three populations of var. *multifidum* and three populations of var.

dissectum, with the Prairie, ID populations of var. *multifidum* being most similar to populations of var. *dissectum*.

Publications:
Serpe, M. 2010. Development of procedures to break dormancy in *Lomatium dissectum* seeds. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report: 116-118. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:
Scholten, M.; Shaw, N.; Serpe, M. 2010. Environmental regulation of dormancy loss in *Lomatium dissectum* seeds. National Native Seed Conference; 2010 May 17-21, Snowbird, UT.

Management Applications:
The populations of *L. dissectum* analyzed in this study contained relatively high amounts of genetic diversity (see Hamrick and Godt 1989), and based on these results we would anticipate that native plant restoration projects that utilize this species would be successful. However, management efforts should be designed to maintain this level of diversity. For example, when germplasm is sampled from each population, we recommend that a relatively large number of individuals be sampled to avoid population bottlenecks. Additionally, genetic diversity in these populations is consistent with what has previously been reported for plants with a mixed mating system. Because high levels of heterozygosity are usually associated with higher fitness levels, management efforts should be designed to protect insect pollinator populations that contribute to outcrossing in this species. Finally, populations of the two subspecies appear to be genetically similar; thus they may be used interchangeably in restoration projects. However, we recommend caution in doing this until additional studies, such as determining whether populations exhibit ecotypic differentiation, are carried out.

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Wright, S. 1965. The interpretation of population structure by F-statistics with special regard to systems of mating. Evolution. 19: 395-420.

Project Title: Modeling Seedling Root Growth of Great Basin Species

Location: Brigham Young University, Provo, Utah

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Project Description:
This work is designed to model seedling root growth of revegetation species using thermal accumulation. Plant scientists have sought to select plant materials for revegetation of rangelands based on physiological and morphological characteristics which allow establishment under conditions of limiting temperatures and available water for plant growth. Thermal and hydrothermal models have been used to predict germination under the environmental conditions of rangelands (Rawlins 2009, Meyer and Allen 2009, Hardegree et al. 2010). However, low seedling survival limits revegetation success on rangelands, even if seeds germinate. Using a thermal accumulation model to predict seedling root growth would allow us to assess the potential for seedlings to survive under a range of field conditions and possibly suggest opportunities for plant improvement.

<u>Objectives</u>

1. Develop thermal accumulation models for seedling root penetration for forbs, grasses, and cheatgrass.
2. Test the ability of thermal models to predict root depth under diurnal temperatures in the growth chamber and in the field.
3. Use thermal models and soil water and temperature data from stations in the Great Basin to predict seedling root growth and survival for dry to wet years.

<u>Growth Chamber Study</u>

We are measuring seedling root depths over time for six forbs, five perennial grasses, and three cheatgrass collections (table 1) in relation to constant temperatures in a walk-in growth chamber. The experiment is organized in a randomized block design of four blocks and two soils. Black plexiglass holders have been constructed to hold 70 (5 replicates x 14 collections) clear plastic root tubes 2.5-cm diameter by 20-cm long. Each block contains two plexiglass holders, one with tubes filled with sand and the other with tubes filled with Borvant gravelly loam soil passed through a 0.6 cm screen. The holders keep the tubes slanted at a 45° angle and minimize root exposure to light. For each of six constant temperature runs (5, 10, 15, 20, 25, and 30° C), three seeds of a collection are sown 0.5 cm below the soil surface against the lower side of a planting tube.

Table 1. Plant materials tested in root study.

	Scientific name	Common name	Cultivar	Source	Collection date
Forbs	*Achillea millefolium*	Eagle yarrow	Eagle	Eastern WA	2003
	Achillea millefolium	White yarrow	White-VNS	Granite Seed	2003
	Agoseris heterophylla	Annual agoseris		USFS Shrub lab	2007
	Astragalus utahensis	Utah milkvetch		USFS Shrub lab	2002
	Linum perenne	Blue flax	Appar	UDWR	2003
	Lupinus arbustus	Longspur lupine		Wells, NV; UDWR	2004
Perennial grasses	*Agropyron cristatum x A. desertorum*	Crested wheatgrass	Hycrest	UDWR	2003
	Agropyron desertorum	Crested wheatgrass	Nordan	Granite Seed	2003
	Elymus elymoides	Squirreltail	Sanpete	UDWR	2003
	Elymus wawaiensis	Snake River wheatgrass	Secar	WA; Granite Seed	2003
	Pseudoroegneria spicata ssp. *spicata*	Bluebunch wheatgrass	Anatone	Granite Seed	2003
Weedy grasses	*Bromus tectorum*	Cheatgrass		Rush Valley, UT	2005
	Bromus tectorum	Cheatgrass		Skull Valley, UT	2007
	Bromus tectorum	Cheatgrass		Skull Valley, UT	2008

Prior to sowing, Utah milkvetch seeds were scarified in sulfuric acid for 15 minutes followed by stratification at 1.5° C for two weeks with squirreltail seeds. Tubes are checked six days per week and the depth of the deepest root is recorded. Time to germination is recorded in petri dishes filled with 25 seeds of each collection and placed on racks below the root experiment in the incubation chamber. Soil temperatures are measured with six thermocouples per block that are placed into the ends of root tubes and attached to a Campbell Scientific, Inc. CR10X micrologger. Temperatures are read each minute and average hourly temperatures recorded. At the end of each temperature run, one tube of each collection per block is harvested and dry weight of root biomass recorded. The entire experiment will also be conducted at three diurnal temperatures based on cold, cool, and warm soil temperatures recorded in the field. We will compare actual with root depths predicted from thermal accumulation models.

<u>Field Experiment</u>
The same experiment as described above was conducted at two locations in Utah for two years 1) on the Brigham Young University campus, and 2) on the east side of the Onaqui Mountains in a Utah juniper/Wyoming big sagebrush plant community where the juniper trees have been shredded. In the first year of the field experiment, natural precipitation watered root tubes. In the second year, root tubes were watered weekly as needed during the growing season. Emergence and root depth were recorded five times per week at the BYU campus and at least monthly at the

Onaqui site. Thermocouples and gypsum blocks were placed in each block in the field outside root tubes, but inside soil or sand surrounding tubes. These sensors are read every minute and hourly averages recorded with Campbell Scientific, Inc. CR10X microloggers.

Modeling

The first step to model or predict days to 15-cm root depth is to model daily root depth as a function of constant temperature. A root depth of 15-cm was selected because we were interested in seedling establishment, most roots are in the top portion of the soil profile, and we already have many thermocouples buried in the field at 15-cm. Second, solve the modeled daily root depth equation at 15-cm root depth to derive the number of days to 15-cm root depth. Third, invert the number of days to 15-cm root depth. The sum of daily inverses serves as an indicator of progress toward the goal of 15-cm root depth. The goal of 15-cm root depth has been achieved on average when the sum of the inverses equals 1. The inverse of the mean number of days to 15-cm root depth for each constant temperature is used as input into TableCurve2D software, which fits a non-linear equation to the data. This non-linear equation is the temperature response curve used to predict days to 15-cm root depth in diurnal temperature or field root trials. Most species temperature response curves had an r^2 greater than 0.9 and all species temperature response curves had an r^2 greater than 0.7 except for Utah milkvetch with an r^2 of 0.47. Days to 15-cm root depth are converted to degree days to 15-cm root depth by summing the daily average temperatures for each day of a root trial until the 15-cm root depth has been achieved. For example, if it took a species 80 days to achieve 15-cm root depth at a constant 7°C, then adding the mean daily temperatures of 7°C for 80 days would equal 560 degree days.

Project Status

Growth Chamber Experiment. We have conducted all of the six constant temperature runs and two of the three diurnal temperature runs in the growth chamber. The statistical results of the experiments so far are as follows:

Actual vs. Predicted for Diurnal Root Trial 4-12°C. In comparing actual versus predicted degree days to 15-cm root depth in diurnal root trial 4-12°C, predicted degree days showed a slightly greater trend than actual degree days (figs. 1 and 2). In soil, Secar, squirreltail, and longspur lupine predicted degree days were significantly greater than their actual degree days. In sand, squirreltail and Nordan predicted degree days were greater than actual. These differences among predicted and actual degree days can be used to adjust future model predictions.

Actual vs. Predicted for Diurnal Root Trial 9-17°C. In sand for diurnal trial 9-17°C, there were no significant differences except predicted squirreltail required more degree days than actual (fig. 3). In soil for diurnal trial 9-17°C, all of the species predicted values were greater than their actual values except for cheatgrass 2005, cheatgrass 2007, annual agoseris, and flax (fig. 4).

Sand vs. Soil Actual for Diurnal Root Trial 4-12°C. For comparing actual sand versus soil degree days in diurnal trial 4-12°C, the grasses required more degree days to reach 15-cm root depth in sand than in soil except for Secar, which grew equally well in sand and soil perhaps because of inherent slower root penetration (fig. 5). Most of the forbs did not achieve 15-cm root depths in sand. The reduced rate of root depth in sand was likely due to lower nutrient availability although other variables probably had an influence. Sand versus soil texture and nutrient availability will be analyzed at a later date.

Sand vs. Soil Actual for Diurnal Root Trial 9-17°C. In diurnal root trial 9-17°C, all grass species required more thermal time in sand than in soil except for squirreltail (fig. 6). Most of the forb roots did not achieve 15-cm root depth in sand.

Inter-species Comparisons for Diurnal Root Trial 4-12°C. For inter-species comparisons in sand for root trial 4-12°C, squirreltail required more degree days than Nordan and cheatgrass 2005. Otherwise, there were no inter-species differences in sand. Comparing across species in soil, flax required more degree days than any other species. The invasive annuals required fewer degree days than all of the forbs and the perennial grasses Secar and Hycrest. Annual agoseris required more degree days than all of the grasses except Secar and Hycrest. The general trend across species in soil was that annual grasses required the least amount of thermal time, forbs required the most thermal time, and perennial grasses were intermediate although, Secar was quite slow for a grass.

Inter-species Comparisons for Diurnal Root Trial 9-17°C. For inter-species comparisons in sand for the 9-17°C root trial, there were few significant differences, but cheatgrass 2005 did require fewer degree days than Anatone. For inter-species comparisons in soil, flax required the most degree days of any species. Cheatgrass 2005 and 2008 required fewer degree days than annual agoseris, Utah milkvetch, longspur lupine, and squirreltail.

As expected, cheatgrass roots grew the fastest at cool temperatures. However, the crested wheatgrasses and Anatone bluebunch wheatgrass definitely grew well enough to compete with cheatgrass. The importance of faster root growth to establishment is suggested by comparing the heat accumulation requirement of the forbs and that of the grasses. Forbs are known to not establish as well as grasses in rangeland revegetation projects. Blue flax, one of the most successfully-seeded forbs requires about 700-800 degree days to reach 15 cm root depth, while Anatone bluebunch wheatgrass requires 250-350 (fig. 2). SageSTEP data from four Great Basin pinyon-juniper locations for two years were used to calculate wet degree days in spring 2008 and 2009. Degree day accumulations when the soil is wet ranged from around 300 in early spring (March and April) to around 700 in late spring (May and June). As long as soil moisture is available from March into June, robust plants of both forbs and grasses should establish because they will have around 42 wet degree days for root growth. However, if soil moisture becomes unavailable by May in a dry year, even robust forbs might not establish because they may have insufficient wet degree days to grow their roots and keep them below the soil drying front. The details of just how many wet degree days are available under different field conditions in relation to how many are needed for successful establishment will become better understood with specific modeling exercises and field validation tests.

What appears to be a major concern for successful establishment of forbs is the lack of robust plants. Occurrence of some vigorous forb plants indicates potential for plant improvement. Such plant improvement work could potentially increase forb establishment success.

Field Experiments
We have conducted the field root trials at both BYU campus and the east side of Onaqui Mountain for two years. This data will be analyzed in the future.

Future Work
We will finish the last diurnal temperature experiment in the growth chamber. We will begin comparing predicted and actual root depths based on measured soil temperatures and water potentials at the field sites.

Publications:
Roundy, B. A.; Young, K. 2010. Modeling seedling root growth of Great Basin species. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p.119-126. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:
Roundy, B. A.; Young, K. 2010. Using wet thermal accumulation to predict germination and seedling root growth of revegetation species and cheatgrass across the Great Basin. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Management Applications:
An important application of thermal accumulation modeling is to predict which seeded species are most likely to establish given site-specific soil temperature and moisture patterns and interspecies interference. As plants have to establish in communities, rates of root depth by invasive weeds influence the duration of resource availability to other species through resource preemption as the soil dries down from spring into summer. Knowing which species are most likely to establish on a site should save money by avoiding the planting of species that are not likely to establish on certain sites. Thermal accumulation modeling can also serve as a cultivar development tool selecting for more consistent and vigorously establishing native plants.

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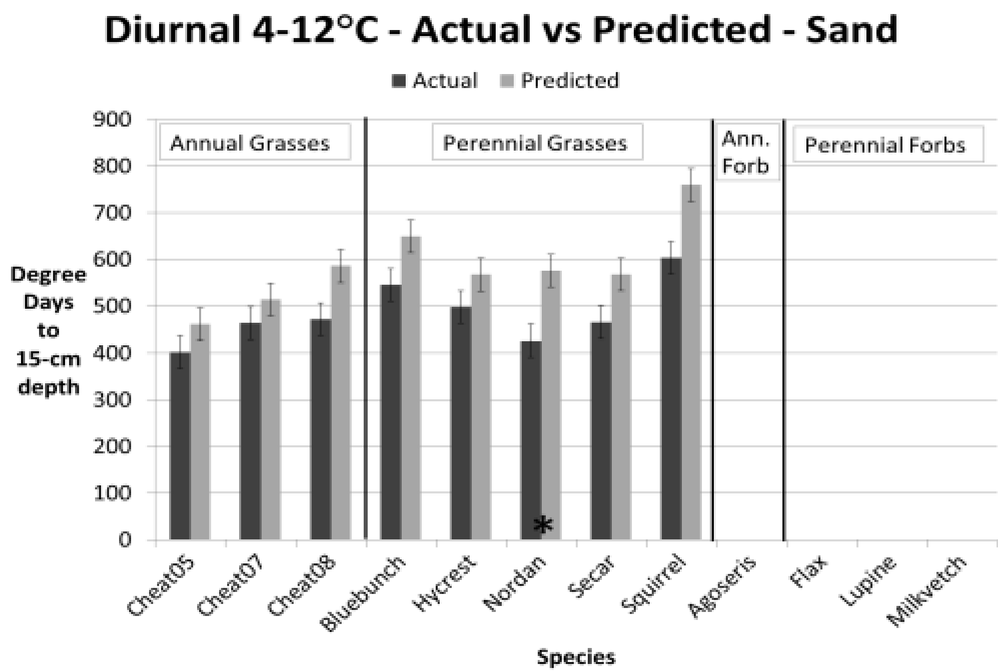

Figure 1. Actual vs. predicted degree days to 15-cm root depth in sand for the growth chamber diurnal root trial 4-12°C. Asterisk indicates significant difference at 95% confidence level.

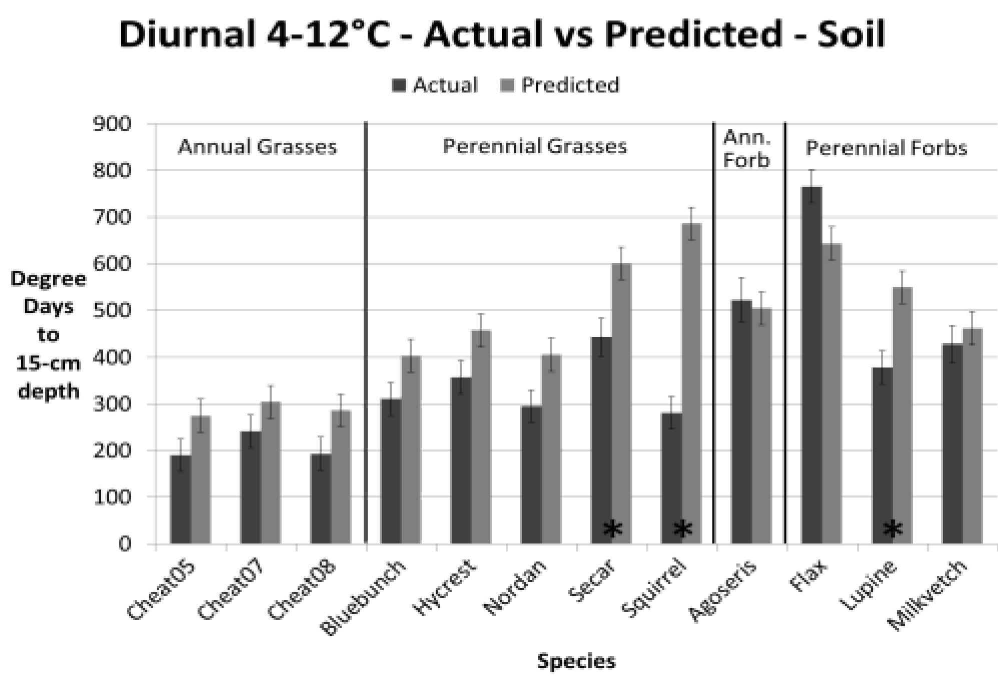

Figure 2. Actual vs. predicted degree days to 15-cm root depth in soil for the growth chamber diurnal root trial 4-12°C. Asterisk indicates significant difference at 95% confidence level.

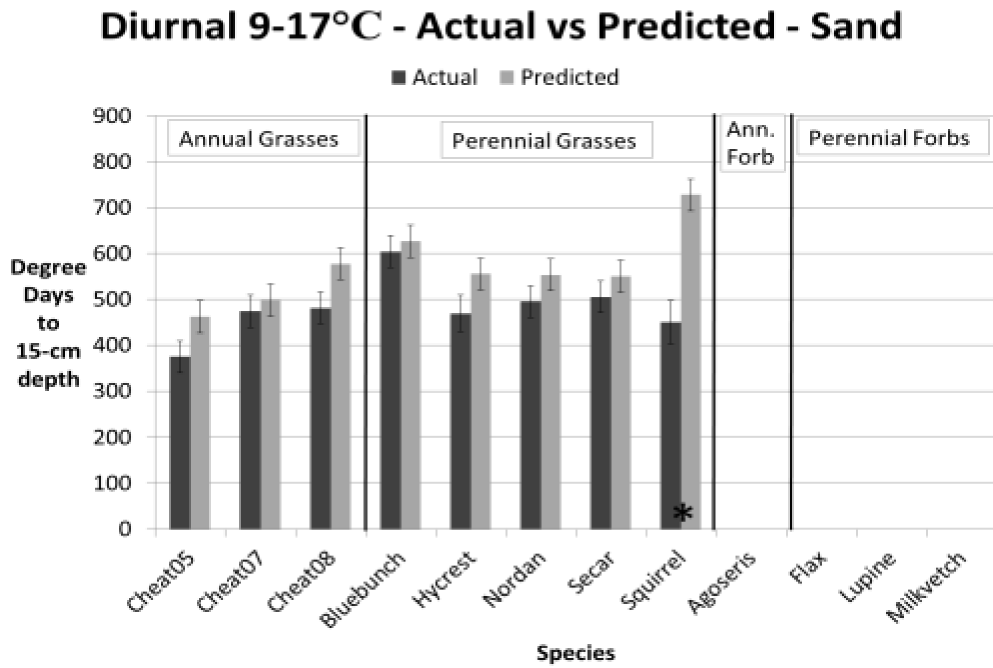

Figure 3. Actual vs. predicted degree days to 15-cm root depth in sand for the growth chamber diurnal root trial 9-17°C. Asterisk indicates significant difference at 95% confidence level.

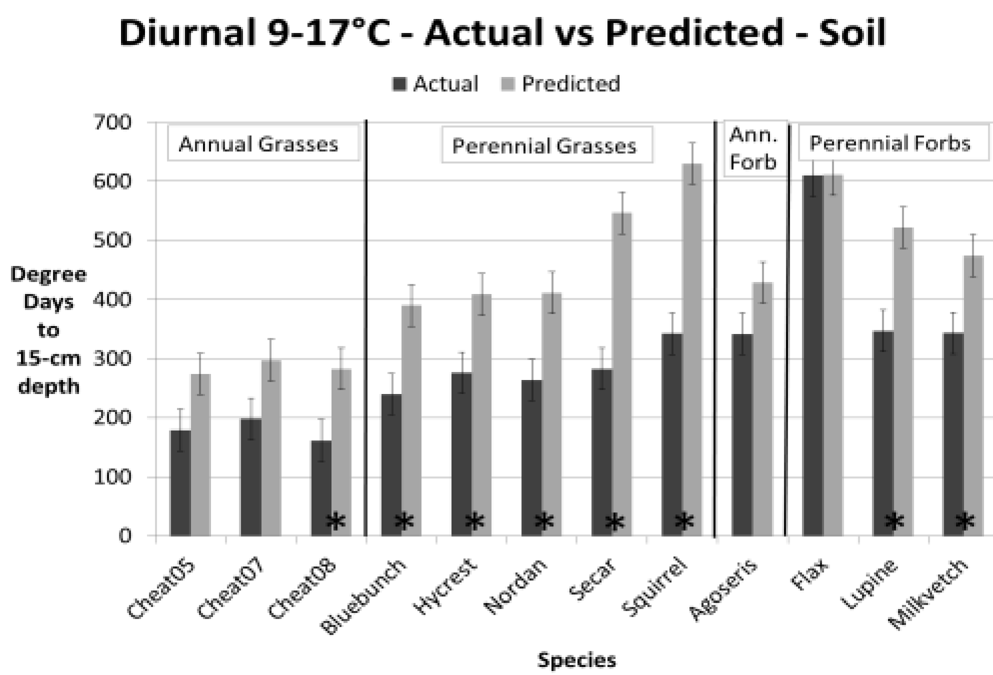

Figure 4. Actual vs. predicted degree days to 15-cm root depth in soil for the growth chamber diurnal root trial 9-17°C. Asterisk indicates significant difference at 95% confidence level.

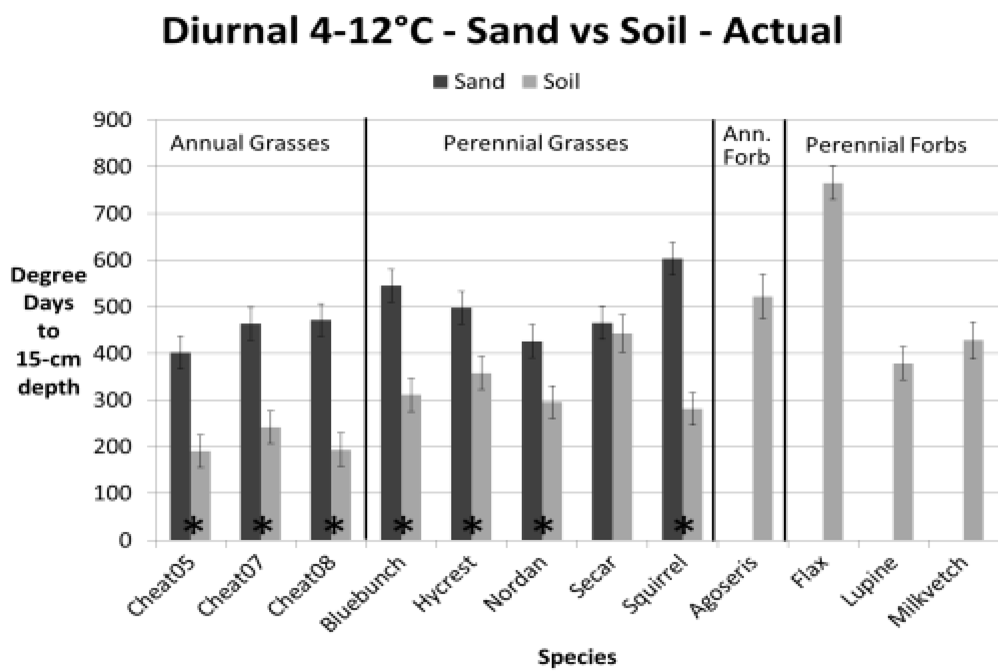

Figure 5. Actual sand vs. soil degree days to 15-cm root depth for the growth chamber diurnal root trial 4-12°C. Asterisk indicates significant difference at 95% confidence level.

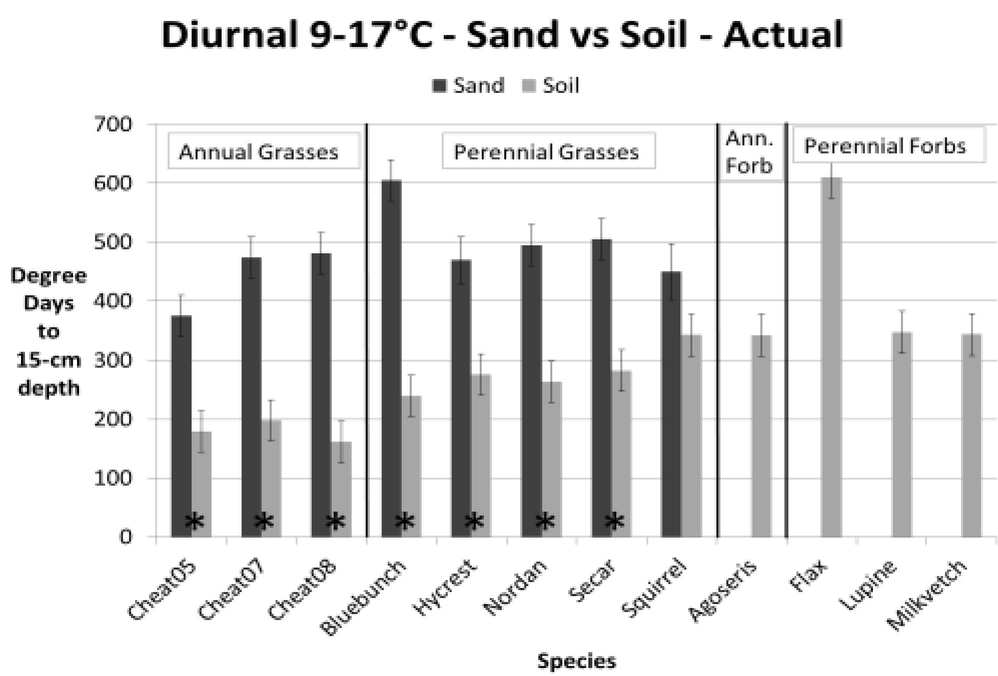

Figure 6. Actual sand vs. soil degree days to 15-cm root depth for the growth chamber diurnal root trial 9-17°C. Asterisk indicates significant difference at 95% confidence level.

Project Title: Diversity of Mycorrhizal Fungi Associated with *Artemisia tridentata* ssp. *wyomingensis*

Project: Boise State University, Department of Biological Sciences, Boise, Idaho

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Project Description:
The general goal of the project is to identify species of arbuscular mycorrhizal fungi (AMF) that colonize *Artemisia tridentata* ssp. *wyomingensis* in sagebrush communities of southwestern Idaho.

Objectives
1. Collection of Wyoming big sagebrush seedlings from sagebrush communities in southern Idaho and identification of the AMF species that colonize their roots.
2. Multiplication and identification of AMF species present in soil samples collected from various sites.

Methods
The approaches used to identify mycorrhizal species in sagebrush roots and soil samples are summarized in figure 1. Roots and soil samples were collected from seven sites:

Kuna Butte	Ada County, ID	N 43° 26.161' W 116° 25.848'
Birds of Prey	Ada County, ID	N 43° 19.272' W 116° 23.643'
Simco Road	Elmore County, ID	N 43° 11.047' W 115° 58.181'
Old Oregon Trail Road	Elmore County, ID	N 43° 05.353' W 115° 38.702'
Bennett Mountain Road	Elmore County, ID	N 43° 03.755' W 115° 19.088'
Sommer Camp Road	Owyhee County, ID	N 43° 27.566' W 116° 50.712'
Cinder Cone Butte	Ada County, ID	N 43° 13.160' W 115° 59.598'

DNA was extracted from the roots using the Qiagen DNAeasy Plant kit and the Fast-DNA Spinkit for soil. The presence of mycorrhizal DNA in the extracts was determined via nested PCR. General fungal primers LR1 and FLR2 were used in the first amplification and their products were amplified in a second PCR reaction with the Glomeromycota specific primers FLR3 and FLR4 (Gollotte et al. 2004). These primers amplify regions of the large subunit ribosomal RNA gene (LSU rDNA). Some of the products amplified by PCR were cloned using the pGEM-T Easy Vector System (Promega). Inserts were amplified, cleaned, and sent for sequencing to a commercial facility. The resulting nucleotide sequences were used for identification of AMF species based on comparison with published sequences via phylogenic analysis.

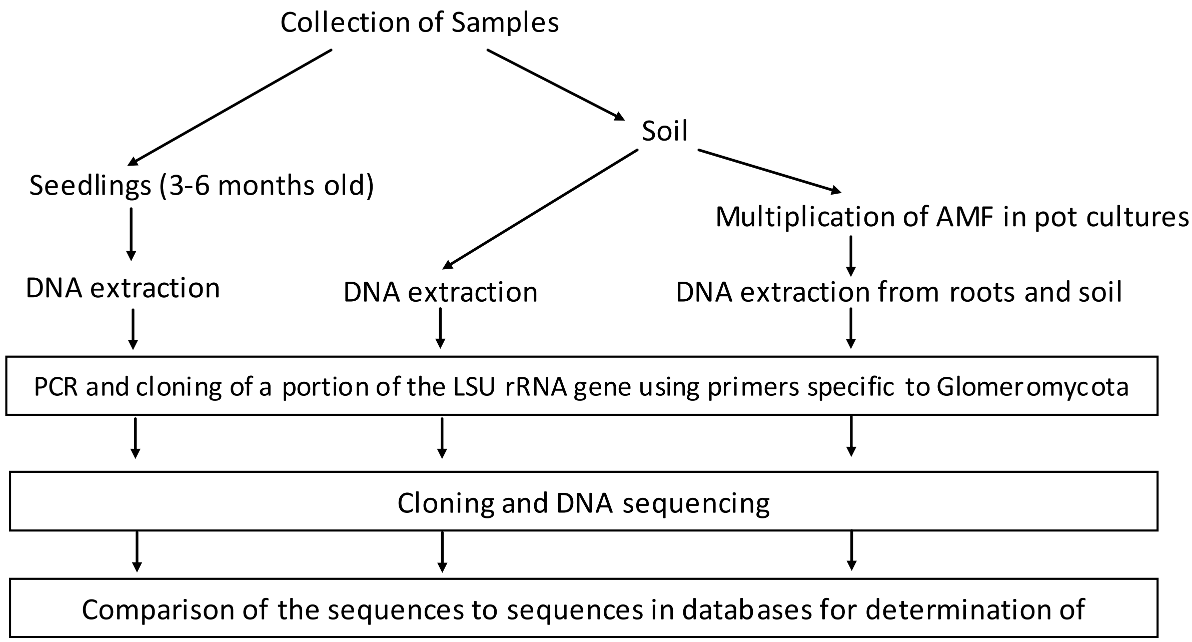

Figure 1. Summary of approaches used to identify mycorrhizal species in sagebrush roots and soil. Left, sagebrush seedlings are collected from the field sites, soil is cleaned from the roots, and fine roots (<2 mm) are used for DNA extraction. Center, DNA is extracted from the soil. Right, the mycorrhizae present in the soil and roots are first multiplied in pot cultures using Sudan grass as a host and DNA is extracted from both roots and soil from the pot cultures.

<u>Results</u>

From the DNA extracted from the roots and soil at the different sites, we obtained PCR products of the expected length, which ranges from 300 to 380 bp. The products appeared to be specific for mycorrhizae. No amplification was observed with DNA extracted from *Arabidopsis* roots, a non-mycorrhizal species, or DNA extracted from sagebrush leaves, which should not have mycorrhizae.

For some of the samples, the PCR products have been cloned and sequenced. Thus far, the only site from where we have sequenced samples from roots, soil, and pot cultures is Kuna Butte. From three other sites we have sequenced samples from sagebrush roots and soil, or soil only. Ten to fifteen clones were sent for sequencing from each site and source. Based on the sequences obtained to date and phylogenetic analyses, we have identified five mycorrhizal species in southwestern Idaho (table 1). The most common species appear to be *Glomus intraradices* and *G. microaggregatum*; these species were found in sagebrush roots and soil. In addition, other species were detected in the soil or after multiplication of mycorrhizae in pot cultures. Future work is aimed at completing the cloning and sequencing of DNA extracted from samples collected at other sites and from pot cultures.

Table 1. Mycorrhizal species identified in southwestern Idaho using DNA sequence data

Site	Source	Species
Kuna Butte	Roots	*Glomus intraradices*
	Soil	*G. intraradices* *G. microaggregatum*
	Pot Cultures	*G. intraradices* *G. microaggregatum* *G. claroideum*
Simco Road	Roots	*G. microaggregatum*
	Soil	*G. intraradices* *G. microaggregatum* *G. claroideum* *Entrophospora infrequens*
Cinder Cone Butte	Roots	*G. intraradices*
	Soil	*G. intraradices* *G. microaggregatum*
Bennett Mountain Road	Soil	*G. intraradices* *G. microaggregatum*

Publications:
Serpe, M. 2010. Development of procedures to break dormancy in *Lomatium dissectum* seeds. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p.116-118. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:
Carter K, Davidson B, White M, Shaw N, Serpe M. Identification of mycorrhizae associated with *Artermisia tridentata* ssp. w*yomingensis* in southwestern Idaho. National Native Seed Conference. (abstract 28).

Carter K, Serpe M. Identification and multiplication of native mycorrhizal species that colonize *Artemisia tridentata* ssp. w*yomingensis* seedlings. Annual Meeting Intermountain Seedling Growers' Association.

Management Applications and Seed Production Guidelines:
The two species identified in sagebrush roots, *G. intraradices* and *G. microaggregatum* are cosmopolitan species found in many commercial inoculums. However, *G. intraradices* and *G. microaggregatum* have different strains. The strains present in sagebrush roots may be different from those in commercial inoculums. Thus, we do not recommend the use of commercial inoculum at this point until more is known about the ability of different strains to aid in the establishment of sagebrush seedlings and to cope with the conditions of sagebrush habitats.

Products:
GBNPSIP research and collaboration with Dr. Nancy Shaw have been very important to obtain a grant from the USDA-NIFA (grant No 2010-85101-20480). This grant has provided funds to study in more detail the mycorrhizal species and strains that colonize sagebrush and to analyze the effect of mycorrhizal colonization on seedling establishment.

Literature Cited:
Gollotte, A., et al. 2004. Diversity of arbuscular mycorrhizal fungi colonizing roots of the grass species *Agrostis capillaries* and *Lolium perenne* in a field experiment. *Mycorrhiza*. 14:111-117.

Project Title: Developing Protocols for Maximizing Establishment of Two Great Basin Legume Species

Project: USDA-ARS Forage and Range Research Lab, Logan, Utah

Principal Investigators and Contact Information:

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Project Description:
This project occurs in two phases. The first phase is to determine how the age of seed, the depth of planting, and the scarification treatment affects germination and emergence of *Dalea ornata* (western prairie clover) and *Astragalus filipes* (basalt milkvetch). The second phase is to plant seed in several sites across genetic and environmental gradients and test if the more local sources germinate or establish better than distal sources. These objective approaches are summarized below.

Determine the best seed treatments to maximize germination
Hard seededness is a common feature in legume species, which limits initial, uniform germination and subsequent establishment. The effects of various seed treatments (mechanical scarification, acid scarification, boiling water treatment, and control) and age of seed (newly harvested up to one-year-old seed) will be investigated for each of the major seed sources of the three legume species. All combinations of these treatments will be tested in a greenhouse to determine which combination of treatments yields the best germination and seedling establishment.

Identify planting depths and seasons that will give the best success
Given the data obtained from Objective 1, the best treatment combination will be used in actual field evaluations. Seeds from each species and source will be planted with either a walk-behind drill seeder or a RoughRider range drill. Replicated fall dormant plantings will be tested twice at each of several locations. First and second year establishment/survival will be recorded at each of the test sites.

Assess how seed sources will establish across genetic structures and environmental gradients
Up to three locations will be planted for each species. Locations for western prairie clover and basalt milkvetch will be at sites in Oregon, Idaho, and Nevada. Exact test locations will be coordinated with the BLM and USFS, or the USDA-ARS Area-Wide Project, and plots will be protected from grazing. The exact locations will be situated to span genetic structures as well as the environmental gradients shown to be most highly correlated with collection sites. Establishment data will be collected for two years post-planting, but sites will be kept to allow for long-term observation.

Publications:

Bhattarai, K. 2010. Phenotypic and genetic characterization of wildland collections of western and Searls prairie clovers for rangeland revegetation in the western USA. PhD Dissertation, Utah State University, Logan, UT.

Bhattarai K, *Bushman B.S., Johnson D.A., Carman JG. 2010. Phenotypic and genetic characterization of western prairie clover collections from the western USA. *Rangeland Ecology and Management* 63(6):696-706.

Bhattarai K, *Bushman B.S., Johnson D.A., Carman JG. 2011. Searls' Prairie Clover (*Dalea Searlsiae*) for Rangeland Revegetation: Phenotypic and Genetic Evaluations. *Crop Science* 51(2):716-727.

Bushman, B. S.; Johnson, D. A.; Bhattarai, K. 2010. Phylogeographic characterization of genetic diversity in basalt milkvetch. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 60-67.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

Bushman, B. S.; Johnson, D. A. Legume seed source decisions from common garden traits and genetically differentiated groups. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Johnson, D. A.; Bushman, B. S. Seed increase needs for three North American rangeland legumes: basalt milkvetch, western prairie clover and Searl's prairie clover. Workshop: seed production of native grasses and forbs, 2010 February 23, Ontario, OR.
http://www.fs.fed.us/rm/boise/research/shrub/projects/Ontario2010.html

Management Applications and Seed Production Guidelines: Seed producers will benefit by knowing how to obtain stands of these two species for seed production. Land managers will be provided with data to show expected germination and establishment in different regions, seasons, and planting practices.

Products: Germplasm releases for the species, seed production guidelines, planting guides, peer reviewed publications, and other reports.

Project Title: Native Plant Material Development and Cultivation Trials for Native Great Basin Forbs and Grasses

Project Location: Great Basin Research Center, Ephraim, Utah

Principal Investigators and Contact Information:

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Project Description:
We are working on developing cultural practices for several forb species in the Great Basin. Currently we are focusing on improving germination techniques through mechanical, chemical, and thermal scarification methods.

We continue maintaining research properties in Fountain Green and Ephraim. In addition to various research projects these properties are used to establish foundation seed fields and increase seed for distribution to growers.

Forging relationships with new growers also continues to be a priority, thereby allowing us to increase seed availability from small collections to larger quantities and providing seed for larger production fields and landscape scale restoration projects.

We are continuing to find new methods to deal with disease and pest issues that have become apparent in agricultural settings. We are also striving to purchase or develop necessary cultivation machinery to enable the success of the project.

Project Status

Wildland Seed Collections. This year after some discussion with the Forest Service and BLM we decided that pooled source accessions would be a more practical approach to increase most forb species in the Great Basin. A pooled source collection allows opportunity for smaller collections and diverse sites to be genetically represented when they would otherwise not be included. Another advantage of pooled source material is the potential it has to be more adapted to a broader variety of sites. Seed was collected primarily by the SOS crews this year and then planted at Fountain Green and Ephraim locations for increase. We will continue maintaining increase plots for distribution to growers in 2011.

Species Status.

Sphaeralcea spp. New common gardens of globemallow species were established in 2009 in Nephi and at the Desert Experimental Range (DER), west of Milford. This was done in an effort to confirm seed production data that was collected in 2008 from the Fountain Green common garden. Grasshoppers ate all the foliage at the Nephi site, but not before the plants had time to establish. However very few plants re-sprouted in 2010. Survival data from the common garden at the DER was collected in June of 2010. The DER site is an extremely dry site so the survival and production data that will be collected from this site will provide good drought tolerance data for the accessions planted there. Climate data is also being collected at the site. Due to the loss of the Fountain Green common garden to rust, we also plan on evaluating the resistance of each accession to rust at the new DER common garden. A pooled source release might not be the best idea for this genus due to the possibility of losing a significant number of plants from a particular accession to disease. Further investigation is needed to determine if some accessions are more resistant and would therefore be better suited for cultivation.

Eriogonum ovalifolium. In 2009 we collected data on the cushion buckwheat common garden using flower height as an indicator of mechanical harvestability. Because of the poor seed set we used flower number as a surrogate for possible seed production. After analyzing the data we discovered that there are significant differences between accessions for both of these categories. We designed a scoring system to incorporate both the flower height and flower number data. In order to obtain better baseline data on seed production we harvested seed from each individual plant in 2010. We are currently cleaning these collections in order to confirm that flower number is a good surrogate for seed set. To try to increase seed set, we are building pollination boxes to induce forced pollination. We will compare quantities between the 2010 collection and the 2011 collection to determine the effect of forced pollination. Once seed is acquired, a pooled source accession increase plot will be established. Evaluation of mechanical harvesting methods will be conducted in order to provide mechanical seed harvesting information for growers.

Balsamorhiza spp. Arrowleaf balsamroot (*B. sagittata*) has posed problems primarily because of the time it takes to establish. In the fall of 2009 we experimented with a new planting method. We used nursery bedding equipment to create a perfectly flat planting surface and then seeded on the beds with a 6-inch row spacing. We were able to establish a dense stand of plants from seed in spring of 2010. In 3 to 4 four years, when the plants are mature, we will use a root lifter to remove the plants from the bed and then transplant them into a production field setting. The use of dense beds until establishment would lower the initial land investment for a grower. We continue to work with Hooker's balsamroot (*B. hookeri*) and have included it in the above mentioned study. More wildland collections are needed for this species to bulk up stock seed for direct seeding.

Seed Scarification Studies.

Sphaeralcea spp. We had success in 2007 using acid scarification to reduce dormancy in globemallow. However, concentrated sulfuric acid is not the easiest chemical to acquire and handling the acid poses some risk. Consequently, treating large quantities of seed using this method is not our first choice. Additionally, thermal scarification is more practical than using sulfuric acid. Pouring boiling water over the globemallow seed melts away the waxy cuticle and allows the seed to imbibe and germinate. Preliminary studies using this method were conducted during fall 2008 and showed promise. In 2009 and 2010, we continued using this method of scarification on globemallow seed prior to direct seeding and were able to establish dense production stands. More research will be done to quantify optimal water temperature and exposure time so that maximum germination is obtained with minimum embryo death.

Lupinus arbustus. We did not show an increase in germination with scarification. All scarification treatments on *L. arbustus* damaged the embryo, negatively impacting germination. The seed coat on *L. arbustus* is noticeably thinner than that of the other species in this study and could explain the embryo damage.

Lupinus argenteus. Acid and mechanical scarification yielded the best results for this species. Germination peaked at 87% with acid scarification after 5.5 minutes of treatment exposure (fig. 1). Germination after mechanical scarification of *L. argenteus* also peaked at 87% with a treatment time between 5.5 and 6.5 seconds. Unlike acid scarification on *L. argenteus,* mechanical scarification did not show the sharp decline in germination after the optimal scarification point was reached. However germination did become less predictable when exposure time was >7 seconds.

Lupinus prunophilus. Chemical scarification worked well for this species. Acid scarification of *L. prunophilus* did not have a definite peak in germination but increased with exposure time to the treatment (fig. 2). The Clorox bath produced the highest germination (79%) when treated for 110 to 115 minutes. Mechanical scarification of *L. prunophilus* resulted in only 59% germination after two seconds and declined by 30% when it reached the final exposure time of 10 seconds (fig. 3). The seed was visibly damaged by the mechanical scarifier.

Lupinus sericeus. This species is typically not a dormant species. However, it did show improvement in germination when scarified. With only 2 seconds of exposure in the mechanical scarifier, germination increased from 22% to 80% (Fig. 4). We demonstrated that some scarification on *L. sericeus* may help with increased uniformity of germination. Scarified seed may be able to take advantage of soil moisture by putting down a root sooner than unscarified seed.

From this study we were able to determine scarification methods that yield the highest germination for these four lupine species. Continued research could focus on using this data as a baseline to test multiple accessions of these same species from The Great Basin. That would help us to better predict how each scarification method and duration would act on a given species and thereby improve germination for cultivation.

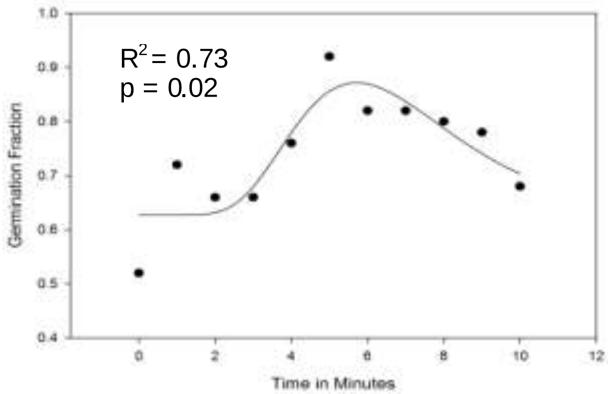

Figure 1. Chemical scarification of *Lupinus argenteus* with sulfuric acid.

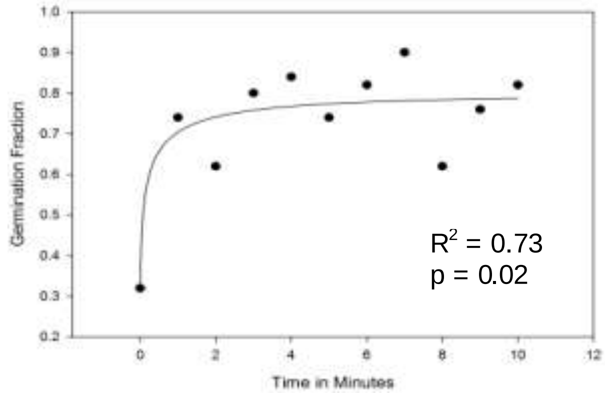

Figure 2. Chemical scarification of *Lupinus prunophilus* with sulfuric acid.

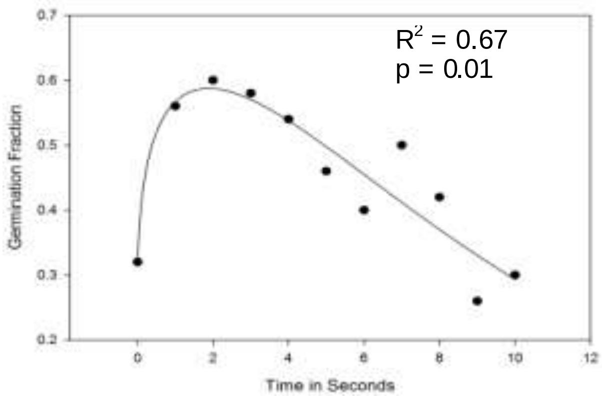

Figure 3. Mechanical scarification of *Lupinus prunophilus*.

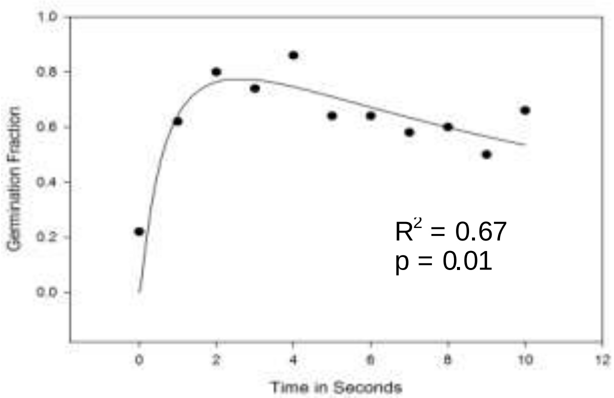

Figure 4. Mechanical scarification of *Lupinus sericeus*.

Forb Island Study

After experiencing much greater germination and establishment success on our field plantings using N-Sulate fabric row cover, we wanted to investigate the use of this fabric to increase establishment of native forbs in a wildland setting. Due to the high cost of native forbs, we wanted to look at targeted establishment of "forb islands" that may have much greater establishment with the help of this row cover. N-Sulate fabric has made as much as a 1,000 fold increase of germination for some species in our field plantings. The fabric is light permeable, increases heat and improves moisture retention during the germination period. In fall 2009 we established four study locations, three in the Great Basin and one on the Colorado Plateau. Each site is set up so that it will statistically stand alone but can also be combined with the other sites. Using two seed mixes we will compare germination and establishment of plots that were either covered with N-Sulate fabric or not covered. In June 2010, we collected germination data on the plots. From this first year of data we found that the N-Sulate fabric increased germination on most of the seeded species (Fig 5a and b). The greatest increase was for germination of *Balsamorhiza sagittata, Hedysarum boreale, Linum lewisii,* and *Agoseris* species.

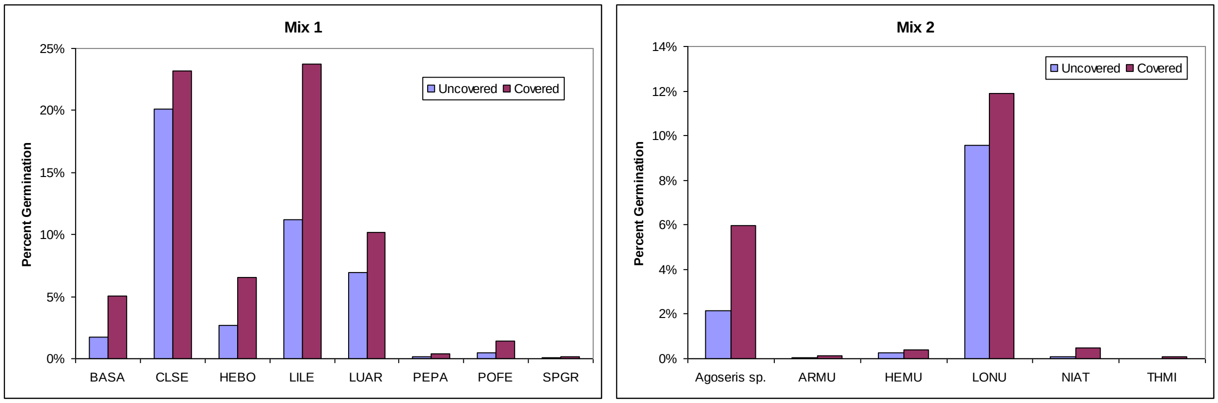

Figure 5a and b. Percent germination in June 2010 for the two seed mixes on all four sites.

We also found that the N-Sulate fabric had a larger effect on germination on the drier sites (Fig 6). The Lookout Pass and Hatch Ranch sites only receive 8-10 inches of precipitation each year, while the other two sites receive 12-14 inches. Another effect of N-Sulate fabric was increased cover of cheatgrass (Fig 7). We saw a large increase in cheatgrass cover on the sites that already had cheatgrass present. In October 2010 we replicated the study at each of the four sites. In 2011, we will collect germination data on the plots established in 2010 and we will collect establishment data on the plots treated in 2009. In the future we will continue to collect survival data as well as recruitment data outside of the plots.

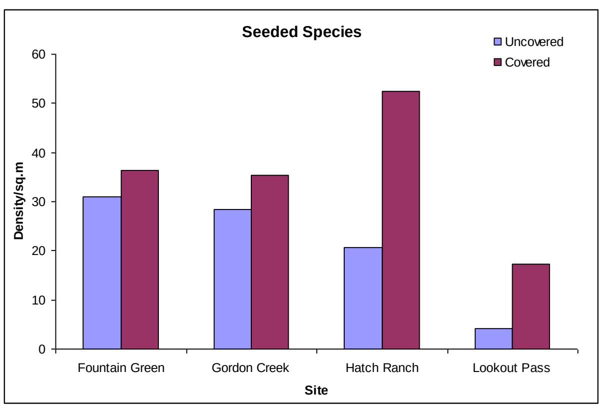

Figure 6. Total density of all of the seeded June species by site in June 2010.

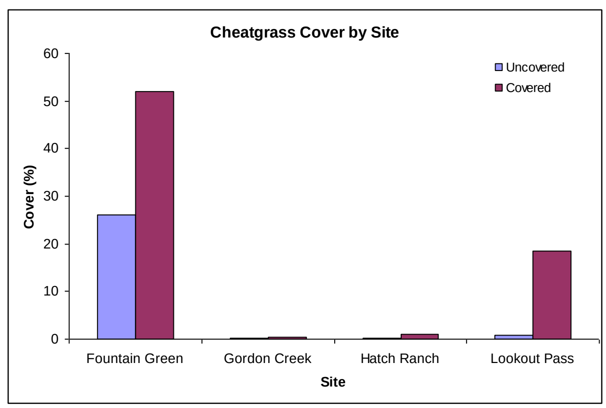

Figure 7. Cheatgrass cover by site in 2010.

Publications:

Jones, C.; Whittaker, A. 2010. Native plant material development and cultivation trials for native Great Basin forbs and grasses. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 18-23.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

Jones, C. Progress on multiple fronts. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Jones, C. Native forbs- cultural practices. Seed Production of Native Grasses and Forbs Workshop; 2010 February 23; Ontario, OR. http://www.fs.fed.us/rm/boise/research/shrub/projects/Ontario2010.html

Jones, C.; Jensen, S.; Stevens, M. R.. 2010. An evaluation of seed scarification methods for four native *Lupinus* species. Seed Ecology III Conference; 2010 June 20-24, Salt Lake City, UT. (poster presentation)

Jones, C.; Whittaker, A.; Summers, D.; Jensen, S. 2010. Establishing forb islands in wildland restoration using N-sulate fabric. National Native Seed Conference; 2010 May 17-21, Snowbird, UT. (poster presentation)

Jones, C.; Whittaker, A.; Summers, D.; Jensen, S. 2010. Establishing forb islands in wildland restoration using N-sulate fabric. 16th Wildland Shrub Symposium; 2010, May 18-20, Logan, UT. (poster presentation)

Field Tours

Vernon, J.; Summers, D.; Whittaker, A.; Jones, C.; Memmott, K. 2010. Common gardens and seed facilities tour. National Native Seed Conference; 2010 May 17, Fountain Green Farm and Great Basin Research Center Headquarters, Ephraim, UT.

Vernon, J.; Summers, D.; Whittaker, A.; Jones, C.; Memmott, K. 2010. Common gardens and seed facilities tour. Seed Ecology III Conference; 2010 June 23, Fountain Green Farm and Great Basin Research Center Headquarters, Ephraim, UT.

Management Applications:

Land Managers

Several of the seed increase fields of globemallow that were established in 2008 did well. We scaled up in 2009 and added three new growers growing different accessions of the same species. With more seed being produced by these growers we encourage seed purchasers to keep these growers in mind when buying seed in the coming years.

After just one year of data collection, the use of N-Sulate fabric appears to be a potential option to help establish native forbs in a wildland setting. This is not a treatment that a land manager could cost effectively apply to an entire landscape-scale project but could be used to establish forbs in specific small areas of the site. More research needs to be done to test cost/benefit and to test other row covers that may be more cost effective.

Seed Producers

We are now able to provide seed producers and restoration facilitators with information on scarification of globemallow and lupine species to facilitate stand establishment using less seed. Depending on the species of lupine it may or may not need scarification. *L. arbustus* doesn't require any scarification and can actually be significantly damaged by it. *L. argenteus* and *L. prunophilus* seed germination increase with both chemical and mechanical scarification. *L. sericeus* seed germination increases with mechanical scarification. Globemallow seed germination is increased by scarifying the seed with a hot water bath.

Products:

Growers

The Canady Farm in Elko, Nevada has 47 acres in a very sandy soil type. They recently acquired the property and about 10 acres were in good planting condition. They have plenty of water to establish and grow native plants. They also have experience with wildland seed collecting. In 2008, we planted 5 acres and 24 different species on the Canady farm. We have the lead on three of the species, but only one of the three species established at increase field density. In 2009, we scaled up, adding 1.5 acres to what they had originally planted using seed from the original source (table 1).

The Bell farm comprises over 700 acres just north of Vernon, Utah, and is a clay loam soil type. Mr. Bell, the managing partner of Biograss Sod Farms, is currently harvesting several species of grass as sod on most of the land. In the past he has grown several penstemon species so growing natives is not completely new to him. We were able to plant 22 species at the Bell farm on 10 acres of land. We have the lead on five of those species. Of those five species planted in 2008, it was determined in 2009 that two did well and established at densities that warrant a seed production field. We scaled up with those two species adding 0.25 acres of scarlet globemallow and one acre of gooseberryleaf globemallow.

The Tripp farm is a small residential orchard in Spring City, Utah. The Tripp farm has limited space on their land so we have worked together with them to establish transplants in weed barrier for some of the more difficult species to cultivate and harvest. We used a pooled source accession approach to increase genetic diversity.

The Jones farm is located 45 minutes north of Kemmerer, Wyoming at just over 7,000 feet in elevation. We planted five species on the Jones farm of which we have the lead on one.

Table 1. Seed production fields established in 2010.

Grower	Species	Common name	Acreage Seeded
Tripp	*Balsamorhiza hookeri*	Hooker's balsamroot	0.01
Tripp	*Balsamorhiza sagittata*	Arrowleaf balsamroot	0.01
Tripp	*Crepis acuminata*	Tapertip hawksbeard	0.01
Tripp	*Crepis intermedia*	Limestone hawksbeard	0.01
Jones	*Sphaeralcea coccinea*	Scarlet globemallow	1.50
Bell	*Sphaeralcea coccinea*	Scarlet globemallow	0.75
Hanks	*Sphaeralcea coccinea*	Scarlet globemallow	0.75
Young	*Sphaeralcea coccinea*	Scarlet globemallow	0.75
Canaday	*Sphaeralcea grossulariifolia*	Gooseberryleaf globemallow	2.13
Bell	*Sphaeralcea grossulariifolia*	Gooseberryleaf globemallow	2.00
Hanks	*Sphaeralcea grossulariifolia*	Gooseberryleaf globemallow	2.00
Young	*Sphaeralcea grossulariifolia*	Gooseberryleaf globemallow	2.00

For a full list of species planted at each location contact Covy Jones or Scott Jensen.

Project Title: Selecting and Growing Great Basin Natives

Project: USDA FS, RMRS, GSD Shrub Sciences Laboratory, Provo, Utah

Principal Investigators and Contact Information:

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[2]Seeds of Success, Chicago Botanic Gardens Interns

Project Description:
As part of the Great Basin Native Plant Selection and Increase Project we work in a variety of areas. In 2010 we were involved in wildland seed collection, seed increase at several farm locations, screening of plant materials, evaluating density dependent seed yields of *Agoseris heterophylla*, evaluating clipping effects on *Ipomopsis aggregata* seed production, soil solarization with plastic mulches, transplanting rootstock of two *Lomatium* species into production fields, and equipment modification and development.

We benefited from four Seeds of Success interns, employees of the Chicago Botanic Garden funded through the 2009 American Recovery and Reinvestment Act. The interns made over 400 seed collections from 81 species. This provided a tremendous boost of stock seed for our research, inclusion into long-term germplasm storage through the ARS GRIN system, distribution to cooperators, increase plantings and distribution to growers.

<u>Cultural Practices</u>
Among *Agoseris* species present in the Great Basin, *Agoseris heterophylla*, an annual species, responds well to cultivation by producing a robust canopy of flowering stems in response to irrigation and fertilizer. The dramatic increase in seed production places this species among the best candidates from the genus for commercial production. *Agoseris heterophylla* disperses seed readily when ripe and as such is viewed as a high risk for outdoor production. If grown indoors, maximizing yield is of value. We evaluated density dependent (4 – 400 plants / 2.9 ft^2) seed yields on two soil types over two years. Data are being analyzed.

<u>Clipping effects on flower production of *Ipomopsis aggregata*</u>. Field observations suggest browsing *Ipomopsis* plants resulted in bushier canopies with increased flower numbers. Canopies of two *Ipomopsis* sources were clipped on June 21, 2010 and July 15, 2010 to simulate browsing.

Both treatments resulted in approximate fourfold reduction in the number of flowers as compared to the control plants. If browsing does result in bushier canopies and increased flower set, the late June and mid-July treatment times miss a critical phenological interval. In a natural setting *Ipomopsis* plants would have been nearing the end of bloom by the June treatment date. With periodic irrigation at our farm site, phenology was delayed and plants were in early to mid bloom. Future evaluation should focus on browsing at the rosette stage or during initial bolting.

Seed yields of three *Lupinus* species. Several *Lupinus* species are often among the most requested herbaceous forbs. Some lupines are available from wildland collections but in limited quantities with prices typically in excess of $60 a pound. Great Basin genera exhibit variation in flowering, ripening and seed shatter. *Lupinus arbustus* flowers more determinately than other Great Basin lupine species. This characteristic facilitates a single mechanical harvest when grown under cultivation. The less determinate species, *Lupinus argenteus* and *Lupinus sericeus* yield best with multiple hand harvests, but timing a single mechanical harvest to peak seed maturity is the best way to minimize harvest cost. Yield data derived from a single mechanical harvest at peak seed ripeness and extrapolated to a per acre basis for *Lupinus argenteus, Lupinus sericeus*, and *Lupinus arbustus*, show yields of 35, 24 and 50 pounds per acre respectively. Based on these yields the market price of lupine is not likely to be reduced under cultivation. As lupines are not particularly difficult to grow, the volume of seed available in the marketplace could be substantially increased through agronomic production.

Soil solarization. Popularity of soil solarization is increasing among organic farmers as a method to control diseases, nematodes and some weeds while increasing nutrient solubility and beneficial soil bacteria. The practice is most common in hot sunny areas such as central California and Florida. The process involves covering moist soil beds with thin (1–4 mil) clear plastic for 4 to 6 weeks to achieve an accumulation of time at temperatures above 120° F. Soil temperatures in excess of 120° F cause mortality to nematodes while temperatures in excess of 140° F cause mortality to fungi and bacteria. To impact other soil insects, bacteria, viruses and weed seeds temperatures must reach 150° F to 180°F. At Fountain Green, Utah 1 mil plastic sheeting was tightly rolled and tucked onto moist nursery beds with a plastic mulch layer on July 28, 2010 and removed August 21, 2010. Under the plastic, temperature sensors were placed both at the soil surface and buried 3 inches below the soil surface. Data loggers recorded temperatures at 10 min. intervals. At the soil surface, 140°F was exceeded for 310 minutes and temperatures between 120 – 140°F were achieved for 1535 min. At the three-inch depth temperatures between 120 – 140°F were achieved for 615 min. while temperatures in excess of 140°F were achieved for only 10 minutes. The full complement of beneficial results may have been attained at the soil surface but did not penetrate to the 3 inch depth. Future work should evaluate whether applying the plastic film by the third week of June and leaving it in place through the end of August would achieve beneficial results.

Transplanting *Lomatium* rootstock into production fields. Several often requested species, hawksbeards, arrowleaf balsamroot and some biscuitroots, require 3 to 5 years to produce the first seed crop. If rootstock of these species could be grown in high-density production beds to flowering size then transplanted into production fields and produce seed the subsequent year, the expense of having non-producing land could be minimized. Rootstock of two biscuitroot species, *L. grayi* and *L. triternatum* were available spring 2010 from Oregon State University's

Malheur Experiment Station. While neither species require an extended timeframe to produce the first seed crop they do serve as a good surrogate for evaluating challenges encountered in the lifting and transplanting process. Using a crop lifter, rootstock was cut 10 inches long then transplanted into private production fields in Nevada using a tree transplanter. Other rootstock was separated into size classes based on crown diameter and transplanted into shovel-dug holes at three locations in Utah. These materials will be evaluated in 2011, assessing survival and seed yields.

Future plans

Database development. Create a Microsoft Access database to house our growing collection of plant materials related information.

Herbarium searches. As part of an effort to understand species distribution across the landscape, herbarium searches are being conducted for approximately 30 species. Vouchers with precise source location information are logged into a database. This data has proven useful in viewing distribution across provisional seed zones. We anticipate extracting data from various GIS layers to aid in understanding species distribution limitations and making recommendations for revegetation plantings.

Screening plant materials using an electronic database. Interactive Plant Keys for the Great Basin, an electronic database, created by Bruce Barnes of Flora ID Northwest is being evaluated for its utility in initial screening of plant materials. A variety of morphological characteristics are common to species currently produced in agronomic settings. The interactive plant key permits exclusion or inclusion of species based on presence or absence of a large number of plant characteristics.

Equipment development. Design and fabrication of a hooded row cover for herbicide spraying on high-density nursery beds. Design and fabrication of wheel extenders to permit a compact Kubota tractor to straddle nursery beds. Modification of a fabric roller to roll both 6' and 12' materials. All projects are in cooperation with Utah Division of Wildlife Resources Great Basin Research Center.

Publications:

Jensen, S.; Anderson, M.; Nielson, M.; Sorenson, K. 2010. The qwest for natives: cultural practices, species screening and private growers. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 11-17. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

Jensen, S. Equipment and cultural practices for native seed production. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Jensen, S. Equipment and cultural practices for native seed production. Workshop: seed production of native grasses and forbs, 2010 February 23, Ontario, OR. http://www.fs.fed.us/rm/boise/research/shrub/projects/Ontario2010.html

Jensen, S. Selecting and growing Great Basin natives. National Native Seed Conference, 2010 May 17 - 21, Snowbird, UT.

Jensen, S. Selecting and growing Great Basin natives for fire restoration. All scientists meeting, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 2010 March 23 – 25, Fort Collins, CO.

Jensen, S., Jones, C., Field tour. Cultural practices and equipment for native forb production. National Native Seed Conference, 2010 May 17-21, Snowbird, UT.

Products:

Equipment development/modification

- Fabrication of a toolbar and plow feet to convert a 6' mulch layer to a 12' model suitable for laying N-Sulate fabric.
- Fabrication of a plow foot and bracket to modify an ECO Weeder II for mid row weeding.

Wildland seed collection 2010

- 21 collections from 2 grass species
- 237 collections from 63 forb species
- 144 collections from 16 shrub species

Tours and Demonstrations

- A hot water bath for scarifying globemallow seed. Workshop: seed production of native grasses and forbs, 2010 February 23, Ontario, OR.
- Cultural Practices and Equipment for Native Forb Production. National Native Seed Conference, 2010 May 17 - 21, Snowbird, UT.

Stock seed production – seed increase

- *Enceliopsis nudicaulis* – 189 g
- *Nicotiana attenuata* – Shipped to USFS Bend for cleaning
- *Heliomeris multiflora* var. *nevadensis* – 5 sources: 13 g, 74 g, 82 g, 151 g, 174 g
- *Phacelia crenulata corrugate* – 4.8 lbs
- *Mentzelia laevicaulis* – 180 g
- *Lupinus arbustus* – 2.51 lbs
- *Agoseris heterophylla* – 124 g

Stock seed production – Increase plot installation

- Between two Utah farm sites, 93 sources of 21 species were planted into 192 increase beds or rows grouped by provisional seed zone.

Seed distribution to growers

- Increase beds of *Agoseris heterophylla* and *Agoseris grandiflora* were spring planted in Fountain Green, Utah at the Hansen farm.
- *Lomatium triternatum* rootstock from Malheur Experiment Station was transplanted in Spring Creek, Nevada at the Canaday farm.

- *Lomatium grayi* rootstock from Malheur Experiment Station was transplanted in Orovada, Nevada, at McClintick Farms.

Seed distribution to cooperators.

- 17 collections of *Elymus elymoides* were sent to Brad St. Clair, Research Geneticist, USDA Forest Service, Pacific Northwest Research Station, for inclusion in a genecological study.
- Seed of *Heliomeris multiflora, Crepis intermedia, Balsamorhiza sagittata* was provided to Clint Shock, Oregon State University Malheur Experiment Station, for emergence trials.

The National Technology and Development program selected two project proposals for development beginning in 2011.

- Development of a specialized seed harvester for species with indeterminate ripening and seed shatter characteristics.
- Development of a propane fired weed control service pack for thermal weed control in nursery beds and seed production fields.

Awards

Partners in Conservation award for the Great Basin Native Plant Selection and Increase Project's partnership with the national BLM Seeds of Success program.

Project Title: Cooperative Work between the Great Basin Native Plant Selection and Increase Project and the Aberdeen Plant Materials Center

Project: USDA-NRCS Plant Materials Center Aberdeen, Idaho

Principal Investigators and Contact Information:

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Project Description:

1. Production of Certified Generation 1 (G1) seed of Anatone Germplasm bluebunch wheatgrass to facilitate commercial seed production.
2. Assist in re-establishment of native plant diversity in crested wheatgrass monocultures of the Great Basin and equipment and strategies to enhance the post-wildfire establishment and persistence of Great Basin native plants.
3. Propagation of native forbs for evaluation and seed increase.

Seed Production

Due to the high demand for Anatone bluebunch wheatgrass Certified stock seed, the Aberdeen Plant Materials Center (PMC) increased acreage of seed production from 1.0 acre to 5.2 acres in 2007. The following table shows acres of seed production, production yields and Certified seed shipped to commercial growers from 2007 to 2010.

Year	Acres in seed production	Seed Yield (pounds)	Seed Shipped (pounds)
2007	5.2	1,384	400
2008	4.2	478	775
2009	7.4	280	450
2010	5.0	896	155

Crested Wheatgrass Diversification and Post-fire Seedings

In 2008, seeding trials were planted near Elko, Nevada in cooperation with the University of Nevada Extension Service and near Aberdeen, Idaho in cooperation with the USDA-ARS Sheep Experiment Station. Modifications were made to a Truax Rough Rider range drill and a Kemmerer range drill to broadcast and drill seed in the same pass with alternate rows of broadcast and drill seeding. The PMC prepared the seed mixes and planted the sites in late October and early November, 2008. The following tables list the mixes for each site:

South Fork, NV 2008

Broadcast Mix (12.5 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Mtn. Home Sandberg bluegrass	0.75	0.92
Appar blue flax	0.75	0.83
Eagle western yarrow	0.20	0.45
Wyoming big sagebrush	0.20	1.31
Spiny hopsage	0.50	1.37
Rice Hulls	n/a	8.88

Drill Mix (12.5 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
'Nezpar' Indian ricegrass	2.00	2.03
Toe Jam squirreltail	2.00	2.26
Needle and thread grass	2.00	3.21
'Magnar' basin wildrye	2.00	2.10
'Secar' Snake River wheatgrass	1.00	1.08
Munro's globemallow	0.50	0.76
Rice Hulls	n/a	2.32

Grandview, ID 2008

Broadcast Mix (12.90 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Maple Grove Lewis flax	0.40	0.43
Mtn. Home Sandberg bluegrass	0.20	0.24
Royal Penstemon	0.40	0.56
Wyoming big sagebrush	0.05	0.29
Rubber rabbitbrush	0.15	1.01
Rice Hulls	n/a	7.29

Drill Mix (12.90 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Anatone bluebunch wheatgrass	3.20	3.60
'Magnar' basin wildrye	0.80	1.04
'Bannock' thickspike wheatgrass	0.60	0.74
Thurber's needlegrass	0.60	0.99
Rice Hulls	n/a	7.29

The second year of seeding trials was completed at the Grandview site in cooperation with the USDA ARS Sheep Experiment Station in 2009. The following seed mixes were prepared and the plots were planted November 2-3, 2009.

Grandview, ID 2009

Broadcast Mix (12.90 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Maple Grove Lewis flax	0.40	0.44
Mtn. Home Sandberg bluegrass	0.20	0.22
Royal Penstemon	0.40	0.50
Wyoming big sagebrush	0.05	0.25
Rubber rabbitbrush	0.15	1.20
Rice Hulls	n/a	7.11

Drill Mix (12.90 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Anatone bluebunch wheatgrass	3.20	3.60
'Magnar' basin wildrye	0.80	0.85
'Bannock' thickspike wheatgrass	0.60	0.67
Thurber's needlegrass	0.60	0.94
Rice Hulls	n/a	6.40

Seed was mixed and seedings were completed October 25-29, 2010 at Black Butte, Idaho and at Southfork, Nevada.

Black Butte, ID 2010

Cover Crop Mix (20.00 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
'Rimrock' Indian ricegrass	3.69	4.03
Anatone bluebunch wheatgrass	4.01	5.17
Rice Hulls	n/a	6.06

Drill Mix (44.2 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Anatone bluebunch wheatgrass	1.97	2.46
Bottlebrush squirreltail	0.99	1.02
'Rimrock' Indian ricegrass	1.82	1.88
Needle and thread grass	1.01	1.30
Thurber's needlegrass	0.82	1.48
Basalt milkvetch	0.45	0.50
Munro's globemallow	0.61	1.00
Rice Hulls	n/a	0.26

10X Broadcast Mix (5.20 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Wyoming big sagebrush	0.94	3.30
Rubber rabbitbrush	0.40	0.98
Sandberg bluegrass	0.39	0.47
Eagle yarrow	0.15	0.16
Royal penstemon	0.12	0.21
Rice Hulls	n/a	6.44

5X Broadcast Mix (33.8 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Wyoming big sagebrush	0.46	1.62
Rubber rabbitbrush	0.40	0.98
Sandberg bluegrass	0.39	0.47
Eagle yarrow	0.15	0.16
Royal penstemon	0.12	0.21
Rice Hulls	n/a	8.67

Standard Broadcast Mix (5 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Wyoming big sagebrush	0.09	0.33
Rubber rabbitbrush	0.39	0.96
Sandberg bluegrass	0.38	0.46
Eagle yarrow	0.14	0.15
Royal penstemon	0.12	0.21
Rice Hulls	n/a	5.60

South Fork, NV 2010

Broadcast Mix (12.5 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Mtn. Home Sandberg bluegrass	0.75	0.85
‘Appar’ blue flax	0.75	0.93
Eagle yarrow	0.20	0.22
Wyoming big sagebrush	0.20	1.20
Spiny hopsage	0.50	1.30
Rice Hulls	n/a	9.26

Drill Mix (12.5 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
'Nezpar' Indian ricegrass	2.00	2.15
Toe Jam squirreltail	2.00	2.17
Needle and thread grass	2.00	2.53
'Magnar' basin wildrye	2.00	2.07
'Secar' Snake River wheatgrass	1.00	1.32
Munro's globemallow	0.50	0.69
Rice Hulls	n/a	2.83

Maintenance of forb seed increase plots

The original project plan in 2005 was to propagate 8,000 plants total of *Lomatium dissectum* (LODI) fernleaf biscuitroot, *Lomatium grayi* (LOGR) Gray's biscuitroot, *Lomatium triternatum* (LOTR) nineleaf biscuitroot, *Eriogonum umbellatum* (ERUM) sulphur-flower buckwheat, *Penstemon deustus* (PEDE) hotrock penstemon, *Penstemon acuminatus* (PEAC) sharpleaf penstemon, and *Penstemon speciousus* (PESP) sagebrush penstemon, in the greenhouse. Approximately 1000 plants each of ERUM and LOTR were to be transplanted at the PMC and remaining plants were to be made available to cooperators for transplanting at field locations.

Due to no plant establishment of *Lomatium* species and minimal success with greenhouse propagation of *Penstemon* species, no plants were made available to cooperators. All plants that were successfully propagated in the PMC greenhouse were transplanted at the PMC during the 2005 growing season and direct dormant seeding of *Eriogonum*, *Lomatium* and *Penstemon* accessions were completed at the PMC in November 2005. Weed barrier fabric was installed to control weeds.

2007 Activities. On May 8, 2007 the biscuitroot and sulphur-flower buckwheat plots were treated with a wick application of 100 percent Roundup to control weeds and on June 18 the plots were hand weeded. On June 20, 2007 survival counts were made and seed was harvested at seed ripeness and the results are shown in the following table:

Species	Survival (percent)	Clean seed (pounds)
ERUM	40	4.0
LODI	25	NA
LOGR	70	NA
LOTR	71	NA
PEAC	68	8.0
PEDE	58	19.0
PESP	60	0.7

By early July, the *Lomatium* species were completely dormant. None of the *Lomatium* plants had yet developed flowers. It is thought that most of their energy was going into the development of the taproot. In early November 2007 the dormant *Lomatium* plots were treated with a spray application of Roundup to control weeds that were still green. PEAC (a short-lived species) was beginning to die out.

2008 Activities. On May 15, 2008 the sulphur-flower buckwheat plots were treated with a wick application of 100 percent Roundup to control weeds and on June 10-11 all plots were hand weeded. The following table shows harvest date and seed yield for the accessions that were harvested:

Species	Harvest Date	Clean seed (pounds)
ERUM	8/13	12.6
LODI	NA	NA
LOGR	NA	NA
LOTR	7/3	2.6
PEAC	NA	NA
PEDE	NA	NA
PESP	8/8	1.5

By early July, the *Lomatium* species were completely dormant. The only *Lomatium* to flower and set seed was LOTR. LODI and LOGR have yet to flower after 3 years of establishment. It was thought that most of their energy was still going into the development of the tap root. In early November 2008 the dormant *Lomatium* plots were treated with a spray application of Roundup to control weeds that were still green. PEAC and PEDE (short-lived species) had died out to the point that no seed was harvested in 2008.

The USDA-FS Rocky Mountain Research Station in Boise, Idaho cleaned the seed that was harvested from the plots. Some of the seed was utilized for the seeding trial conducted at Snowville, Utah for the Equipment and Strategies to Enhance the Post-wildfire Establishment and Persistence of Great Basin Native Plants study.

2009 Activities. Weeds were controlled by hand during 2009. ERUM was harvested mostly by combine but was followed by hand harvesting. The plots of the other species were harvested by hand. LODI and LOGR finally produced seed in 2009, the fourth year of establishment. PESP was the only penstemon accession still surviving, the others being short-lived. The following table shows harvest date and seed yield for the accessions that were harvested in 2009:

Species	Harvest Date	Clean seed (pounds)
ERUM	8/4	11.3
LODI	7/1	1.3
LOGR	7/1	0.9
LOTR	7/1	4.5
PEAC	NA	NA
PEDE	NA	NA
PESP	8/8	0.4

By early July, the *Lomatium* species were completely dormant. In early October 2009 the dormant *Lomatium* plots were treated with a spray application of Roundup to control weeds that were still green.

The USDA-FS Rocky Mountain Research Station in Boise, Idaho cleaned the ERUM seed that was harvested from the plots. Some of the seed was utilized for the seeding trial planted near Aberdeen, Idaho in November, 2009 for the study to improve the diversity of introduced grass stands.

2010 Activities. Weeds were controlled by hand during 2010. The Penstemon plots had all died out by 2010. The remaining plots were harvested with the PMC jet harvester. The following table shows harvest date and seed yield for the accessions that were harvested in 2010:

Species	Harvest Date	Clean seed (pounds)
ERUM	8/5	5.0 (estimated)
LODI	7/13	2.0 (estimated)
LOGR	7/13	1.5 (estimated)
LOTR	7/13	1.5 (estimated)

Harvested seed was sent to the USDA-FS Rocky Mountain Research Station in Boise, Idaho in September, 2010. The plots were removed after the end of the 2010 growing season.

Publications:

St. John, L.; Ogle, D. 2010. Establishment and maintenance of certified generation 1 (G1) seed, propagation of native forbs, develop technology to improve the diversity of introduced grass stands, equipment and strategies to enhance the post-wildfire establishment and persistence of Great Basin native plants. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 33-38.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Tilley, D.; D. Ogle; and L. St. John. 2010. Plant guide for Douglas' dusty maiden (*Chaenactis douglasii*). Aberdeen, ID: U.S. Department of Agriculture, Natural Resources Conservation Service, Aberdeen Plant Materials Center. 4p.
http://plant-materials.nrcs.usda.gov/idpmc/publications.html

Tilley, D.; D. Ogle; and L. St. John. 2010. Plant guide for hoary tansyaster (*Machaeranthera canescens*). Aberdeen, ID: U.S. Department of Agriculture, Natural Resources Conservation Service, Aberdeen Plant Materials Center. November 2010. 4p.
http://plant-materials.nrcs.usda.gov/idpmc/publications.html

Presentations:

St. John, L.; Ogle, D. 2010. Aberdeen PMC report of activities 2009. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Management Applications:

1. Certified seed stock of Anatone bluebunch wheatgrass, produced by the PMC is available though the University of Idaho Foundation Seed Program and Utah Crop Improvement Association.

2. Based on propagation studies at the PMC, sulphur-flower buckwheat, hotrock penstemon, sagebrush penstemon and sharpleaf penstemon can be commercially grown, at least with the use of weed barrier fabric. Lomatium species appear to require a number of years (3 - 4) to mature to reproductive stage under the climatic conditions at Aberdeen, Idaho and may not be conducive to commercial production because of the long period to reach reproductive capability.

3. The Truax Rough Rider drill performs well in seeding studies and should be used for large scale seedings.

Products:
1. Certified seed stock of Anatone bluebunch wheatgrass produced by the PMC is available though the University of Idaho Foundation Seed Program and Utah Crop Improvement Association

2. Seed of sulphur-flower buckwheat that were produced from the propagation studies were used in the seed mixtures for the study to improve the diversity of introduced grass stands. Seed of the *Lomatium* species and *Penstemon speciosus* was made available to cooperators for seeding trials.

3. Plant Guides are available for royal penstemon, hotrock penstemon and sharpleaf penstemon; fernleaf biscuitroot, nineleaf biscuitroot and Gray's biscuitroot; Douglas' dusty maiden and hoary tansyaster.

Project Title: Pollinator and Seed Predator Studies

Project: USDA-ARS Pollinating Insect Research Center, Logan, Utah

Principal Investigator and Contact Information:

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Project Description:
Native bees and/or honey bees are needed to pollinate most all of the wildflower species thus far studied for Great Basin plant community rehabilitation. The pollinator faunas of many of these candidate plant genera include one or more bee genera with potentially manageable species, especially species of *Osmia*. A minority of the later-blooming species attracts and can be pollinated by honey bees or managed alfalfa leaf-cutting bees.

Pollinator needs are being evaluated by comparing fruit and seed sets at caged flowers, openly visited flowers, and manually pollinated flowers. If plant reproduction proves to be pollinator limited, then native bee faunas are surveyed and evaluated at managed and wild flowering populations. If bees are sufficiently abundant, then single-visit pollination efficiencies at previously caged flowers can directly evidence each bee species' contribution to seed production.

Captive populations of several species of cavity-nesting *Osmia* bees with pollination promise are being multiplied either with a private grower or at our lab, for eventual distribution to growers needing them for pollination. Currently managed bee species (alfalfa leaf-cutting bees, blue orchard bees, honey bees) are being evaluated for their pollination prowess with each of the target plant species as well using our lab's common garden. Practical management protocols and materials are being developed to sustainably manage pollinators on-farm. Pollination information is being disseminated to collaborators and growers.

Anticipating that seed from some of these perennial forb species will be used for post-fire restoration, we have been evaluating susceptibilities and fates of wild bee communities to wildfire in the sage-steppe and juniper woodlands. Inasmuch as bees are necessary for pollination of most of these forbs, bee communities must persist in or recolonize burns if seeded forbs are to reproduce. Nesting habits will likely predict a bee species' risk with fire, which will be evaluated through lab experiments and sampling of faunas in natural burns throughout the Intermountain West.

<u>Status Report</u>
Many ground-nesting wild bees are present and populous in the years after wildfires where the pre-existing flora was in good shape. The wet winters of 2009-10, plus a capable student, allowed me to redouble sampling for bee communities (actually floral guilds) in pairs of burned

and neighboring unburned plots across a 15-year chronosequence of wildfires in sagebrush steppe and juniper woodlands in 5 states of the northern Great Basin and Columbia Plateau. We have curated and identified most specimens. Once complete, we will: 1) compare sites on a bees/plant basis for taxonomic diversity, nesting habits and abundance; 2) compare with paired samples from standardized passive trapping of bees; 3) relate these similarity measures with our measures of the plant communities, being densities of shrubs and prevalent wildflowers (done using Morisita's ordered distance method) and 4) simple binomial diversity measures for genera in flower at each site. To date, we have now sampled bees and flora in 27 site pairs in a chronosequence representing a span from 1-15 years since the last large fire (>1000 acres). We focused on three species of *Balsamorhiza,* but also some *Lomatium*, globemallows, *A. filipes*, and *Penstemon*. Most all are ground-nesters and non-social. Our impression is that forb communities are more plentiful and slightly more diverse in most of the fires than the control sites, but this awaits analytical confirmation.

Further evidence that bee faunas are surviving fires in the sage-steppe comes from several samples taken this year from very recent fires; the Skatepark fire near Boise and the Big Pole fire west of Salt Lake. Both were sampled in the first growing season after the burn. Since there was no bloom, we sampled emerging bees using long-term vane traps deployed in the charred landscape and around the perimeter. Only eight or so sampling units were deployed per fire, sitting out for a month at a time. What we thought would be a test of the method has proven productive. We are still processing and identifying bees, but here are our preliminary numbers:

Skatepark Fire: May & Jun, 258 and 325 burn bees; in Aug, 563 burn bees vs. 861 control

Big Pole Fire: controls 880 and 600 bees versus burns 438 and 500 bees

Clearly, many bees are emerging and in need of floral bloom if they are to reproduce on-site.

Lastly, we also netted bees at surviving sunflowers along gravel roadways traversing the 450 sq mile Long Butte fire west of Twin Falls, ID. Just 4 weeks after the fire, we found the same bee fauna at the same densities 3-7 miles into the burn as we found around the perimeter, all of them collecting pollen, indicative of active nesting even within the fire.

Some of these bee species, especially at *Lomatium* and *Sphaeralcea*, are near impossible to identify to species, even with our lab's expertise and reference collection of ½ million bees. We therefore submitted samples to the "The Barcode of Life Data Systems" (BOLD), an online workbench that aids collection, management, analysis, and use of DNA barcodes, processed through the Canadian Centre for DNA Barcoding at the University of Guelph. DNA sequences of the COI gene have been successfully amplified, sequenced and taxonomically associated for nearly all of the 155 bees sent. The prevalent tiny *Micrandrena* bees that pollinate wild *L. dissectum* and *L. bicolor* are a single species, not two indistinguishable sibling species as suggested by the monograph of the subgenus. Our identifications of difficult but important species of bees at globemallows have been confirmed as well. Together the bees that we have submitted lay a foundation for cheap molecular ID of some of the prevalent pollinators of dominant Great Basin forbs from this project.

Pollinators and breeding biologies of target forbs. From a growing list of samples, we have become convinced that long-leaf phlox, *Phlox longifolia*, is pollinated by bees, not bee-flies as thought. The prevalent bees at this flower are female ground-nesting *Eucera*, which also visit *Astragalus* and *Balsamorhiza*. We also made unexpected progress in studying the breeding biology of Douglas' dusty maiden, *Chaenactis douglasii*. We had intended to establish plants with a March seeding under the snow, but these plants grew and bloomed the first season. We manually pollinated some 4000 flowers, collected the achenes, and are now in the process of x-raying them to score endosperm fill as a measure of fertility. This plant grows well in cultivation. Its ability to flower in the first growing season bodes well for adding it to seed mixes where it can feed resident bee communities in the year after a fire (as can *Helianthus, Eriophyllum* and even *Sphaeralcea*).

Nematode controls for seed weevils. We have also been studying the tiny weevils and their relatives that infest forb seeds, especially the legumes. With a nematologist, Dr. Edwin Lewis at UC Davis, we hoped to test some of the predatory nematodes as controls for these seed predators during their resting pupal stages in the soil. Practical logistics proved difficult, in that we needed to be able to introduce adult weevils to hosts within developing pods so as to get a generation of mature larvae in the seeds to test. Because neither the hosts (e.g. *Astragalus filipes*) nor their beetles are native to our part of Utah, rearing in confinement proved impossible in Logan.

Publications:

Cane, J. H. 2010. Pollinator and seed predator studies. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 80-83.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Cane, J. H. [In press]. Specialist *Osmia* bees forage indiscriminately among hybridizing *Balsamorhiza* floral hosts. Oecologia.

Watrous, K. and J. H. Cane. [In press]. Breeding biology of the threadstalk milkvetch, *Astragalus filipes* (Fabaceae), with a review of the genus. Amer. Midl. Natur.

Presentations:

Cane, James H. Bees are key for producing native forb seed. Consortium of western NRCS Plant Materials Centers;2010 April 26-28; Logan, UT.

Cane, James H. Bees are key for producing native forb seed. Seed Production of Native Grasses and Forbs Workshop; 2010 February 23; Ontario, OR.
http://www.fs.fed.us/rm/boise/research/shrub/projects/Ontario2010.html

Cane, James H. From Buds to Seeds: Bees are key. 7th SER European Conference on Ecological Restoration; 2010 August 23-27; Avignon, France.
http://www.fs.fed.us/rm/boise/research/shrub/projects/2010SEREurope.HTML

Cane, James H. On-farm pollinator surprises ease some pollination challenges for native forb production. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Cane, James H. Peculiar factors enable sustained mass-production of native alkali bees for alfalfa pollination. Entomological Society of America, Pacific Branch, Symposium; 2010 April 11-14; Boise, ID.

Cane, James H. Pollination and pollinators for wildflower seed farming and post-fire wildland rehabilitation. International Conference on Pollinator Biology, Health and Policy, Penn State Univ.; 2010 July 24-28; University Park, PA.

Watrous, Kristal M.; Cane, James H. Evaluation of pollinator manageability for agricultural use on a native Great Basin legume. International Conference on Pollinator Biology, Health and Policy, Penn State Univ.; 2010 July 24-28; University Park, PA. Poster.

Management Applications:
Growers of native forbs for seed who do not plan for pollination will have poor seed production for most of the species chosen for the Intermountain West. A subset of species (e.g. *Dalea ornata*) can be handily pollinated with any one of several currently managed pollinators (e.g. honey bees, alfalfa leafcutting bees). A commercial grower that finally adopted my advice with a related prairie species, *D. purpurea*, increased his seed yield 40% by using alfalfa leaf-cutting bees. More than half of the forb species can be pollinated with cavity-nesting native *Osmia* bee species. We are successfully multiplying several native *Osmia* species. For the sweetvetch pollinator, *O. sanrafaelae*, we tripled this year's nesting population to 17,000 progeny, enough to share with a second grower. We continue to multiply *O. bruneri* as a pollinator for *Astragalus filipes*. At the NRCS facility in Corvallis, we provided cocoons and nest blocks for *Osmia montana* that managers were able to set up to nest as well as forage on and pollinate a large plot of *Eriophyllum*.

Growers that do not scout for seed beetles risk losing a well-pollinated crop (or risk losing their pollinators if sprayed during bloom). I continue to follow the literature and speak with research presenters about risks or safety for bees of neonicotinoid systemic insecticides, as these should control weevils without aerial spraying. Unfortunately, I have heard convincing data, both pro and con, all involving nanogram doses, so I remain tempted but hesitant to recommend neonicotinoids.

Products:
Two *Osmia* bee species that effectively pollinate *Hedysarum* and *Astragalus* are increasing well for us. Once numerous enough, we will distribute them to seed growers. For one of these, *O. sanrafaelae*, we have an estimated 17,000 individuals (nest x-rays are being scored now). We are increasing it at Wind River Farm in Wyoming for pollination of *Hedysarum*. This may be enough bees, rearing experience, etc. to offer this bee to another grower of *Hedysarum* in southwest Colorado (where this bee is also native). The other bee, *O. bruneri*, we are increasing on raspberry and sweetclover bloom in our screenhouse. We expect several thousand progeny, but have only pulled the nesting straws for x-ray and tally. Another pair of species, *O. montana* and *O. californica*, pollinate balsamroots and *Eriophyllum*. We manage them easily now, and they are available in the thousands as by-catch from businesses that are trap-nesting blue orchard bees from the wild.

Project Title: *Allium acuminatum* Seed Production: First look at cultural parameters

Project Location: Plant Germplasm Introduction and Research, USDA ARS Western Regional Plant Introduction Station (WRPIS), Pullman, Washington

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Project Description:
As a component of Greater Sage-Grouse and Southern Idaho Ground Squirrel habitat, *Allium acuminatum* Hook. (Tapertip onion) has been targeted for use in restoration projects. In the related project titled "Genetic diversity patterns of *Allium acuminatum* in the Great Basin" locally adapted seed sources and seed transfer zones were identified for this species. A next step needed before *A. acuminatum* can be used for restoration projects is to understand how to make quantities of propagules available. Either dormant bulbs or true seed may be viable options for taper-tip onion stand establishment. For use of either type of propagule, quantities of true seed will be needed. Minimal information is available on the cultural needs of this species for seed production in an agricultural setting. The objectives of this project are to look at production parameters needed to grow *A. acuminatum* for a seed crop.

<u>Methods</u>
It takes 3-4 years for *A. acuminatum* plants grown from seed to flower. The average bulb diameter of plants that age is 4-5 mm (Dave Skinner, personal communication). For this trial, dormant mature bulbs with a diameter of 7-15 mm were used. This was a 2-year trial. Bulbs were planted in October 2008 and 2009 in Pullman, WA in randomized complete blocks with 4 replications. The treatments were 1) mechanical planting with bulbs spaced 1 inch apart, 2) mechanical planting with bulbs spaced 2 inches apart, 3) hand planting with 1 inch bulb spacing, and 4) hand planting with 2 inch bulb spacing. Each plot had 60 bulbs planted at a depth of 1 inch. The plots were rototilled prior to planting but no pre-plant herbicide or fertilizer was applied. A single row Hege belt cone planter was used for the mechanically planted plots. No irrigation was applied to the trial during the growing season. Emergence was taken April 16,

2009 and April 21, 2010. Flowers per umbel counts were taken for 25 randomly selected plants per plot on June 11, 2009 and from June 22 to July 2, 2010. When half or more seed capsules were open on individual umbels and all plants in a plot had mature seed, whole umbels from 25 individual plants were harvested by hand from each plot. Harvest dates were July 14 and 15, 2009 and July 22, 2010. In August 2009 the bulbs from all plots were dug and stored in the Western Regional Plant Introduction drying shed until September 2009 when they were moved to a temperature and humidity controlled chamber. Bulbs were stored at 14°C and 40% RH until early October 2009 when they were cleaned, counted, sized and repackaged for planting. During repackaging, bulbs were discarded if they showed signs of disease, herbivory, were soft and rubbery, or hard and desiccated. Seed was cleaned, counted, and weighed on a per plant basis. Only fully filled seed was included in the counts. Light or partially filled seeds were discarded.

Results and Discussion

Table 1 summarizes emergence, flower production, seed harvested per plant, and seed weights for the 2009 and 2010 trials. There were no statistically significant differences found among any of the treatments for the production of flowers per umbel, seeds per plant, total seed harvested or seed weights in 2010 or between years. In 2009 for all parameters there were no statistically significant differences except for flowers/umbel. At the $P<0.05$ level the differences seen in flower production per umbel were statistically different with interaction between method and spacing but this did not result in differences in seed production.

Based on these results we can say that mechanical planting was successful as an efficient planting technique. Also, when using mature bulbs for seed production, bulbs can be spaced as close as 1 inch without compromising yield.

Seed production per plant was lower than expected in both years. Based on the number of flowers per umbel produced and the potential number of seed per flower (3-locular with 2 ovules per locule per capsule), average seed per plant should be approximately 180. During harvest, shattered seed was observed on the ground. Since *A. acuminatum* seed ripens in lower capsules before the upper capsules it is easily dislodged from open fruit. In many harvested umbels there were some green capsules. Even though the seed in these capsules looked fully filled, they didn't dry down to produce high quality seed. In 2010 umbels were harvested on two dates, July 22 and July 30. For the July 30 harvest, more upper capsules were open with ripe seed than with the July 22 harvest, which had more lower capsules open. Seed yield per plant was lower for the later harvest suggesting that the seed in the upper capsules does not fully fill and produce as high a quality seed as seed from lower capsules, even if left on the plant. Because of these factors, timing seed collection to maximize harvest will be critical for *A. acuminatum* production.

Table 2 summarizes bulb production from the 2009 trial. In 2010 bulb yield was not recorded due to disease in the plots. There were no statistical differences found among treatments for total bulb production, bulbs < 7mm in diameter and the number of discarded bulbs. There were statistical differences between spacing treatments for the number of 7-15mm diameter bulbs produced. The number of 7-15mm diameter bulbs was highest for the mechanically planted, the 1-inch spacing treatment, and lowest for the hand planted, 1-inch spacing treatment. The mechanical 1-inch spacing and hand planted 2-inch spacing treatments were intermediate (Table 2). We had difficulty getting a consistent 1 inch spacing using the Hege belt cone planter. The bulbs tended to bunch in the cone making bulb spacing greater than 1-inch in some cases. This potentially wider average spacing could have caused the increased number of bulbs produced in the mechanically planted 1-inch bulb spacing treatment.

The results show that mechanically planting mature bulbs of taper-tip onion is an efficient planting method for seed and bulb production. Bulbs can be spaced 1 inch apart for maximum seed production, but a wider between bulb spacing is needed for maximum larger (7-15mm) diameter bulb production. Bulb survival and propagule production was achieved in an agricultural setting for this wild species. To maximize seed production, seed shattering will need to be addressed.

Table 1. Summary of emergence, flowers per umbel, seed harvest per plant, total seed weight (for the 25 plants harvested), total number of seed harvested, and 100 seed weight data collected from *Allium acuminatum* seed production trial planted in Pullman, WA in 2009 and 2010.

Year	Planting method	Spacing	Emergence	Avg. flowers/ umbel	Avg. seed/ plant	Avg. total seed weight(g)	Avg. total no. seeds	Avg. 100 seed weight(g)
2009	hand	1 inch	55.5	30.8	31.1	1.5	778.0	0.19
2009	hand	2 inch	57.0	28.9	37.2	2.0	929.0	0.22
2009	mechanical	1 inch	56.0	29.5	39.0	1.9	975.5	0.20
2009	mechanical	2 inch	56.5	30.9	34.5	1.8	860.8	0.20
2010	hand	1 inch	51.8	36.8	33.1	1.7	828.0	0.20
2010	hand	2 inch	50.3	34.6	30.2	1.6	756.5	0.21
2010	mechanical	1 inch	47.8	39.4	41.8	2.2	1043.5	0.21
2010	mechanical	2 inch	52.0	37.0	34.7	1.8	866.3	0.21

Table 2. Summary of bulb production from the *Allium acuminatum* seed production trial 2009.

Planting method	Between bulb spacing	Total no. bulbs produced	No. bulbs 7 to 15 mm diameter	No. bulbs <7 mm diameter	No. discarded bulbs
Hand	1 inch	94.0a*	64b	4.2a	25.8a
Hand	2 inch	103.5a	79ab	1.2a	23.8a
Mechanical	1 inch	104.2a	81a	1.2a	21.8a
Mechanical	2 inch	104.2a	72ab	1.0a	31.0a

*Means sharing letters are not different using the LSD at P<0.05.

<u>Future Plans</u>

Submit production information to the Native Plants database.
Prepare plant production guide in collaboration with the NRCS Aberdeen Plant Materials Center.

Publications:

Hellier, B; Johnson, R. C. 2010. *Allium acuminatum* seed production: first look at cultural parameters. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 88-90.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

Hellier, B.; Johnson, R.C. 2010. Seed and bulb production from mechanically planted *Allium acuminatum* bulbs. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Project Title: Cultural Thinning of Native Sagebrush Stands to Increase Seed Yields

Project: USDA Forest Service, Shrub Science Laboratory, Provo, Utah

Principle Investigators and Contact Information:

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Project Description:
Seed harvesting has become an important part for restoration of public lands and increasing seed production of native shrubs would be beneficial. There is a crucial need for large volumes of sagebrush seed of higher quality for the use in rehabilitation projects (Beetle and Young 1965). By removing neighboring plants, there is less competition for water for the remaining stand (Armstrong 2007). This study is designed to expand previous research by determining if thinning stands can improve seed yields in established native populations of Wyoming big sagebrush. The specific objective of this research is to determine if treated areas can increase seed yield over natural stands of sagebrush. Removal of competition between stands has been the best application for increasing seed yield.

Objectives

1. Determine if chemical elimination of competing shrubs increases seed yield over natural stands.
2. Determine if mechanical elimination of competing shrubs increases seed yield over natural stands.
3. Determine if treatments are viable options for seed production.

Methods

Two sites were chosen for this study based on area (50 acres or larger), sagebrush stand uniformity, and sagebrush density. Both sites are in Utah, the first site is approximately 10 miles south of Scipio along the I-15 corridor. The second site is found approximately 10 miles southeast at the main entrance to the Little Sahara Recreation Area. Treatments involved in this research have the potential for reducing overall seeding costs to revegetate large areas of disturbed grounds with Wyoming big sagebrush seed. Treatments in this study are: 1) general mechanical thinning; 2) mechanical kill in 10-ft strips; 3) general chemical thinning; 4) chemical kill in 10-ft strips; and 5) control (natural stand, undisturbed). All treatments were established during the summer of 2010. Mechanical thinning and killing was accomplished with a Dixie harrow. Plot areas (150 ft x 700 ft) had the Dixie harrow pulled across the terrain once to thin the sagebrush. Ten kill strips had the Dixie harrow pulled across the 10-ft strips three times, each time the Dixie harrow was going in the opposite direction of the previous pass. Chemical thinning and kill treatments used 2,4-D applied foliarly. Thinning treatments were treated with a lower rate and no oil adjuvants to increase chemical uptake. Ten foot killing strips were treated with a higher rate of 2,4-D and an adjuvant oil was added. Control areas were left untouched.

Project Status

Seed production in 2010 in treatment areas was minimal due to the chemical and mechanical disturbances that occurred from the treatments, therefore data for 2010 is not usable. The first seed collection to determine treatment difference will occur in 2011.

Literature Cited:

Beetle, A.A.; Young, A. 1965. A third species of the *Artemisia tridentata* complex. Rhodora 67: 405-406.

Armstrong, Jeremiah C. 2007. Improving sustainable seed yield in Wyoming big sagebrush. Provo, UT: Brigham Young University. 29 p. Thesis.

Project Title: Evaluation of Imazapic Rates and Forb Planting Times on Native Forb Establishment

Project: Utah State University, Logan, Utah

Principal Investigators and Contact Information:

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Project Description:

Successful establishment of native forb species is critical in order to re-establish structure and function to disturbed range sites. A large portion of the degraded rangeland in the Intermountain Region of the Western U.S. is invaded by downy brome (*Bromus tectorum*). The most common herbicide currently available for downy brome control is imazapic (Plateau). Since restoration sites will likely be treated with imazapic for downy brome control prior to establishment of desirable species, a greater understanding of the tolerance of different forb species to imazapic is needed. This project aims to describe native forb and grass species tolerance to imazapic and other herbicides applied to suppress downy brome. This project will also examine the effect of herbicide application timing and planting dates on successful species germination and growth.

Materials and Methods

Trials were established at Cache Junction and Nephi, Utah. Herbicide treatments were applied to plots measuring 6 ft wide and 60 ft in length. Herbicides were applied with a CO_2- pressurized backpack sprayer calibrated to deliver 20 gpa at 30 psi. Herbicide treatments included imazapic at various rates compared to propozycarbazone (Olympus), sulfosulfuron (Outrider), rimsulfuron (Matrix), and sulfometuron (Oust). Herbicide rates are shown in Table 2. Spring applications were made April 29 and May 1 and fall application November 30 and 23 at Nephi and Cache Junction, respectively. Two applications of Roundup were used to suppress weed growth at Cache Junction, while one handweeding was used to remove weeds at the Nephi site. Species were seeded perpendicular to the herbicide plots on November 23 at Cache Junction and November 25 at Nephi. At Nephi a modified cone seeder was used to plant two rows of each species spaced 2.5 ft apart. At Cache Junction, species were seeded in strips 7 feet wide with plants rows 8 inches apart with a Tye no-till drill. A list of species seeded at each location is included in Table 1. Because field bindweed was prevalent at the Cache Junction location, only grass species were seeded at that location. Species densities were determined in the summer of 2010 by counting the number of plants present in each plot. Plots were hand weeded three times during the season, but significant weed growth still occurred between weeding times.

For an additional project, a graduate student compiled a list of grass and forb species and their reported sensitivity to imazapic. The majority of the information was found on the Plateau label, but few forb species are listed. Very little other information exists.

Table 1. Species seeded in herbicide tolerance trials at Nephi and Cache Junction, Utah in 2009.

Nephi	
Utah sweetvetch	*Astragalus filipies*
Prairie clover	*Dalea ornata*
Searle's prairie clover	*Dalea searlsiae*
Sulphur-flower buckwheat	*Eriogonum umbellatum*
Nevada goldeneye	*Heliomeris multiflorum* var. *nevadensis*
Silky lupine	*Lupinus sericeus*
Big blue penstemon	*Penstemon cyaneus*
Globemallow	*Spharalcea*
Big bluegrass ('Sherman")	*Poa secunda*
Bluebunch wheatgrass (Anatone)	*Pseudoroegneria spicata*
Cache Junction	
Slender wheatgrass ('First Strike')	*Elymus trachycaulus*
Basin wildrye ('Magnar')	*Leymus cinereus*
Big bluegrass ('Sherman')	*Poa secunda*
Bluebunch wheatgrass (Anatone)	*Pseudoroegneria spicata*

Results

Grass plantings failed to establish at the Cache Junction location and no data was colleted.

Only three plant species established at the Nephi location, and densities were highly variable among the replicate plots (Table 2). Numbers were recorded for Utah sweetvetch, silky lupine and bluebunch wheatgrass. Because of variable establishment only general trends are apparent. Utah sweetvetch densities were among the highest at 0.0625 lb ai/A imazapic applied in the spring and 0.0313 lb ai/A applied in the fall. Densities were generally lower at rates of 0.125 lb ai/A and above depending on the application timing. Sulfosulfuron and sulfometuron treatments had among the lowest sweetvetch densities and densities were similar between the application timings, while densities were significantly higher when rimsulfuron was applied in the spring as opposed to in the fall at planting. Propoxycarbazone appeared to have minimal impact on sweetvetch establishment. Few conclusions can be made based on silky lupine data as numbers were highly variable. Bluebunch wheatgrass established at much higher numbers than the broadleaf species with fall applied imazapic at 0.0625 lb ai/A recording among the highest density. Lower imazapic rates in the spring or fall as well as the 0.094 lb ai/A rate in the fall had similar densities as did fall applied sulfosulfuron and spring or fall applied propoxycarbazone. The sulfometuron treatments had among the lowest bluebunch wheatgrass stands but were similar to some of the higher imazapic rates. Rimsulfuron had reduced stands compared to the best treatment, but was similar to many of the other treatments in the trial. Grass densities in general were not improved with the spring application timings as compared to the fall application just prior to planting, possibly because dry conditions did not allow significant herbicide degradation to take place during the summer. Apparent increases in density for treatments compared to the untreated plots are likely due to competition with weeds that grew between times of hand weeding.

Table 2. Plant densities evaluated June 10, 2011 in response to spring or fall herbicide applications at Nephi, UT.

		Utah sweetvetch		Silky lupine		Bluebunch wheatgrass	
Herbicide[1]	Rate	Spring	Fall	Spring	Fall	Spring	Fall
	lb ai/A	Density (plants/25ft^2)					
Untreated	-	3.75	4.25	3.13	1.88	12.13	14.75
Plateau	0.0156	4.38	5.50	2.25	1.50	19.50	14.50
Plateau	0.0313	4.00	6.25	4.00	1.63	15.00	14.25
Plateau	0.0625	6.88	2.38	1.88	1.63	21.25	12.63
Plateau	0.094	4.38	4.13	4.63	1.63	10.63	16.38
Plateau	0.125	3.38	3.25	1.13	2.38	8.00	10.25
Plateau	0.156	2.38	2.38	2.38	3.50	9.25	6.00
Plateau	0.188	2.25	1.50	2.63	2.75	8.75	6.38
Olympus	0.0534	4.50	4.50	2.88	2.13	15.25	15.38
Outrider	0.047	2.88	1.63	2.00	1.75	15.25	9.63
Matrix	0.039	6.75	2.00	2.50	1.25	12.25	8.75
Oust	0.0703	2.13	0.00	1.00	0.00	7.13	1.00
LSD (0.05)	-	3.37		2.15		7.34	

[1]All treatments included a non-ionic surfactant at 0.25% v/v.

Direction for 2011

In 2011, additional evaluations of the Nephi site will be made if possible. A location in closer vicinity to Logan will be selected, and treatments reestablished in preparation for plantings in the fall. Plot size will be reduced and seeding rates increased to try to reduce variability and to facilitate potential use of row covers or other techniques to improve planting establishment. Laboratory approaches to evaluating seedling tolerance to imazapic and other herbicides will proceed. Soil sampling will be delayed until it can be done at the new site.

Publications:

Ransom, C. 2010. Evaluation of imazapic rates and forb planting times on native forb establishment. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 148-149.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Ransom, C; Edvarchuk, K. 2010. Identification of herbicides for use in native forb seed production. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 97-101.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

Ransom, C. 2010. Weed Management Concepts: Developing forb seed production strategies. Seed Production of Native Grasses and Forbs Workshop; 2010 February 23; Ontario, OR
http://www.fs.fed.us/rm/boise/research/shrub/projects/Ontario2010.html

Ransom, C; Edvarchuk, K. 2010. Forb response to herbicides for seed production and rangeland restoration. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Products:
List of species including information published on tolerance to imazapic.

Project Title: Identification of Herbicides for Use in Native Forb Seed Production

Project: Utah State University, Logan, Utah

Principal Investigators and Contact Information:

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Project Description:
Native forb seed is needed to restore the rangelands of the Intermountain West. Weed control is essential for the commercial production of native forb seed. Weeds compete with crop plants reducing establishment, vigor, and seed production. In addition, some weed seeds can contaminate the seed crop reducing its value or introducing weeds to reclamation areas. Removal of weeds by hand or with cultivation is economically restrictive.

The overall objective of this research project is to identify herbicides that can be used to control weeds in forb seed production with limited injury to the forbs. The forbs evaluated in this project include: basalt milkvetch (*Astragalus filipes)*, Western prairie clover (*Dalea ornata*), and Searls' prairie clover (*Dalea searlsiae*).

Results for 2010

Few results were obtained in 2010 due to lack of a field site and limited seed availability. One accomplishment was the establishment of field plots at Herrman Northwest Farms in Washington on new and established seedings of *Astragalus filipies* (Dry River, germplasm) and *Dalea ornata* (Aridlands, germplasm). Most of the applications will be made in spring of 2011 and evaluated through the summer of 2011. Another accomplishment was procurement of enough seed from Herrman Northwest to allow the planting of 0.125 acre research sites each of *Astragalus filipies* and *Dalea ornata* at the Utah State University, Greenville Research Farm. Seed had been scarified and treated with fungicide by Herrman Northwest. Enough seed remains to allow another 0.125 acre planting of both species in spring 2011. Preemergence and postemergence herbicide applications will be made in spring 2011 and evaluated throughout the summer 2011.

Direction for 2011

Field trials will be established as mentioned above and evaluated during the summer of 2011. Treatments will include herbicides that were identified as having minimal injury to *Astragalus filipies* and *Dalea ornata* in earlier trials.

Publications:

Ransom, C.V. 2010. Evaluation of imazapic rates and forb planting times on native forb establishment. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 148-149. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Roerig, K. C.; Ransom, C. V. 2010. Searls' prairie clover (*Dalea searlsie*) tolerance to postemergence herbicide applications. West Society of Weed Science Research Progress Report. p. 74.

Presentations:

Edvarchuk, K.; Ransom, C. V. 2010. Herbicide tolerance in grasses and native forb species. Proceedings of the Western Society of Weed Science. 63: 9-10.

Ransom, C. V. Weed management concepts: developing native forb seed production strategies. Native Forb Seed Production Workshop, 2010 February 23, Ontario, OR. http://www.fs.fed.us/rm/boise/research/shrub/projects/Ontario2010.html

Ransom, C.V.; Edvarchuk, K. 2010. Forb response to herbicides for seed production and rangeland restoration. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Project Title: Seed Production of Great Basin Native Forbs --- Subsurface Drip Irrigation (SDI) for stable, efficient native forb seed production using small amounts of supplemental irrigation water; Weed Control; and Seeding Practices

Project Location: Oregon State University Malheur Experiment Station, Ontario, Oregon

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Project Description: Plant Irrigation Needs (supplied by subsurface drip irrigation)

Native wildflower seed is needed to restore rangelands of the Intermountain West. Commercial seed production is necessary to provide the quantity of seed needed for restoration efforts. A major limitation to economically viable commercial production of native wildflower (forb) seed is stable and consistent seed productivity over years. In natural rangelands, the natural variations in spring rainfall and soil moisture result in highly unpredictable water stress at flowering, seed set, and seed development, which for other seed crops is known to compromise seed yield and quality.

Native wildflower plants are not adapted to croplands. Native plants are often not competitive with crop weeds in cultivated fields. Poor competition with weeds could also limit wildflower seed production. Both sprinkler and furrow irrigation could provide supplemental water for seed production, but these irrigation systems risk further encouraging weeds. Also, sprinkler and furrow irrigation can lead to the loss of plant stand and seed production due to fungal pathogens. By burying drip tapes at 12-inch depth and avoiding wetting of the soil surface, we hoped to assure flowering and seed set without undue encouragement of weeds or opportunistic diseases. The trials reported here tested the effects of three low rates of irrigation on the seed yield of 13 native forb species.

Materials and Methods

Plant Establishment. Seed of the seven Intermountain West forb species (the first seven species in Table 1) was received in late November in 2004 from the Rocky Mountain Research Station (Boise, ID). The plan was to plant the seed in the fall of 2004, but due to excessive rainfall in October, the ground preparation was not completed and planting was postponed to early 2005. To try to ensure germination the seed was submitted to cold stratification. The seed was soaked overnight in distilled water on January 26, 2004, after which the water was drained and the seed soaked for 20 minutes in a 10 percent by volume solution of 13 percent bleach in distilled water. The water was drained and the seed was placed in thin layers in plastic containers. The plastic containers had lids with holes drilled in them to allow air movement. These containers were placed in a cooler set at approximately 34°F. Every few days the seed was mixed and, if necessary, distilled water added to maintain seed moisture. In late February, seed of *Lomatium grayi* and *L. triternatum* had started to sprout.

In late February, 2005 drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth between two rows (30-inch rows) of a Nyssa silt loam with a pH of 8.3 and 1.1 percent organic matter. The drip tape was buried in alternating inter-row spaces (5 ft apart). The flow rate for the drip tape was 0.34 gal/min/100 ft at 8 psi with emitters spaced 16 inches apart, resulting in a water application rate of 0.066 inch/hour.

On March 3, seed of all species was planted in 30-inch rows using a custom-made plot grain drill with disk openers. All seed was planted at 20-30 seeds/ft of row. The *Eriogonum umbellatum* and the *Penstemon* spp. were planted at 0.25-inch depth and the *Lomatium* spp. at 0.5-inch depth. The trial was irrigated with a minisprinkler system (R10 Turbo Rotator, Nelson Irrigation Corp., Walla Walla, WA) for even stand establishment from March 4 to April 29. Risers were spaced 25 ft apart along the flexible polyethylene hose laterals that were spaced 30 ft apart and the water application rate was 0.10 inch/hour. A total of 1.72 inches of water was applied with the minisprinkler system. *Eriogonum umbellatum*, *Lomatium triternatum*, and *L. grayi* started emerging on March 29. All other species except *L. dissectum* emerged by late April. Starting June 24, the field was irrigated with the drip system. A total of 3.73 inches of water was applied with the drip system from June 24 to July 7. The field was not irrigated further in 2005.

Plant stands for *Eriogonum umbellatum*, *Penstemon* spp., *Lomatium triternatum*, and *L. grayi* were uneven. *Lomatium dissectum* did not emerge. None of the species flowered in 2005. In early October 2005, more seed was received from the Rocky Mountain Research Station for replanting. The blank lengths of row were replanted by hand in the *Eriogonum umbellatum* and *Penstemon* spp. plots. The *Lomatium* spp. plots had the entire row lengths replanted using the planter. The seed was replanted on October 26, 2005. In the spring of 2006, the plant stands of the replanted species were excellent, except for *P. deustus*.

On April 11, 2006 seed of three globemallow species (*Sphaeralcea parvifolia, S. grossulariifolia, S. coccinea),* two prairie clover species *(Dalea searlsiae, D. ornata),* and basalt milkvetch (*Astragalus filipes*) was planted at 30 seeds/ft of row (Table 1). The field was sprinkler irrigated until emergence. Emergence was poor. In late August of 2006 seed of the three globemallow species was harvested by hand. On November 9, 2006 the six forbs that were planted in 2006 were mechanically flailed. On November 10, 2006 the six forbs were replanted. On November 11, the *Penstemon deustus* plots were also replanted at 30 seeds/ft of row.

Table 1. Forb species planted in the drip irrigation trials at the Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Common names
Eriogonum umbellatum	Sulphur-flower buckwheat
Penstemon acuminatus	Sharpleaf penstemon, sand-dune penstemon
Penstemon deustus	Scabland penstemon, hot-rock penstemon
Penstemon speciosus	Royal penstemon, sagebrush penstemon
Lomatium dissectum	Fernleaf biscuitroot
Lomatium triternatum	Nineleaf biscuitroot, nineleaf desert parsley
Lomatium grayi	Gray’s biscuitroot, Gray’s lomatium
Sphaeralcea parvifolia	Smallflower globemallow
Sphaeralcea grossulariifolia	Gooseberryleaf globemallow
Sphaeralcea coccinea	Scarlet globemallow, red globemallow
Dalea searlsiae	Searls’ prairie clover
Dalea ornata	Western prairie clover
Astragalus filipes	Basalt milkvetch

<u>Irrigation for Seed Production</u>. In April, 2006, each strip of each forb species was divided into plots 30 ft long. Each plot contained 4 rows of each species. The experimental designs were randomized complete blocks with four replicates. The three irrigation treatments were a non-irrigated check, 1 inch per irrigation, and 2 inches per irrigation. Each treatment received four irrigations that were applied approximately every 2 weeks starting with flowering of the forbs. The amount of water applied to each treatment was calculated by the duration necessary to deliver 1 or 2 inches through the drip system; the amount was measured by a water meter and recorded after each irrigation to ensure correct water applications. Irrigations were controlled with a controller and solenoid valves.

In March of 2007, the drip-irrigation system was modified to allow separate irrigation of the species due to different timings of flowering. The three *Lomatium* spp. were irrigated together and *Penstemon deustus* and *P. speciosus* were irrigated together, but separately from the others. *Penstemon acuminatus* and *Eriogonum umbellatum* were irrigated individually. In early April, 2007 the three globemallow species, two prairie clover species, and basalt milkvetch were divided into plots with a drip-irrigation system to allow the same irrigation treatments that were received by the other forbs.

Irrigation dates can be found in Table 2. In 2007, irrigation treatments were inadvertently continued after the fourth irrigation. In 2007, irrigation treatments for all species were continued until the last irrigation on June 24.

Soil volumetric water content was measured by neutron probe. The neutron probe was calibrated by taking soil samples and probe readings at 8-, 20-, and 32-inch depths during installation of the access tubes. The soil water content was determined volumetrically from the soil samples and regressed against the neutron probe readings, separately for each soil depth. The regression equations were then used to transform the neutron probe readings during the season into volumetric soil water content.

Flowering, Harvesting, and Seed Cleaning. Flowering dates for each species were recorded (Table 2). The *Eriogonum umbellatum* and *Penstemon* spp. plots produced seed in 2006, in part because they had emerged in the spring of 2005. Each year, the middle two rows of each plot were harvested when seed of each species was mature (Table 2) using the methods listed on Table 3. The plant stand for *P. deustus* was too poor to result in reliable seed yield estimates. Replanting of *P. deustus* in the fall of 2006 did not result in adequate plant stand in the spring of 2007.

Eriogonum umbellatum seeds did not separate from the flowering structures in the combine; the unthreshed seed was taken to the U.S. Forest Service Lucky Peak Nursery (Boise, ID) and run through a dewinger to separate seed. The seed was further cleaned in a small clipper seed cleaner.

Penstemon deustus seed pods were too hard to be opened in the combine; the unthreshed seed was precleaned in a small clipper seed cleaner and then seed pods were broken manually by rubbing the pods on a ribbed rubber mat. The seed was then cleaned again in the small clipper seed cleaner.

Penstemon acuminatus and *P. speciosus* were threshed in the combine and the seed was further cleaned using a small clipper seed cleaner.

Cultural Practices in 2006. On October 27, 2006, 50 lb phosphorus (P)/acre and 2 lb zinc (Zn)/acre were injected through the drip tape to all plots of *Eriogonum umbellatum, Penstemon* spp., and *Lomatium* spp. On November 11, 100 lb N/acre as urea was broadcast to all *Lomatium* spp. plots. On November 17, all plots of *Eriogonum umbellatum*, *Penstemon* spp. (except *P. deustus*), and *Lomatium* spp. had Prowl® at 1 lb ai/acre broadcast on the soil surface. Irrigations for all species were initiated on May 19 and terminated on June 30. Harvesting and seed cleaning methods for each species are listed in Table 3.

Cultural Practices in 2007. *Penstemon acuminatus* and *P. speciosus* were sprayed with Aza-Direct® at 0.0062 lb ai/acre on May 14 and May 29 for lygus bug control. Irrigations for each species were initiated and terminated on different dates (Table 2a). Harvesting and seed cleaning methods for each species are listed in Table 3. All plots of the three *Sphaeralcea* species were flailed on November 8, 2007.

Cultural Practices in 2008. On November 9, 2007 and on April 15, 2008, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Capture® 2EC at 0.1lb ai/acre was sprayed on all plots of *Penstemon acuminatus* and *P. speciosus* on May 20 for lygus bug control. Irrigations for each species were initiated and terminated on different dates (Table 2a). Harvesting and seed cleaning methods for each species are listed in Table 3.

Cultural Practices in 2009. On March 18, Prowl at 1 lb ai/acre and Volunteer at 8 oz/acre were broadcast on all plots for weed control. On April 9, 50 lb N/acre and 10 lb P/acre were applied through the drip irrigation system to the three *Lomatium* species.

The flowering, irrigation timing, and harvest timing were recorded for each species (Table 2b). Harvesting and seed cleaning methods for each species are listed in Table 3.

Cultural Practices in 2010. On December 4, 2009, Prowl at 1 lb ai/acre was broadcast on all plots for weed control. Flowering, irrigation timing, and harvest timing were recorded for each species (Table 2b). Harvesting and seed cleaning methods for each species are listed in Table 3.

Table 2a. Native forb flowering, irrigation, and seed harvest dates by species in 2006, 2007, and 2008, Malheur Experiment Station, Oregon State University, Ontario, OR.

	Flowering			Irrigation		
Species	start	peak	end	start	end	Harvest
				2006		
Eriogonum umbellatum	19-May		20-Jul	19-May	30-Jun	3-Aug
Penstemon acuminatus	2-May	10-May	19-May	19-May	30-Jun	7-Jul
Penstemon deustus	10-May	19-May	30-May	19-May	30-Jun	4-Aug
Penstemon speciosus	10-May	19-May	30-May	19-May	30-Jun	13-Jul
Lomatium dissectum				19-May	30-Jun	
Lomatium triternatum				19-May	30-Jun	
Lomatium grayi				19-May	30-Jun	
Sphaeralcea parvifolia						
S. grossulariifolia						
Sphaeralcea coccinea						
Dalea searlsiae						
Dalea ornata						
				2007		
Eriogonum umbellatum	25-May		25-Jul	2-May	24-Jun	31-Jul
Penstemon acuminatus	19-Apr		25-May	19-Apr	24-Jun	9-Jul
Penstemon deustus	5-May	25-May	25-Jun	19-Apr	24-Jun	
Penstemon speciosus	5-May	25-May	25-Jun	19-Apr	24-Jun	23-Jul
Lomatium dissectum				5-Apr	24-Jun	
Lomatium triternatum	25-Apr		1-Jun	5-Apr	24-Jun	29-Jun, 16-Jul
Lomatium grayi	5-Apr		10-May	5-Apr	24-Jun	30-May, 29-Jun
Sphaeralcea parvifolia	5-May	25-May		16-May	24-Jun	20-Jun, 10-Jul, 13-Aug
S. grossulariifolia	5-May	25-May		16-May	24-Jun	20-Jun, 10-Jul, 13-Aug
Sphaeralcea coccinea	5-May	25-May		16-May	24-Jun	20-Jun, 10-Jul, 13-Aug
Dalea searlsiae						20-Jun, 10-Jul
Dalea ornata						20-Jun, 10-Jul
				2008		
Eriogonum umbellatum	5-Jun	19-Jun	20-Jul	15-May	24-Jun	24-Jul
Penstemon acuminatus	29-Apr		5-Jun	29-Apr	11-Jun	11-Jul
Penstemon deustus	5-May		20-Jun	29-Apr	11-Jun	
Penstemon speciosus	5-May		20-Jun	29-Apr	11-Jun	17-Jul
Lomatium dissectum				10-Apr	29-May	
Lomatium triternatum	25-Apr		5-Jun	10-Apr	29-May	3-Jul
Lomatium grayi	25-Mar		15-May	10-Apr	29-May	30-May, 19-Jun
Sphaeralcea parvifolia	5-May		15-Jun	15-May	24-Jun	21-Jul
S. grossulariifolia	5-May		15-Jun	15-May	24-Jun	21-Jul
Sphaeralcea coccinea	5-May		15-Jun	15-May	24-Jun	21-Jul
Dalea searlsiae		19-Jun				
Dalea ornata		19-Jun				

Table 2b. Native forb flowering, irrigation, and seed harvest dates by species in 2009 and 2010, Malheur Experiment Station, Oregon State University, Ontario, OR.

	Flowering			Irrigation		
Species	start	peak	end	start	end	Harvest
			2009			
Eriogonum umbellatum	31-May		15-Jul	19-May	24-Jun	28-Jul
Penstemon acuminatus	2-May		10-Jun	8-May	12-Jun	10-Jul
Penstemon deustus				19-May	24-Jun	
Penstemon speciosus	14-May		20-Jun	19-May	24-Jun	10-Jul
Lomatium dissectum	10-Apr		7-May	20-Apr	28-May	16-Jun
Lomatium triternatum	10-Apr	7-May	1-Jun	20-Apr	28-May	26-Jun
Lomatium grayi	10-Mar		7-May	20-Apr	28-May	16-Jun
Sphaeralcea parvifolia	1-May		10-Jun	22-May	24-Jun	14-Jul
S. grossulariifolia	1-May		10-Jun	22-May	24-Jun	14-Jul
Sphaeralcea coccinea	1-May		10-Jun	22-May	24-Jun	14-Jul
			2010			
Eriogonum umbellatum	4-Jun	12-19 Jun	15-Jul	28-May	8-Jul	27-Jul
Penstemon acuminatus						
Penstemon deustus						
Penstemon speciosus	14-May		20 June	12-May	22-Jun	22-Jul
Lomatium dissectum	25-Apr		20 May	15-Apr	28-May	21-Jun
Lomatium triternatum	25-Apr		15 Jun	15-Apr	28-May	22-Jul
Lomatium grayi	15-Mar		15 May	15-Apr	28-May	22-Jun
Sphaeralcea parvifolia	10-May	4-Jun	25-Jun	28-May	8-Jul	20-Jul
S. grossulariifolia	10-May	4-Jun	25-Jun	28-May	8-Jul	20-Jul
Sphaeralcea coccinea	10-May	4-Jun	25-Jun	28-May	8-Jul	20-Jul

Table 3. Native forb seed harvest and cleaning by species, Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Number of harvests/year	Harvest method	Pre-cleaning	Threshing method	Cleaning method
Eriogonum umbellatum	1	combine[a]	none	dewinger[b]	mechanical[d]
Penstemon acuminatus	1	combine[c]	none	combine	mechanical[d]
Penstemon deustus	1	combine[a]	mechanical[d]	hand[e]	mechanical[d]
Penstemon speciosus[f]	1	combine[c]	none	combine	mechanical[d]
Lomatium dissectum	1	hand	hand	none	mechanical[d]
Lomatium triternatum	1 – 2	hand	hand	none	mechanical[d]
Lomatium grayi	1 – 2	hand	hand	none	mechanical[d]
Sphaeralcea parvifolia	1 – 3	hand or combine[c]	none	combine	none
Sphaeralcea grossulariifolia	1 – 3	hand or combine[c]	none	combine	none
Sphaeralcea coccinea	1 – 3	hand or combine[c]	none	combine	none
Dalea searlsiae	0 or 2	hand	none	dewinger	mechanical[d]
Dalea ornate	0 or 2	hand	none	dewinger	mechanical[d]

[a] Wintersteiger Nurserymaster small-plot combine with dry bean concave.

[b] Specialized seed threshing machine at USDA Lucky Peak Nursery used in 2006. Thereafter an adjustable hand-driven corn grinder was used to thresh seed.

[c] Wintersteiger Nurserymaster small-plot combine with alfalfa seed concave. For the *Sphaeralcea* species, flailing in the fall of 2007 resulted in more compact growth and one combine harvest in 2008, 2009, and 2010.

[d] Clipper seed cleaner.

[e] Hard seed pods were broken by rubbing against a ribbed rubber mat.

[f] Harvested by hand in 2007 and 2009 due to poor seed set.

Results and Discussion

The soil volumetric water content in the various species in 2010 responded to the irrigation treatments (Figs. 3 - 7) and remained fairly moist due to the late distribution of precipitation in 2010 (Figure 2).

Emergence for the two prairie clover (*Dalea* spp.) species in the spring of 2007 was again poor. Emergence for *Penstemon deustus* and for basalt milkvetch (*Astragalus filipes*) was extremely poor; *A. filipes* produced negligible amounts of seed in 2007.

Flowering and Seed Set. *Penstemon acuminatus* and *P. speciosus* had poor seed set in 2007, partly due to a heavy lygus bug infestation that was not adequately controlled by the applied insecticides. In the Treasure Valley, the first hatch of lygus bugs occurs when 250 degree days (52^oF base) are accumulated. Data collected by an AgriMet weather station adjacent to the field indicate that the first lygus bug hatch occurred on May 14, 2006, May 1, 2007, May 18, 2008, May 19, 2009, and May 29, 2010. The average (1995 - 2010) lygus bug hatch date was May 18. *Penstemon acuminatus* and *P. speciosus* start flowering in early May. The earlier lygus bug hatch in 2007 probably resulted in harmful levels of lygus bugs present during a larger part of the *Penstemon* spp. flowering period than normal. Poor seed set for *P. acuminatus* and *P. speciosus* in 2007 also was related to poor vegetative growth compared to 2006 and 2008. In 2009, all plots of *P. acuminatus* and *P. speciosus* again showed poor vegetative growth and seed set. Root rot affected all plots of *P. acuminatus* in 2009, killing all plants in two of the four plots of the wettest treatment (2 inches per irrigation).

The three *Sphaeralcea* species (globemallow) showed a long flowering period (early May through September) in 2007. Multiple manual harvests were necessary because the seed falls out of the capsules once they are mature. The flailing of the three *Sphaeralcea* species starting in the fall of 2007 was done annually to induce a more concentrated flowering allowing one mechanical harvest. Precipitation in June of 2009 (2.27 inches) and 2010 (1.95 inches) was substantially higher than average (0.76 inches). Rust (*Puccinia sherardiana*) infected all three *Sphaeralcea* species in June of 2009 and 2010, causing substantial leaf loss and reduced vegetative growth.

<u>Seed Yields</u>.

Eriogonum umbellatum. In 2006, seed yield increased with increasing water application, up to 8 inches, the highest amount tested (Table 5, Fig. 3). In 2007, 2008, and 2009 seed yield showed a quadratic response to irrigation rate (Tables 5 and 6). Seed yields were maximized by 8.1 inches, 7.2 inches, and 6.9 inches of water applied in 2007, 2008, and 2009, respectively. In 2010, there was no significant difference in yield between treatments. The 2010 season had unusually cool (Table 3, Figure 1) and wet weather (Figure 2). The precipitation accumulated in April through June of 2010 was the highest since 2006 (Table 3). The relatively high seed yield (252 lb/acre) of *E. umbellatum* in the non-irrigated treatment in 2010 seemed to be related to the high April-June precipitation in 2010. Averaged over 5 years, seed yield of *Eriogonum umbellatum* increased with increasing water applied up to 8 inches, the highest amount tested (Fig. 3). The quadratic seed yield responses most years suggests that additional irrigation above 8 inches would not be beneficial.

Penstemon acuminatus. There was no significant difference in seed yield between irrigation treatments in 2006 (Table 5). Precipitation from March through June was 6.4 inches in 2006. The 64-year average precipitation from March through June is 3.6 inches. The wet weather in 2006 could have attenuated the effects of the irrigation treatments. In 2007 and 2008, seed yield showed a quadratic response to irrigation rate (Figure 4). Seed yields were maximized by 4.0 and 8.5 inches of water applied in 2007 and 2008, respectively. In 2009, there was no significant difference in seed yield between treatments (Table 6). However, due to root rot affecting all plots in 2009, the seed yield results were compromised. By 2010, substantial lengths of row only contained dead plants. Measurements in each plot showed that plant death increased with increasing irrigation rate. The percent of stand loss was 51.3, 63.9, and 88.5 for the 0, 4, and 8-inch irrigation treatments, respectively. The trial area was disked out in 2010. Following the 2005 planting, seed yields were substantial in 2006 and moderate in 2008. *P. acuminatus* is a short-lived perennial.

Penstemon speciosus. In 2006, 2007, 2008, and 2009 seed yield showed a quadratic response to irrigation rate (Fig. 5). Seed yields were maximized by 4.3, 4.2, 5.0, and 4.3 inches of water applied in 2006, 2007, 2008, and 2009, respectively. In 2010, there was no difference in seed yield between treatments. Seed yield was low in 2007 due to lygus bug damage, as discussed previously. Seed yield in 2009 was low due to stand loss from root rot. The plant stand recovered somewhat in 2010, due in part to natural reseeding, especially in the non-irrigated plots. The average of the seed yield for 2006 and 2008 was estimated to be maximized by 4.7 inches of water applied (Fig. 5).

Penstemon deustus. There was no significant difference in seed yield between irrigation treatments in 2006 or 2007. Both the replanting of the low stand areas in October 2005 and the replanting of the whole area in October 2006 resulted in very poor emergence and in plots with very low and uneven stands. The production of *P. deustus* seed will depend on learning how to establish plant stands.

Lomatium triternatum. A trend emerged for increasing seed yield with increasing irrigation rate in 2007 (Table 5). The highest irrigation rate resulted in significantly higher seed yield than the non-irrigated check treatments. Seed yields of *L. triternatum* were substantially higher in 2008, 2009, and 2010 (Tables 5 and 6). In 2008, 2009, and 2010 seed yields of *L. triternatum* showed a quadratic response to irrigation rate (Fig. 6). Seed yields were estimated to be maximized by 8.4, 5.4, and 7.8 inches of water applied in 2008, 2009, and 2010, respectively. Averaged over 4 years, seed yield of *L. triternatum* was estimated to be maximized by 7.2 inches of water applied.

Lomatium grayi. A trend emerged for increasing seed yield with increasing irrigation rate in 2007 (Table 5). The highest irrigation rate resulted in significantly higher seed yield than the non-irrigated check. Seed yields of *L. grayi* were substantially higher in 2008 and 2009. In 2008, seed yields of *L. grayi* showed a quadratic response to irrigation rate (Fig. 7). Seed yields were estimated to be maximized by 6.9 inches of water applied in 2008. In 2009, seed yield showed a linear response to irrigation rate. Seed yield with the 4 inch irrigation rate was significantly higher than with the non-irrigated check, but the 8 inch irrigation rate did not result in a significant increase above the 4 inch rate. In 2010, seed yield was not responsive to irrigation. The unusually wet spring of 2010 could have caused the lack of response to irrigation. A further complicating factor in 2010 that compromised seed yields was rodent damage. Extensive rodent (vole) damage occurred over the 2009/2010 winter. The affected areas were transplanted with 3-year old *L. dissectum* plants from an adjacent area in the spring of 2010. To reduce the attractiveness to voles, the plants were mowed after becoming dormant in early fall of 2010. Averaged over 4 years, seed yield of *L. grayi* was estimated to be maximized by 5.6 inches of water applied.

Lomatium dissectum. Exhibited very poor vegetative growth in 2006, 2007, and 2008, and produced only very small amounts of flowers in 2008. In 2009, vegetative growth and flowering for *L. dissectum* were higher. Seed yield of *L. dissectum* showed a linear response to irrigation rate in 2009 (Fig. 8). Seed yield with the 4-inch irrigation rate was significantly higher than with the non-irrigated check, but the 8-inch irrigation rate did not result in a significant increase above the 4-inch rate. In 2010, seed yield of *L. dissectum* showed a quadratic response to irrigation rate. Seed yield was estimated to be maximized by 5.4 inches of applied water in 2010. Averaged over the two years, seed yield showed a quadratic response to irrigation rate and was estimated to be maximized by 5.8 inches of water applied.

All the *Lomatium* species tested were affected by *Alternaria* fungus, but the infection was greatest on the *L. dissectum* selection planted in this trial. This infection might have delayed *L. dissectum* plant development.

*Sphaeralcea sp***.** In 2007, 2008, 2009, and 2010 there were no significant differences in seed yield among irrigation treatments for the three *Sphaeralcea* species (Tables 5 and 6).

Dalea ornata and *Dalea searlsiae.* Emergence for the two *Dalea* species was poor, and plots had poor and uneven stands. In 2007, there was no significant difference in seed yield among irrigation treatments for the two *Dalea* species, with *D. ornata* having the highest seed yield. The stand of the three *Dalea* species declined and was too poor for seed harvest in 2008. The three *Dalea* species were replanted in the fall of 2008, but emergence was again poor and stands were not adequate for seed harvest in 2009. *D. ornata* and *D. searlsiae* were replanted in new areas in the fall of 2009. Irrigation treatments will be applied starting in 2011.

Conclusions

Subsurface drip irrigation systems were tested for native seed production because they have two potential strategic advantages, a) low water use, and b) the buried drip tape provides water to the plants at depth, precluding stimulation of weed seed germination on the soil surface and keeping water away from native plant tissues that are not adapted to a wet environment.

Due to the arid environment, supplemental irrigation may be often required for successful flowering and seed set because soil water reserves may be exhausted before seed formation. The total irrigation requirements for these arid-land species were low and varied by species. The *Sphaeralcea* spp. and *Penstemon acuminatus* did not respond to irrigation in these trials. *Penstemon speciosus* and *Lomatium dissectum* required approximately 4 inches of irrigation. *Lomatium grayi, Lomatium triternatum*, and *Eriogonum umbellatum* responded quadratically to irrigation with optimum near 8 inches. The other species tested had insufficient plant stands to reliably evaluate response to irrigation.

Literature Cited:

USDA, NRCS. 2009. The PLANTS Database (http://plants.usda.gov, 13 March 2009). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Table 4. Precipitation and growing degree days at the Malheur Experiment Station.

	Precipitation (inches)		Growing degree days (50 - 86 °F)
Year	January - June	April - June	Jan - June
2006	9.0	3.1	1120
2007	3.1	1.9	1208
2008	2.9	1.2	936
2009	5.8	3.9	1028
2010	8.3	4.3	779
66-year average	5.8	2.7	1053[a]

[a]24-year average

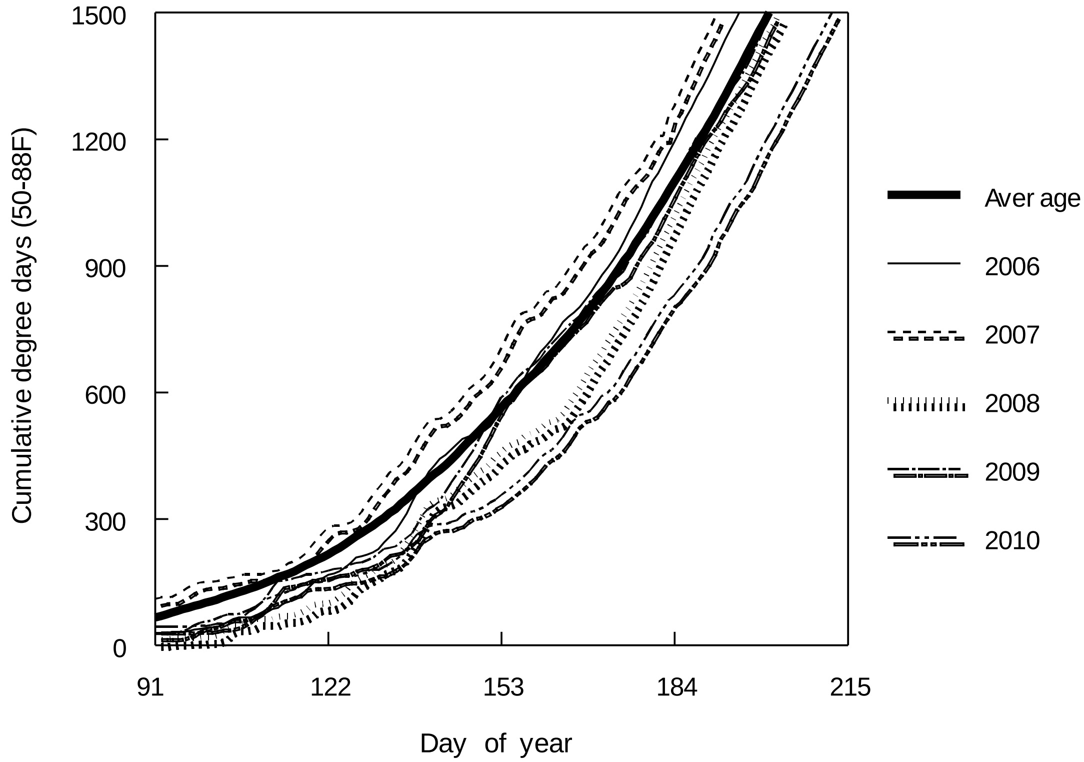

Figure 1. Cumulative annual and 20-year average growing degree days at the Malheur Experiment Station, Oregon State University, Ontario, OR.

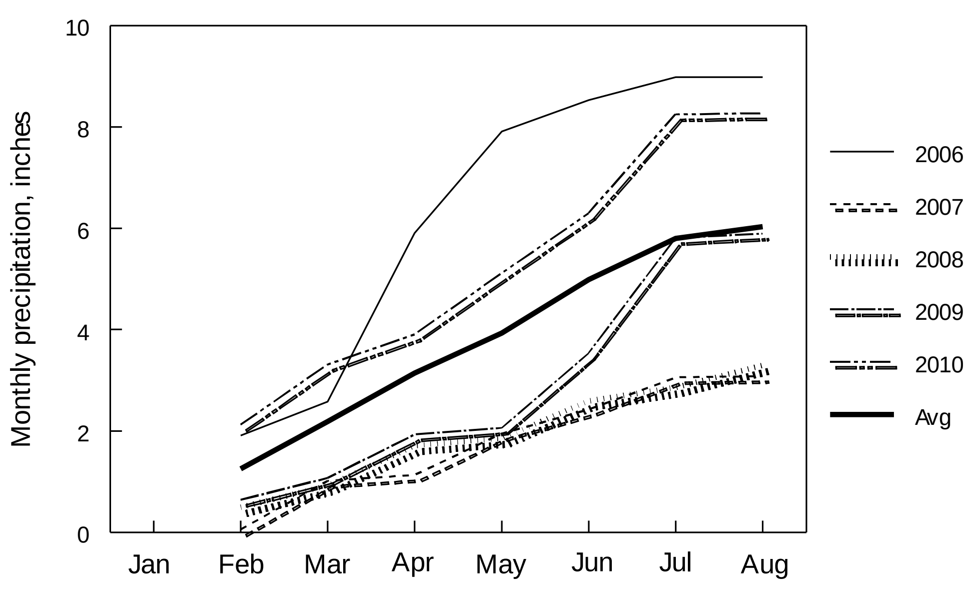

Figure 2. Cumulative annual and 66-year average precipitation from January through July at the Malheur Experiment Station, Oregon State University, Ontario, OR.

Table 5. Native forb seed yield response to irrigation rate (inches/season) in 2006, 2007, and 2008. Malheur Experiment Station, Oregon State University, Ontario, OR.

	2006				2007				2008			
Species	0 inches	4 inches	8 inches	LSD (0.05)	0 inches	4 inches	8 inches	LSD (0.05)	0 inches	4 inches	8 inches	LSD (0.05)
	---------------- lb/acre ----------------											
Eriogonum umbellatum[a]	155.3	214.4	371.6	92.9	79.6	164.8	193.8	79.8	121.3	221.5	245.2	51.7
Penstemon acuminatus[a]	538.4	611.1	544.0	NS	19.3	50.1	19.1	25.5[b]	56.2	150.7	187.1	79.0
Penstemon deustus[c]	1246.4	1200.8	1068.6	NS	120.3	187.7	148.3	NS	--- very poor stand ---			
Penstemon speciosus[a]	163.5	346.2	213.6	134.3	2.5	9.3	5.3	4.7[b]	94.0	367.0	276.5	179.6
Lomatium dissectum[d]	---- no flowering ----				--- no flowering ---				-- very little flowering --			
Lomatium triternatum[d]	---- no flowering ----				2.3	17.5	26.7	16.9[b]	195.3	1060.9	1386.9	410.0
Lomatium grayi[d]	---- no flowering ----				36.1	88.3	131.9	77.7[b]	393.3	1287.0	1444.9	141.0
Sphaeralcea parvifolia[e]					1062.6	850.7	957.9	NS	436.2	569.1	544.7	NS
Sphaeralcea grossularifolia[e]					442.6	324.8	351.9	NS	275.3	183.3	178.7	NS
Sphaeralcea coccinea[e]					279.8	262.1	310.3	NS	298.7	304.1	205.2	NS
Dalea searlsiae[e]					11.5	10.2	16.4	NS	----- very poor stand ----			
Dalea ornata[e]					47.4	27.3	55.6	NS	----- very poor stand ----			

[a] planted March, 2005, areas of low stand replanted by hand in October 2005.
[b] LSD (0.10).
[c] planted March, 2005, areas of low stand replanted by hand in October 2005 and whole area replanted in October 2006. Yields in 2006 are based on small area with adequate stand. Yields in 2007 are based on whole area of very poor and uneven stand.
[d] planted March, 2005, whole area replanted in October 2005.
[e] planted spring 2006, whole area replanted in November 2006.
[f] Based on small areas with good plant stands in 2006.

Table 6. Native forb seed yield response to irrigation rate (inches/season) in 2009, 2010, and 2 to 5-year averages. Malheur Experiment Station, Oregon State University, Ontario, OR.

	2009				2010				2 to 5-year averages			
Species	0 inches	4 inches	8 inches	LSD (0.05)	0 inches	4 inches	8 inches	LSD (0.05)	0 inches	4 inches	8 inches	LSD (0.05)
	---------- lb/acre ----------											
Eriogonum umbellatum[a]	132.3	223.0	240.1	67.4	252.9	260.3	208.8	NS	153.9	215.2	250.1	25.6
Penstemon acuminatus[a]	20.7	12.5	11.6	NS	-- Stand disked out --							
Penstemon deustus[c]	--- very poor stand ---											
Penstemon speciosus[a]	6.8	16.1	9.0	6.0b	147.2	74.3	69.7	NS	81.3	148.5	114.5	NS
Lomatium dissectum[d]	50.6	320.5	327.8	196.4b	265.8	543.8	499.6	199.6	158.2	432.2	413.7	158.6
Lomatium triternatum[d]	181.6	780.1	676.1	177.0	1637.2	2829.6	3194.6	309.4	504.1	1172.0	1321.1	149.7
Lomatium grayi[d]	359.9	579.8	686.5	208.4	1035.7	1143.5	704.8	NS	456.2	774.7	742.0	196.9
Sphaeralcea parvifolia[e]	285.9	406.1	433.3	NS	245.3	327.3	257.3	NS	507.5	538.3	548.3	NS
Sphaeralcea grossularifolia[e]	270.7	298.9	327.0	NS	310.5	351.0	346.6	NS	324.8	289.5	301.1	NS
Sphaeralcea coccinea[e]	332.2	172.1	263.3	NS	385.7	282.6	372.5	NS	324.1	255.2	287.8	NS
Dalea searlsiae[e]	-- very poor stand --				--- very poor stand ---							
Dalea ornata[e]	--- very poor stand ----				--- very poor stand ---							

[a] planted March, 2005, areas of low stand replanted by hand in October 2005.
[b] LSD (0.10).
[c] planted March, 2005, areas of low stand replanted by hand in October 2005 and whole area replanted in October 2006. Yields in 2006 were based on small areas with adequate stand. Yields in 2007 were based on whole area of very poor and uneven stand.
[d] planted March, 2005, whole area replanted in October 2005.
[e] planted spring 2006, whole area replanted in November 2006.
[f] Based on small areas with good plant stands in 2006.

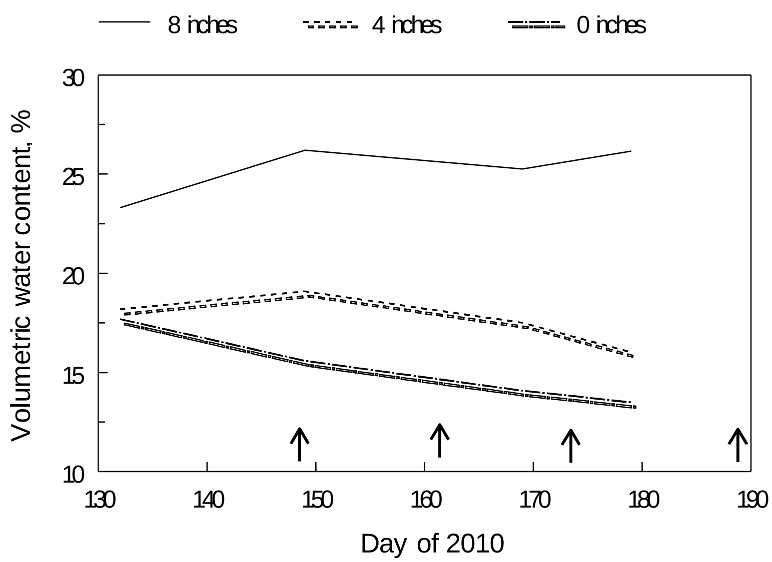

Figure 3. Soil volumetric water content for *Eriogonum umbellatum* over time in 2010. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 28 and ended on July 8. Arrows denote irrigations. *E. umbellatum* was harvested on July 27 (day 208).

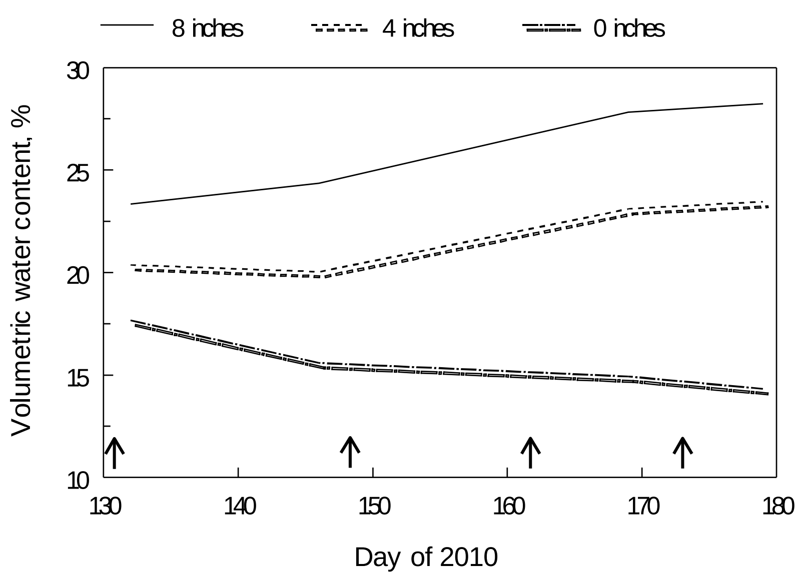

Figure 4. Soil volumetric water content for *Penstemon speciosus* over time in 2010. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 12 and ended on June 22. Arrows denote irrigations. *P. speciosus* was harvested on July 22 (day 203).

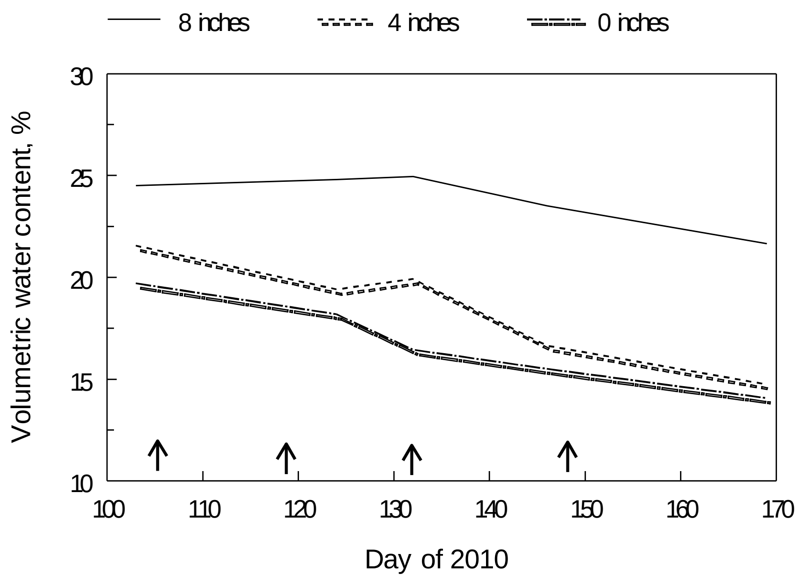

Figure 5. Soil volumetric water content for *Lomatium triternatum* over time in 2010. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 15 and ended on May 28. Arrows denote irrigations. *L. triternatum* was harvested on July 22 (day 203).

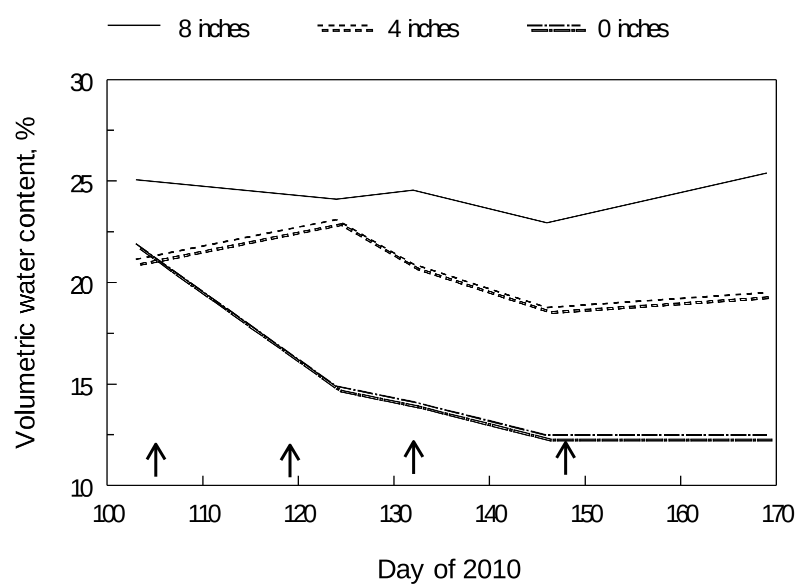

Figure 6. Soil volumetric water content for *Lomatium grayi* over time in 2010. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 15 and ended on May 28. Arrows denote irrigations. *L. grayi* was harvested on June 22 (day 173).

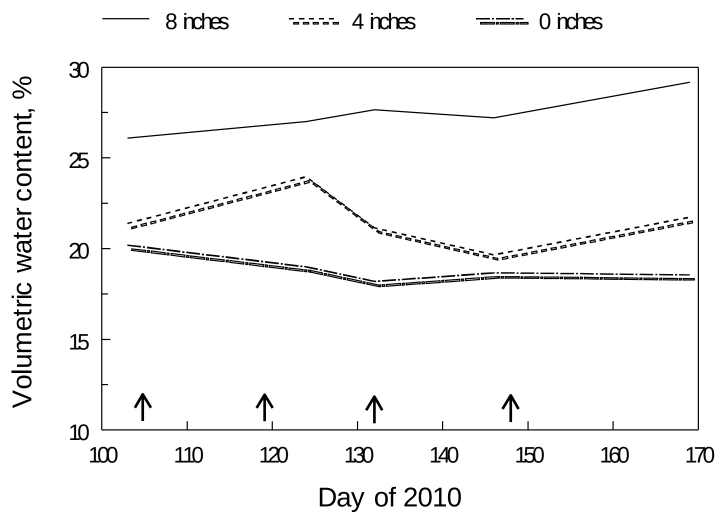

Figure 7. Soil volumetric water content for *Lomatium dissectum* over time in 2010. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 15 and ended on May 28. Arrows denote irrigations. *L. dissectum* was harvested on June 21(day 172).

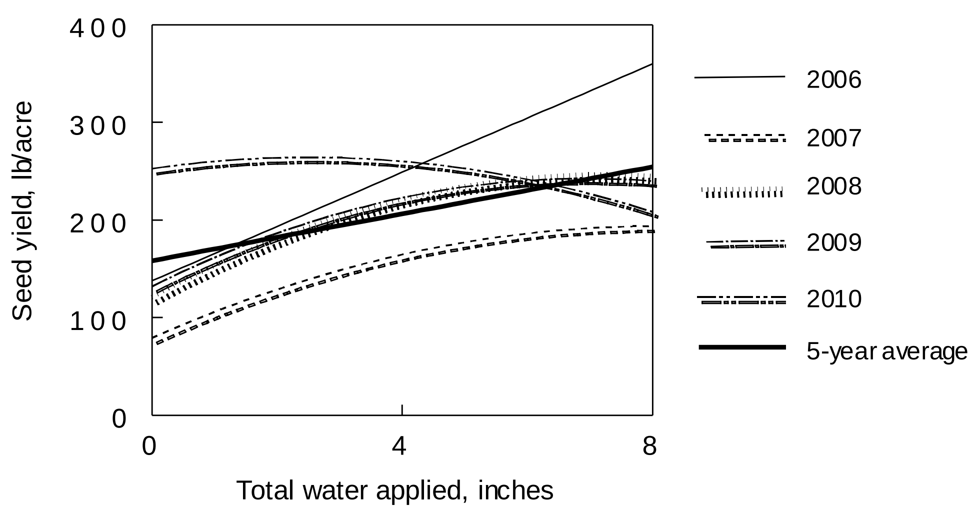

Figure 8. Average annual *Eriogonum umbellatum* seed yield response to irrigation water applied in 5 years and averaged over 5 years.
Regression equations:
2006, $Y = 137.9 + 27.8X$, $R^2 = 0.68$, $P = 0.01$; **2007**, $Y = 79.6 + 28.3X – 1.75X^2$, $R^2 = 0.69$, $P = 0.05$;
2008, $Y = 121.3 + 34.6X – 2.4X^2$, $R^2 = 0.73$, $P = 0.01$; **2009**, $Y = 132.3 + 31.9X – 2.3X^2$, $R^2 = 0.60$, $P = .05$;
2010, $Y = 252.9 + 9.21X – 1.8X^2$, $R^2 = 0.08$, P = NS; **5-year average**, $Y = 158.3 + 12X$, $R^2 = 0.77$, $P = 0.001$

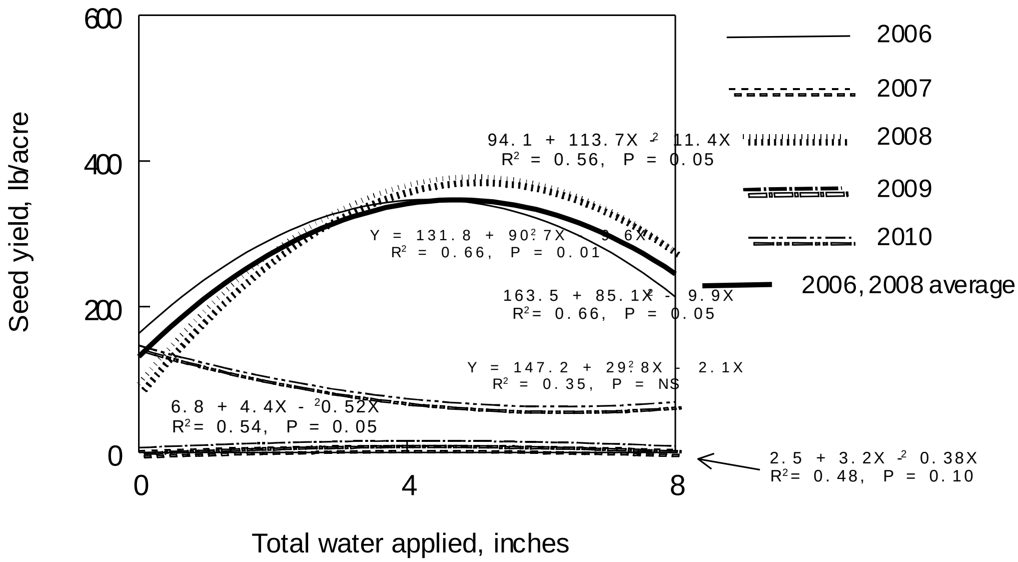

Figure 9. Annual and 2-year average *Penstemon speciosus* seed yield response to irrigation water.

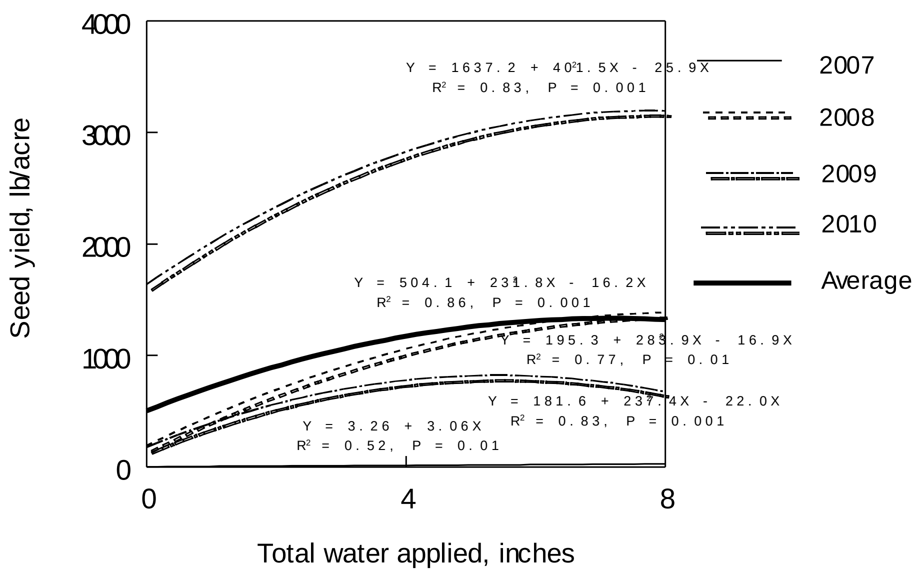

Figure 10. Annual and 4-year average *Lomatium triternatum* seed yield response to irrigation water applied.

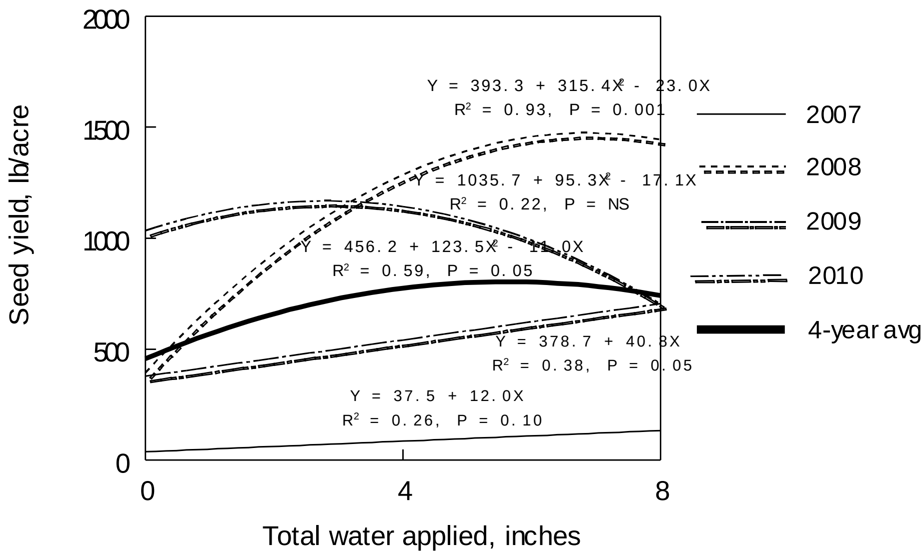

Figure 11. Annual and 4-year average *Lomatium grayi* seed yield response to irrigation water applied.

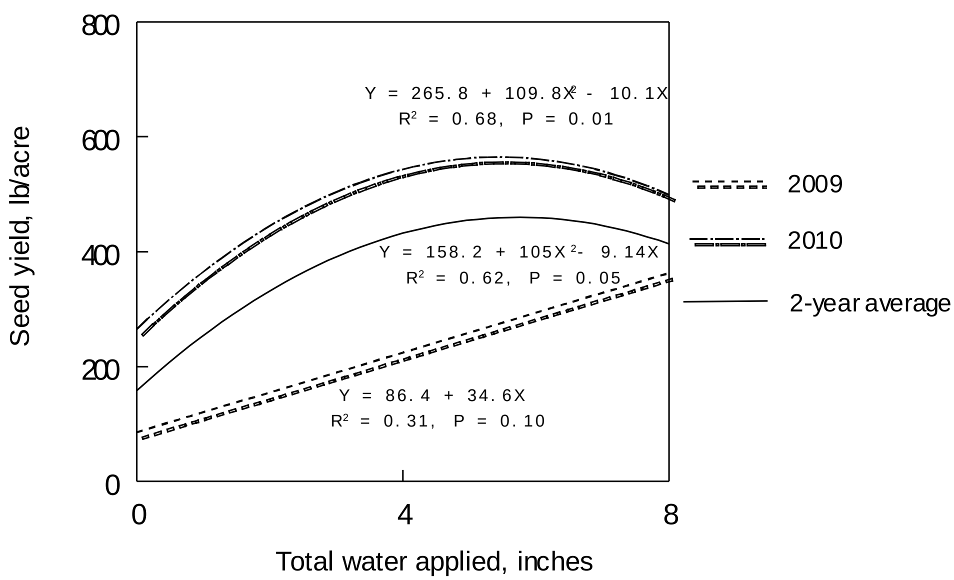

Figure 12. Annual and 2-year average *Lomatium dissectum* seed yield response to irrigation water.

Management Applications:
The report above describes practices that can be immediately implemented by seed growers. A multi-year summary of research findings is below in Table 7.

Table 7. Amount of irrigation water for maximum seed yield, years to seed set, and life span. A summary of multi-year research findings.

Species	Optimum amount of irrigation	Years to first seed set	Life span
	inches/season	from fall planting	years
Eriogonum umbellatum	8	1	6+
Penstemon acuminatus	4-8	1	3
Penstemon deustus	insufficient stand	2	6+
Penstemon speciosus	4-6	1	3
Lomatium dissectum	6-8	4	6+
Lomatium triternatum	6	2	6+
Lomatium grayi	6-8	2	6+
Sphaeralcea parvifolia	no response	1	5+
Sphaeralcea grossularifolia	no response	1	5+
Sphaeralcea coccinea	no response	1	5+
Dalea searlsiae	insufficient stand	1	?
Dalea ornata	insufficient stand	1	?

Project Description: Weed Control
Native forb seed is needed to restore rangelands of the Intermountain West. Commercial seed production is necessary to provide the quantity of seed needed for restoration efforts. A major limitation to economically viable commercial production of native forb seed is weed competition. Weeds are adapted to growing in disturbed soil, and native forbs are not competitive with these weeds. The use of preemergence and postemergence herbicides for forb weed control is important, because forbs are fall planted. Fall planting results in nearly simultaneous forb and weed emergence early in the spring, complicating weed control. There is a considerable body of knowledge about the relative efficacy of different herbicides to control target weeds, but few trials have tested the tolerance of native forbs to commercial herbicides.

This work sought to discover products that could eventually be registered for use for native forb seed production. The information in this report is for the purpose of informing cooperators and colleagues in other agencies, universities, and industry of the research results. Reference to products and companies in this publication is for the specific information only and does not endorse or recommend that product or company to the exclusion of others that may be suitable. Nor should any information and interpretation thereof be considered as recommendations for the application of any of these herbicides. Pesticide labels should always be consulted before any pesticide use. Considerable efforts may be required to register these herbicides for use for native forb seed production.

The four trials reported here had certain procedures in common. The trials were conducted on a field of Nyssa silt loam with a pH of 8.3 and 1.1 percent organic matter. Before planting, drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth midway between two rows (30-inch rows). The drip tape was buried in alternating inter-row spaces (5 ft apart). The flow rate for the drip tape was 0.34 gal/min/100 ft at 8 psi with emitters spaced 16 inches apart, resulting in a water application rate of 0.066 inch/hour.

Trial 1: Tolerance of Native Forbs to Preemergence Herbicides, 2009-2010
This trial tested the tolerance of native forb species to conventional preemergence and postemergence herbicides in the field.

Procedures for Trial 1
The trial was conducted on a part of the field where soybean was the previous crop. After the soybean harvest in the fall of 2009, the stubble was flailed and the field was plowed, disked, and groundhogged.

The experimental design was a randomized complete block with 8 herbicide treatments (Table 1) replicated 4 times. Each plot consisted of 8 single rows 5 feet long with one forb species planted per row. The herbicides were applied on November 30, 2009 using a CO_2 sprayer with 8002 nozzles at 30 PSI applying 20 gallons per acre. The results of a tetrazolium test were used to adjust the seeding rate to 30 viable seeds/foot of row. Seed of the 8 forb species (Table 2) was planted on the soil surface on December 1, 2009. After planting, a thin layer of sawdust was applied over the seed row. The sawdust was applied at approximately 0.18 oz per foot of row (198 lb per acre). Row cover (N-sulate, DeWitt Co., Inc., Sikeston, MO 63801) that covered 4 rows was applied with a mechanical plastic mulch layer after the sawdust application. The field was irrigated to apply 2 inches of water on December 7. On April 7, 2010, the row cover was removed from the three *Lomatium* species and *Astragalus filipes* and stand counts were made in each plot. On April 20, 2010, the row cover was removed from *E. umbellatum, P. acuminatus, P. deustus,* and *P. speciosus*, and stand counts were made in each plot.

Results and Discussion for Trial 1
Emergence was poor and uneven for all species (Table 3). Both *Penstemon acuminatus* and *Penstemon deustus* had zero emergence for all treatments. There were statistically significant differences in stand between treatments only for *Eriogonum umbellatum* and *Penstemon speciosus*. For these two species only Kerb and Treflan resulted in lower stand than the untreated check. The uneven emergence casts doubt on the validity of the results.

Table 1. Forb preemergence herbicide treatments.

Herbicide treatment	Formulation	Application rate
		lb ai/acre
Untreated		
Prefar	4 EC	5
Kerb	50 WP	1
Treflan	4 EC	0.375
Prowl H_2O	3.8 SC	0.75
Balan	1.5 lb ai/gal	1.2
Outlook	6 EC	0.656
Lorox	50 DF	0.5

Table 2. Forb species submitted to preemergence herbicides.

Species	Common name
Astragalus filipes	Basalt milkvetch
Eriogonum umbellatum	Sulphur-flower buckwheat
Penstemon acuminatus	Sand penstemon
Penstemon deustus	Hotrock penstemon
Penstemon speciosus	Royal or sagebrush penstemon
Lomatium dissectum	Fernleaf biscuitroot
Lomatium triternatum	Nineleaf desert parsley
Lomatium grayi	Gray's lomatium

Table 3. Emergence of eight forb species in the spring of 2010 in response to preemergence herbicide treatments applied in the fall of 2009.

Herbicide	*Eriogonum umbellatum*	*Penstemon acuminatus*	*Penstemon deustus*	*Penstemon speciosus*	*Lomatium dissectum*	*Lomatium triternatum*	*Lomatium grayi*	*Astragalus filipes*
	----------	----------	----------	---------- % emergence	----------	----------	----------	----------
Untreated	37.3	0.0	0.0	7.3	6.8	26.0	4.0	66.0
Prefar	38.7	0.0	0.0	2.5	10.3	26.5	3.7	32.3
Kerb	0.7	0.0	0.0	0.0	4.7	17.2	3.3	19.8
Treflan	12.0	0.0	0.0	0.0	4.3	24.2	5.3	33.8
Prowl H_2O	19.1	0.0	0.0	1.0	8.5	24.3	4.2	30.3
Balan	12.4	0.0	0.0	0.7	10.8	26.3	2.8	32.5
Outlook	14.2	0.0	0.0	5.7	12.0	21.2	2.2	21.0
Lorox	13.8	0.0	0.0	11.2	6.3	24.0	2.8	26.5
Average	18.5	0.0	0.0	3.5	8.0	23.7	3.5	32.8
LSD (0.05)	25.30	NS	NS	7.2	NS	NS	NS	NS

Trial 2: A Preliminary Evaluation of Activated Charcoal to Protect Forbs from a Preemergence Herbicide

A preliminary trial at the Malheur Experiment Station showed that some forb species are tolerant to some pre-emergence applied herbicides (Shock et al., 2007). The use of a pre-emergence herbicide for forb weed control is important, because forbs are fall planted. Fall planting results in simultaneous forb and weed emergence early in the spring, complicating weed control. Research at the Malheur Experiment Station in 2009, showed that activated charcoal could protect direct seeded onions from two pre-emergence applied herbicides (Felix and Ishida, 2010). This preliminary trial evaluated activated charcoal to protect seed of eight forb species from Prowl herbicide.

Procedures for Trial 2

The trial was conducted on a part of the field where soybean was the previous crop. After the soybean harvest in the fall of 2009, the stubble was flailed and the field was plowed, disked, and groundhogged.

The experimental design was a randomized complete block with 2 treatments: a charcoal treated and untreated check. The treatments were replicated 4 times. Each plot consisted of 8 single rows 5 feet long with one forb species planted per row. The results of a tetrazolium test were used to adjust the seeding rate to 30 viable seeds/foot of row. Seed of the 8 forb species (Table 4) was planted manually on the soil surface on December 1, 2009. After planting, a thin layer of sawdust alone (untreated check) or sawdust mixed with activated charcoal (Gro Safe, Norit Americas, Atlanta, GA) was applied over the seed row. The sawdust for both treatments was applied at approximately 198 lb per acre. For the charcoal treatment, the charcoal was mixed with the sawdust at 25% of charcoal by weight. The charcoal applied in the sawdust was equivalent to 48 lb charcoal per acre.

After planting and the sawdust application, both treatments had Prowl H_2O (3.8 SC) broadcast at 0.75 lb ai/acre on December 1, 2009. The Prowl was applied using a CO_2 sprayer with 8002 nozzles at 30 PSI and applying 20 gallons per acre. Row cover (N-sulate, DeWitt Co., Inc., Sikeston, MO 63801) that covered 4 rows was applied with a mechanical plastic mulch layer after the herbicide application. The field was drip-irrigated to apply 2 inches of water on December 7. On April 7, 2010, the row cover was removed from the three *Lomatium* species and *Astragalus filipes* and stand counts were made in each plot. On April 20, 2010, the row cover was removed from *E. umbellatum*, *P. acuminatus*, *P. deustus*, and *P. speciosus*, and stand counts were made in each plot.

Results and Discussion for Trial 2

Activated charcoal applied with the sawdust over the seed row resulted in higher emergence than sawdust alone (untreated check) for *E. umbellatum*, *P. acuminatus*, *P. deustus*, *P. speciosus*, and *A. filipes* (Table 4). For *L. triternatum*, the charcoal had a detrimental effect on emergence. These results suggest that activated charcoal might allow the use of a preemergence herbicide in forb weed control for selected species. Further research is needed to refine these procedures.

Table 4. Emergence of eight forb species in the spring of 2010 in response to Prowl herbicide applied with and without activated charcoal in the fall of 2009.

Charcoal	*Eriogonum umbellatum*	*Penstemon acuminatus*	*Penstemon deustus*	*Penstemon speciosus*	*Lomatium dissectum*	*Lomatium triternatum*	*Lomatium grayi*	*Astragalus filipes*
	------ % emergence ------							
yes	34.8	5.5	3.0	34.8	24.3	27.2	9.2	45.0
no	16.3	0.0	0.7	3.3	27.3	45.5	5.8	1.5
LSD(0.05)	0.8	4.9	1.9	13.6	NS	13.5	NS	22.1

Trial 3: Native Perennial Forb Tolerance to Repeated Annual Applications of Postemergence Herbicides, 2007-2010

Procedures for Trial 3

Plant Establishment. Seed of seven Great Basin forb species (Table 5) received in October 2005 was planted November 1, 2005. The field had been disked, groundhogged, and marked in rows

30 inches apart. The seven forb species were planted in individual rows 435 ft long and 30 inches apart. Planting depths were similar to those used in the irrigation trial (Shock et al. 2007) and varied by species. The crop preceding forbs was wheat. Prior to planting, one drip tape was inserted 12 inches deep equidistant between pairs of rows to be planted. The drip tape was supplied with irrigation water using filtration and other common drip-irrigation practices (Shock 2006).

<u>2006 Postemergence Treatments</u>. The lower 200 ft of the field was staked out to make 5-ft-wide plots perpendicular to the forb rows, crossing all seven species. Eight treatments including the untreated check were replicated four times in a randomized complete block design (Table 6). Treatments were applied May 24, 2006 at 30 psi, 2.63 mph, in 20 gal/acre using 8002 nozzles with 3 nozzles spaced 20 inches apart. Plant injury in 2006 was rated visually on May 31, June 15, and June 30.

In 2006 the trial was irrigated very little because of ample rainfall. Very few plants flowered and seed was not harvested in 2006.

<u>Spring of 2007</u>. By March 30, 2007, it was difficult if not impossible to distinguish any effects of the 2006 postemergence herbicide applications on any of the seven forb species. These observations suggest that some degree of phytotoxic damage may be acceptable in establishing native forb seed fields if effective weed control is achieved.

<u>2007 Postemergence Treatments</u>. The same treatments as in 2006 were applied again to the same plots on April 24, 2007. The same application specifications as in 2006 were used in 2007. Plant injury was rated visually on May 1, May 11, May 25, and June 12.

Drip irrigations were applied every 2 weeks starting on April 10 and ending on May 29 (total of 4 irrigations). Each irrigation applied 1 inch of water.

Seed of *Eriogonum umbellatum, Penstemon acuminatus, P. deustus,* and *P. speciosus* was harvested by hand as the seed reached maturity. The seed was cleaned and weighed. *Lomatium dissectum, L. triternatum,* and *L. grayi* did not flower in 2007.

<u>2008 Postemergence Treatments</u>. The same treatments as in 2006 were applied again to the same plots on March 13, 2008. The same application specifications as in 2006 were used in 2008.

Drip irrigations were applied every 2 weeks starting on April 5 and ending on June 24 (total of 4 irrigations). Each irrigation applied 1 inch of water.

Seed of *Eriogonum umbellatum, Penstemon acuminatus, P. deustus, P. speciosus,* and *Lomatium triternatum was* harvested by hand as the seed reached maturity from the 5 ft of row across the plot width. The seed was cleaned and weighed. *Lomatium dissectum* and *L. grayi* had only a few flowers in 2008.

2009 Postemergence Treatments. The same treatments as in 2006 were applied again to the same plots on March 20, 2009. The same application specifications as in 2006 were used in 2009.

Drip irrigations were applied every 2 weeks starting on May 22 and ending on June 24 (total of 4 irrigations). Each irrigation applied 1 inch of water.

Seed of *Lomatium dissectum,* and *Lomatium grayi* was harvested by hand as the seed reached maturity from the 5 ft of row across the plot width. The seed was cleaned and weighed.

2010 Postemergence Treatments. The same treatments as in 2006 were applied again to the same plots on April 7, 2010. The same application specifications as in 2006 were used in 2010.

The trial was not irrigated in 2010.

Seed of *Eriogonum umbellatum, Lomatium dissectum,* and *Lomatium triternatum* was harvested by hand as the seed reached maturity from the 5 ft of row across the plot width. The seed was cleaned and weighed.

General Considerations:
The focus of the evaluations was forb tolerance to the herbicides, not weed control. Therefore, weeds were removed as needed in each year. In 2008, 2009, and 2010 the weeds of each species were counted in each plot (data not shown).

For each species the effects of herbicides on plant stand and injury were evaluated independently from the effects on other species. Treatment differences were compared using ANOVA and protected least significant differences at the 95 percent confidence LSD (0.05) using NCSS Number Cruncher software (NCSS, Kaysville, UT).

Results and Discussion Procedures for Trial 3
All observations made on the herbicides tested are strictly preliminary observations. Herbicides that were observed to be damaging to the forbs as reported here might be helpful if used at a lower rate or in a different environment. The herbicides were relatively safe for the forbs in these trials but they might be harmful if used at higher rates or in a different environment. Nothing in this report should be construed as a recommendation.

2007 Postemergence Treatments. For *Eriogonum umbellatum*, applications of Buctril, Caparol, and Lorox resulted in lower seed yields than the untreated check (Table 6). For *Penstemon acuminatus*, applications of Buctril, Select, Caparol, and Lorox resulted in lower seed yields than the untreated check. For *P. deustus* and *P. speciosus* applications of Buctril, Goal, Caparol, and Lorox resulted in lower seed yields than the untreated check.

2008 Postemergence Treatments. There was no significant difference in seed yield between the reapplied herbicide treatments and the check for *Eriogonum umbellatum, Penstemon acuminatus, P. deustus,* and *P. speciosus* in 2008 (Table 7). For *Lomatium triternatum,* seed yield was reduced for the Buctril® treatment, despite the early application. The *Lomatium* spp. break dormancy early in the growing season, and *L. triternatum* could have been susceptible at the early application date. Buctril, applied later in 2007 also reduced seed yield of *L. triternatum*.

2009 Postemergence Treatments. Root rot caused severe damage to plant stands of *Penstemon acuminatus* and *Penstemon speciosus*. *Penstemon deustus, Lomatium triternatum,* and *Eriogonum umbellatum* produced very little seed in 2009. *Lomatium dissectum* and *Lomatium grayi* produced seed in 2009. There was no significant difference in seed yield between any of the applied herbicides and the check in 2009 for *Lomatium dissectum* and *Lomatium grayi* (Table 8).

2010 Postemergence Treatments. The *Penstemon* species had compromised stand in 2010 due to root rot. Herbicide effects were not evaluated on these species and seed was not collected. *Lomatium grayi* did not produce seed in 2010. There was no significant difference in seed yield between any of the applied herbicides and the check in 2010 for *Lomatium dissectum* and *Lomatium triternatum* (Table 9). For *Eriogonum umbellatum*, applications of Buctril and Goal in 2010 resulted in lower seed yields than the untreated check.

Summary for Trial 3

All seven species tested were tolerant to Prowl® and Outlook® applied as postemergence treatments at the rate, timing, and soils used in these trials. All species were also tolerant to postemergence applications of Select® at the rate, timing, and soils used in these trials. Prowl and Outlook are broad-spectrum, soil-active herbicides that can prevent weed emergence during the season. Select is a foliar-contact, grass herbicide. The use of these three herbicides may provide the basis for an effective weed control program for seed production of these five native forb species if they become registered options. Further tests are warranted to describe the range of safety for these herbicides and whether or not they have any undesirable interactions.

Table 5. Forb species planted at the Malheur Experiment Station, Oregon State University, Ontario, OR and their origins.

Species	Common name	Origin	Year
Eriogonum umbellatum	Sulphur-flower buckwheat	Shoofly Road, Owyhee Co., ID	2004
Penstemon acuminatus	Sharpleaf or sand-dune penstemon	Bliss Dam, Elmore Co., ID	2004
Penstemon deustus	Scabland or hot-rock penstemon	Blacks Cr. Rd., Elmore Co., ID	2003
Penstemon speciosus	Royal or sagebrush penstemon	Leslie Gulch, Malheur Co., OR	2003
Lomatium dissectum	Fernleaf biscuitroot	Mann Creek, Washington Co., ID	2003
Lomatium triternatum	Nineleaf biscuitroot or nineleaf desert parsley	Hwy 395, Lake Co., OR	2004
Lomatium grayi	Gray’s biscuitroot or Gray’s lomatium	Weiser R. Rd., Washington Co, ID	2004

Table 6. Seed yield of native forbs in response to annually repeated postemergence herbicides last applied on April 24, 2007. Seed yields may not be representative since they are from small, one row plots without borders.

Treatment	Rate	Mode of action	*Eriogonum umbellatum*	*Penstemon acuminatus*	*Penstemon deustus*	*Penstemon speciosus*
	lb ai/acre		---------------------------- lb/acre ----------------------------			
Untreated	--		91.7	520.4	903.1	55.3
Buctril 2.0 EC	0.125	foliar	38.1	305.7	348.5	24.6
Goal 2XC	0.125	foliar	42.6	417.8	333.0	20.9
Select 2.0 EC	0.094	foliar	57.6	304.6	927.3	51.2
Prowl H2O 3.8 C	1	soil	115.0	509.4	747.6	52.9
Caparol FL 4.0	0.8	foliar	27.3	162.9	86.8	15.7
Outlook 6.0 EC	0.656	soil	75.1	502.6	835.1	56.6
Lorox 50 DF	0.5	soil/foliar	35.6	264.9	108.5	20.0
LSD (0.05)			51.8	183.4	334.8	29.7*

*LSD (0.10)

Table 7. Seed yield of native forbs in response to annually applied postemergence herbicides last applied on March 12, 2008. Seed yields may not be representative since they are from small, one row plots without borders.

Treatment	Rate	Mode of action	*Eriogonum umbellatum*	*Penstemon deustus*	*Penstemon acuminatus*	*Penstemon speciosus*	*Lomatium triternatum*
	lb ai/acre		----------------------------- lb/acre -----------------------------				
Untreated	--		365.1	330.2	93.9	487.5	981.5
Buctril 2.0 EC	0.125	foliar	285.5	309.1	195.6	781.7	187.9
Goal 2XC	0.125	foliar	279.7	427.0	173.3	728.1	820.8
Select 2.0 EC	0.094	foliar	263.0	421.3	107.8	814.7	1062.1
Prowl H2O 3.8 C	1	soil	385.0	345.4	112.6	608.4	922.7
Caparol FL 4.0	0.8	foliar	298.5	267.2	184.6	785.3	1069.8
Outlook 6.0 EC	0.656	soil	354.8	420.1	110.3	569.0	987.0
Lorox 50 DF	0.5	soil/foliar	368.4	360.4	140.0	672.2	888.1
LSD (0.05)			NS	NS	NS	NS	388.7

Table 8. Seed yield of two native forbs in response to annually repeated postemergence herbicides last applied on March 20, 2009. Seed yields may not be representative since they are from small, one row plots without borders. This was the third consecutive year these forbs received the same herbicide treatments.

Treatment	Rate	Mode of action	*Lomatium dissectum*	*Lomatium grayi*
	lb ai/acre		----------- lb/acre ------------	
Untreated	--		83.4	32.6
Buctril 2.0 EC	0.125	foliar	83.3	20.8
Goal 2XC	0.125	foliar	88.0	28.2
Select 2.0 EC[a]	0.094	foliar	78.1	38.2
Prowl H2O 3.8 C	1	soil	85.6	28.6
Caparol FL 4.0	0.8	foliar	66.1	27.8
Outlook 6.0 EC	0.656	soil	80.9	26.6
Lorox 50 DF	0.5	soil/foliar	104.5	31.2
LSD (0.05)			NS	NS

Table 9. Seed yield of three native forbs in response to annually repeated postemergence herbicides last applied on April 7, 2010. Seed yields may not be representative since they are from small, one row plots without borders.

Treatment	Rate	Mode of action	*Eriogonum umbellatum*	*Lomatium triternatum*	*Lomatium dissectum*
	lb ai/acre		----------------------------	lb/acre	-------------------------
Untreated	--		831.1	485.6	475.3
Buctril 2.0 EC	0.125	foliar	354.5	317.1	462.8
Goal 2XC	0.125	foliar	271.5	534.7	421.6
Select 2.0 EC	0.094	foliar	625.6	384.8	449.1
Prowl H2O 3.8 C	1	soil	773.7	403.9	488.7
Caparol FL 4.0	0.8	foliar	470.5	296.3	449.1
Outlook 6.0 EC	0.656	soil	853.5	322.0	413.4
Lorox 50 DF	0.5	soil/foliar	460.7	487.5	533.3
LSD (0.05)			373.4	NS	NS

Trial 4: Native Perennial Forb Tolerance to Rates and Mixtures of Postemergence Herbicides, 2008-2010

Procedures for Trial 4

In the fall of 2006 *Eriogonum umbellatum, Penstemon acuminatus, P. deustus,* and *P. speciosus* were each planted in areas 10 ft wide and 220 ft long (Table 10). The seeds were planted in 4 rows 30 inches apart. The field previously had been disked, ground hogged, and marked in rows 30 inches apart. Planting depths were similar to those used in the irrigation trial (Shock et al. 2007) and appropriate to each species. Prior to planting, one drip tape was inserted 12 inches deep equidistant between pairs of rows to be planted. A total of 4 drip irrigations applying 1 inch of water each were applied every 2 weeks in 2009 and 2010. Drip irrigations were applied from April 10 to May 29 in 2008 and from May 22 to June 24 in 2009. Each irrigation applied 1 inch of water. The trial was not irrigated in 2010.

On March 12, 2008, March 20, 2009, and on April 7, 2010, 13 herbicide treatments (Table 2) were applied to plots 4 rows wide and 5 ft long. The treatments consisted of different rates and combinations of the soil-active herbicides Prowl® and Outlook®. The treatments were arranged within each species in randomized complete block designs with four replicates. Treatments were applied at 30 psi, 2.63 mph, in 20 gal/acre using 8002 nozzles with 6 nozzles spaced 20 inches apart.

Seed of each species was harvested at maturity. Seed was harvested from the middle two rows in each plot of *Eriogonum umbellatum, Penstemon acuminatus,* and *P. speciosus* in 2008. Plant populations of *P. deustus* prior to herbicide applications were not adequate for data on seed yield to be meaningful. For *P. deustus,* only observations on herbicide damage were made. In 2009 and 2010, only seed of *E. umbellatum* was harvested. *Penstemon acuminatus* and *P. speciosus* stands were severely reduced in 2009 due to root rot.

General Considerations:

The focus of the evaluations was forb tolerance to the herbicides, not weed control. Therefore, weeds were removed as needed.

The effects of herbicides for each species on plant stand and injury were evaluated independently from the effects on other species. Treatment differences were compared using ANOVA and protected least significant differences at the 95 percent confidence LSD (0.05) using NCSS Number Cruncher software (NCSS, Kaysville, UT).

Table 10. Forb species planted at the Malheur Experiment Station, Oregon State University, Ontario, OR and their origins.

Species	Common name	Origin	Year
Eriogonum umbellatum	Sulfur-flower buckwheat	Shoofly Road, Owyhee Co., ID	2004
Penstemon acuminatus	Sharpleaf or sand-dune penstemon	Bliss Dam, Elmore Co., ID	2004
Penstemon deustus	Scabland or hot-rock penstemon	Blacks Cr. Rd., Elmore Co., ID	2003
Penstemon speciosus	Royal or sagebrush penstemon	Leslie Gulch, Malheur Co., OR	2003

Results and Discussion of Trial 4

All observations made on the herbicides tested are strictly preliminary observations. Herbicides that damaged forbs as reported here might be helpful if used at a lower rate or in a different environment. The herbicides were relatively safe for the forbs in these trials but they might be harmful if used at higher rates or in a different environment. Nothing in this report should be construed as a recommendation.

Symptoms of herbicide injury were not observed in any of the plants in 2008, 2009, or 2010. Foliar injury would not be expected since all herbicides tested (except Select®) were soil active and were applied early. There were no significant differences in seed yield between the herbicide treatments and the untreated check for *Eriogonum umbellatum, Penstemon acuminatus,* and *P. speciosus* (Tables 11 and 12).

Summary of Trial 4

All four species tested were tolerant to Prowl and Outlook applied as postemergence treatments at the rate, timing, and soils used in these trials. Prowl and Outlook are broad-spectrum, soil-active herbicides that will prevent weed emergence during the season. Select is a foliar-contact, grass herbicide. The use of these three herbicides may provide the basis for an effective weed control program for seed production of these five species. Further tests are warranted to describe the range of safety for these herbicides and whether or not they have any undesirable interactions.

Table 11. Seed yield of two forbs in response to post emergence herbicides applied on March 12, 2008. All herbicides except Select are soil active.

Treatment	Rate	*Penstemon speciosus*	*Penstemon acuminatus*
	(lbs ai / ac)	------------ lb/acre ------------	
Weed Free, untreated control		820.9	557.9
Select 2.0 EC[a]	0.094	876.7	491.0
Prowl	0.95	644.2	403.7
Prowl	1.19	1242.0	506.1
Prowl	1.43	941.0	573.0
Outlook	0.84	992.5	463.1
Outlook	0.98	860.4	348.1
Prowl + Outlook	0.95 + 0.66	653.7	472.3
Prowl + Outlook	0.95 + 0.84	965.4	483.6
Prowl + Outlook	0.95 + 0.98	827.3	466.4
Prowl + Outlook	1.19 + 0.66	917.0	627.8
Prowl + Outlook	1.19 + 0.84	835.0	434.4
Prowl + Outlook	1.19 + 0.98	707.4	460.0
LSD (0.05)		NS	NS

[a]applied with Herbimax adjuvant at 1% v/v.

Table 12. Seed yield of *Eriogonum umbellatum* in response to repeated postemergence herbicides applied on March 12, 2008, March 20, 2009, and April 7, 2010. All herbicides, except Select, are soil active.

Treatment	Rate	2008	2009	2010
	(lbs ai/acre)	-------------- lb/acre ---------------		
Weed free, untreated control		276.5	430.0	622.6
Select 2.0 EC[a]	0.094	149.1	475.2	618.1
Prowl	0.95	387.2	440.8	549.7
Prowl	1.19	533.1	596.6	736.5
Prowl	1.43	250.6	596.4	988.8
Outlook	0.84	319.8	474.5	725.2
Outlook	0.98	143.5	501.4	627.4
Prowl + Outlook	0.95 + 0.66	300.9	555.5	795.5
Prowl + Outlook	0.95 + 0.84	440.0	763.8	861.3
Prowl + Outlook	0.95 + 0.98	330.9	569.1	614.8
Prowl + Outlook	1.19 + 0.66	244.0	699.8	618.5
Prowl + Outlook	1.19 + 0.84	336.7	556.0	592.2
Prowl + Outlook	1.19 + 0.98	285.6	506.2	684.3
LSD (0.05)		NS	NS	NS

[a]applied with Herbimax adjuvant at 1 percent v/v.

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Management Applications:
Prowl and Outlook herbicides were found to not harm growth and seed production of some forb species when applied post emergence. These results can support a potential future registration process for these herbicides. In addition, activated charcoal was found to have the potential of allowing the use of soil active herbicides applied pre emergence. These results can support a potential future registration process for the use of activated charcoal in forb seed production.

Project Description: Plant Establishment Practices
Seed of native plants is needed to restore rangelands of the Intermountain West. Reliable commercial seed production is desirable to make seed readily available. Direct seeding of native range plants has been generally problematic, but especially for certain species. Fall planting is important for many species, because seed of many species requires a period of cold to break dormancy (vernalization). Fall planting of native seed has resulted in poor stands in some years at the Malheur Experiment Station. Loss of soil moisture, soil crusting, and bird damage are some detrimental factors hindering emergence of fall planted seed. Previous trials at the Malheur Experiment Station have examined seed pelleting, planting depth, and soil anti-crustants (Shock et al., 2010). Planting at depth with soil anti-crustant improved emergence compared to surface planting. Seed pelleting did not improve emergence. Despite these positive results, emergence was extremely poor for all treatments, due to soil crusting and bird damage.

In established native perennial fields at the Malheur Experiment Station and in rangelands we have observed prolific natural emergence from seed that falls on the soil surface and is covered by thin layers of organic debris. This trial tested the effect of four factors on surface planted seed (Table 1). Row cover can be a protective barrier against soil desiccation and bird damage. Sawdust can mimic the protective effect of organic debris. Sand can help hold the seed in place. Seed treatment can protect the emerging seed from fungal pathogens that might cause seed decomposition or seedling damping off. The treatments did not test all possible combinations of factors, but tested the combinations that would theoretically be most likely to result in the best stand establishment.

This trial tested seed cover, row cover, and seed treatment for emergence of seven important species that are native to Malheur County and surrounding rangelands.

Table 1. Treatments evaluated for emergence of seven native plant species. Mouse bait packs were scattered over the trial area.

Treatment	Row cover	Sawdust	Seed treatment*	Sand
1	yes	yes	yes	yes
2	yes	yes	yes	no
3	yes	yes	no	no
4	yes	no	yes	no
5	no	yes	yes	no

*mixture of Captan and Ridomil fungicides for prevention of seed decomposition and seedling damping off.

Materials and Methods

Six species for which stand establishment has been problematic were chosen. A seventh species (*Penstemon acuminatus*) was chosen as a check, because it has reliably produced good stands at Ontario. Seed of *Dalea ornata* was scarified by immersion for 5 minutes in 98% sulfuric acid. Seed weights for all species were determined. A portion of the seed was treated with a liquid mix of the fungicides Ridomil MZ58 and Captan (100g Ridomil, 100g Captan in 1 liter of water). Seed weights of the treated seeds were determined after treatment. The seed weights of untreated and treated seed were used to make seed packets containing approximately 300 seeds each. The seed packets were assigned to one of five treatments (Table 2). The trial was planted manually on November 12, 2009. The experimental design was a randomized complete block with 6 replicates. Plots were one 30-inch bed by 5 feet long. Two seed rows were planted on each bed.

Table 2. Seed weights and tetrazolium test (seed viability) for native plants submitted to emergence treatments.

Species	Common name	Untreated seed weight	Tetrazolium test
		seeds/g	%
Achnatherum thurberianum	Thurber's needlegrass	326.6	81
Dalea ornata	blue mountain prairie clover	328.0	89
Penstemon acuminatus	sharpleaf penstemon	922.1	84
Penstemon deustus	hotrock or scabland penstemon	5555.6	52
Heliomeris multiflora	showy goldeneye	1393.2	88
Crepis intermedia	limestone hawksbeard	186.3	39
Balsamorhiza sagittata	arrowleaf balsamroot	135.8	77

Tetrazolium tests were conducted to determine seed viability of each species (Table 2). The tetrazolium results were used to correct the emergence data to emergence of viable seed.

After planting, the sawdust was applied in a narrow band over the seed row at 0.26 oz per foot of row (558 lb/acre). For the treatments receiving both sawdust and sand, the sand was applied at 0.65 oz per foot of row (1404 lb/acre) as a narrow band over the sawdust. Following planting and sawdust and sand applications, some of the beds were covered with row cover. The row cover (N-sulate, DeWitt Co., Inc., Sikeston, MO 63801) covered 4 rows (2 beds) and was applied with a mechanical plastic mulch layer. The field was drip-irrigated for 24 hours on November 20 to ensure adequate moisture for germination.

On March 10, 2010, the row cover was removed and emergence counts were made in each plot. Emergence counts were again taken on April 9. Seed of *Dalea ornata*, *Penstemon acuminatus*, and *Heliomeris multiflora* was harvested by hand in August. *Heliomeris multiflora* continued to flower and seed was again harvested in November.

Data was analyzed using analysis of variance (General Linear Models Procedure, NCSS, Kaysville, UT). Means separation was determined using Fisher's least significant difference test at the 5 percent probability level, LSD (0.05).

<u>Results and Discussion</u>
By the first emergence count on March10, 2010, all species had started emerging. By March 10, 2010, row cover with sawdust and seed treatment resulted in higher emergence than bare ground with sawdust and seed treatment for *Achnatherum thurberianum*, *Penstemon deustus*, *Heliomeris multiflora*, *Crepis intermedia*, and *Balsamorhiza sagittata* (Table 3). By April 9, row cover with sawdust and seed treatment had resulted in higher emergence than bare ground with sawdust and seed treatment for *Penstemon deustus*, *Heliomeris multiflora*, *Crepis intermedia*, and *Balsamorhiza sagittata* (Table 4). On both dates, adding sawdust to row cover and seed treatment did not improve emergence of any species, but reduced emergence of *Penstemon deustus.*

On either date, adding seed treatment to sawdust and row cover did not improve emergence of any species. Adding seed treatment to sawdust and row cover reduced emergence of *Penstemon acuminatus*, *Penstemon deustus*, *Heliomeris multiflora*, *Crepis intermedia*, and *Balsamorhiza sagittata* on March 10 and reduced emergence of *Penstemon deustus*, *Heliomeris multiflora,* and *Crepis intermedia* on April 9. Adding sand to sawdust, seed treatment, and row cover increased emergence only for *Crepis intermedia* on March 10. There was no difference in emergence between treatments for *Dalea ornata* on either date. Averaged over species, row cover with sawdust resulted in the highest emergence. In conclusion, row cover was the important factor in improving emergence.

Plant establishment and growth were excellent in 2010. *Dalea ornata*, *Penstemon acuminatus,* and *Heliomeris multiflora* produced seed in 2010 (Table 5). Seed yields of *Penstemon acuminatus*, and *Heliomeris multiflora* were substantial (based on two hand harvests in 2010). Seed yields of *Heliomeris multiflora* were not realistic on a commercial scale, because there were no border rows and the plants grew beyond the plot boundaries. For *D. ornata*, row cover with sawdust and seed treatment resulted in higher emergence than bare ground with sawdust and seed treatment. For *D. ornata*, adding sand to row cover, sawdust, and seed treatment significantly reduced yields. Adding seed treatment to row cover and sawdust increased yields of *D. ornata*.

Table 3. Emergence of seven species on March 10, 2010 in response to 5 treatments applied at planting in the fall of 2009. Emergence for each species was corrected to the percent emergence of viable seed. Means within columns followed by the same letter are not significantly different at $P = 0.05$ according to Fisher's protected LSD.

Treatment	Row cover	Sawdust	Seed treatment	Sand	*Achnatherum thurberianum*	*Dalea ornata*	*Penstemon acuminatus*	*Penstemon deustus*	*Heliomeris multiflora*	*Crepis intermedia*	*Balsamorhiza sagittata*	Average
						----------	----------	---------- % emergence	----------	----------	----------	
1	yes	yes	yes	yes	48.6ab	6.74a	26.8a	23.2b	21.4b	76.6a	53.0ab	36.6b
2	yes	yes	yes	no	47.7ab	8.7a	15.3ab	23.5b	21.6b	64.5b	47.3b	32.7b
3	yes	yes	no	no	55.8a	3.6a	24.6a	39.1a	37.1a	86.2a	62.9a	44.2a
4	yes	no	yes	no	44.5b	11.9a	19.7ab	42.8a	24.2b	57.6b	40.1b	34.4b
5	no	yes	yes	no	33.3c	4.1a	10.5b	9.8c	8.3c	38.6c	19.5c	17.7c
			Average		46.0	6.2	19.4	27.7	19.8	64.7	34.3	25.5
	LSD (0.05)		Treatment									6.9
	LSD (0.05)		Species									5.2
	LSD (0.05)		Treat. X Spec.									11.6

Table 4. Plant stands of seven species on April 9, 2010 in response to 5 treatments applied at planting in the fall of 2009. Plant stands for each species was corrected to the percent of viable seed. Means within columns followed by the same letter are not significantly different at $P = 0.05$ according to Fisher's protected LSD.

Treatment	Row cover	Sawdust	Seed treatment	Sand	*Achnatherum thurberianum*	*Dalea ornata*	*Penstemon acuminatus*	*Penstemon deustus*	*Heliomeris multiflora*	*Crepis intermedia*	*Balsamorhiza sagittata*	Average
						----------	----------	---------- % emergence	----------	----------	----------	
1	yes	yes	yes	yes	47.2ab	13.9a	22.5a	29.8b	22.4b	66.5ab	59.3ab	37.4b
2	yes	yes	yes	no	44.3ab	9.6a	19.6a	32.3b	26.0b	57.0b	60.0ab	35.6b
3	yes	yes	no	no	54.3a	3.2a	26.4a	43.8a	39.2a	77.2a	66.7a	44.4a
4	yes	no	yes	no	41.9b	9.8a	18.9a	49.1a	23.4b	50.7b	49.6b	34.8b
5	no	yes	yes	no	41.2b	5.0a	18.1a	17.1c	10.9c	27.1c	25.5c	20.7c
			Average		45.8	7.4	21.1	34.4	21.4	55.7	40.2	27.4
	LSD (0.05)		Treatment									6.0
	LSD (0.05)		Species									5.0
	LSD (0.05)		Treat. X Spec.									11.2

Table 5. Seed yield in 2010 of three species planted on November 12, 2009. Yields are based on very small plots without border rows. The seed yields of *H. multiflora* are not realistic in terms of commercial production, because the plants grew beyond the plot boundaries.

Treatment	Row cover	Sawdust	Seed treatment	Sand	*Dalea ornata*	*Penstemon acuminatus*	*Heliomeris multiflora*	Average
					------------------ lb/acre ------------------			
1	yes	yes	yes	yes	40.5b	848.7	891.0	593.4
2	yes	yes	yes	no	77.0a	632.4	966.2	558.6
3	yes	yes	no	no	35.9b	783.6	885.5	568.3
4	yes	no	yes	no	41.2ab	524.4	863.0	476.2
5	no	yes	yes	no	11.2b	861.0	768.7	547.0
			Average		41.2	730.0	874.9	548.7
LSD (0.10)	Treatment				35.9	NS	NS	

Management Applications:
The report above describes practices that can be immediately implemented by seed growers.

General Conclusions:
- Row cover improved emergence for all species except *Penstemon acuminatus*.
- Sawdust did not improve emergence with the probable exception of *Balsamorhiza sagittata*.
- Seed treatment reduced emergence of six species. Seed treatment might be beneficial for *Dalea ornata*.
- Sand improved the early emergence of *Penstemon acuminatus* and *Crepis intermedia*.

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Shock, C.C., E.B.G. Feibert, L.D. Saunders, and N. Shaw. 2010. Identification of herbicides for use in native forb seed production. Native Plant Seed Growers Workshop: Cultural Practices for Native Plants; 2010 February 23; Ontario, OR. http://www.fs.fed.us/rm/boise/research/shrub/projects/Ontario2010.html

Shock, C.C., E.B.G. Feibert, L.D. Saunders, and N. Shaw. 2010. Native Forb Seed Production in Response to Irrigation. Native Plant Seed Growers Workshop: Cultural Practices for Native Plants; 2010 February 23; Ontario, OR. http://www.fs.fed.us/rm/boise/research/shrub/projects/Ontario2010.html

Field days

Shock, C.C., E.B.G. Feibert, L.D. Saunders, and N. Shaw. 2010. SDI practices for native wildflower seed production. Summer Farm Festival and Annual Field Day, OSU Malheur Experiment Station. 13 July 2010. Ontario, OR.

Products:

- Seed produced from these planting was used to establish commercial seed production fields.
- A field tour for growers was conducted in May 2010.
- A tour of the seed production trials was incorporated into the annual Summer Farm Festival and Malheur Experiment Station Field Day activities in July of 2010.

Project Title: Etiology, Epidemiology and Management of Diseases of Native Wildflower Seed Production

Project: University of Idaho, Parma R&E Center, Parma, Idaho

Principal Investigators and Contact Information:

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Project Description:
General objectives are (1) to identify and evaluate potentially important diseases to include pathogen identification (etiology) and disease biology regarding occurrence, development and spread, and (2) to develop disease management practices.

Significance:
- Diseases of economic crops are well known and studied but not the diseases affecting native plants.
- Prescreen plant materials for natural resistance to pests and diseases.

Project status

Several diseases (leaf spots, blights, rusts, wilts and powdery mildews) were recorded on forbs. Arid conditions prevailing in the Pacific Northwest is favorable for powdery mildew disease cycle.

Publications:
Sampangi, R. K.; Aime, M. C.; Mohan, S. K.; Shock, C. C. 2010. New and re-emerging rust diseases from Idaho and Oregon. Phytopathology 100: S113.

Sampangi, R.K, M.C. Aime and S. K. Mohan. 2010. First Report of Rust Caused by *Puccinia similis* on *Artemisia tridentata* in Idaho and Oregon. Plant disease 94,380, 2010 http://dx.doi.org/10.1094/PDIS-94-3-0380B

Sampangi, R. K.; Almeyda, C.; Druffel, K. L.; Mohan, S. K.; Shock, C. C.; Pappu, H. R. 2009. First report of natural infection of *Penstemon acuminatus* with *Cucumber mosaic virus* in the Treasure Valley region of Idaho and Oregon. Plant Disease 93: 762.

Sampangi, R. K.; Glawe, D. A.; Mohan, S. K. 2007. First North American record of powdery mildew of *Cleome hassleriana* caused by *Leveillula taurica*. Online. Plant Health Progress doi:10.1094/PHP-2007-02XX-01-BR.

Presentations:

Sampangi, R.; Mohan, K.; Shock, C. 2010. Diseases of native plants. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

<u>Field Tours</u>

Attended and gave a talk at the Annual Native Plant Seed Production Field Day, Oregon State University, Malheur Experiment Station, 2010 July, Ontario, OR.

Project Title: Stock Seed Production of Native Plants for the Great Basin

Project Location: Utah Crop Improvement Association, Utah State University, Logan, Utah

Principle Investigators and Contact Information:

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Project Description:
This project was initially titled "Establishment and Maintenance of the Buy-Back Program for Certified Seed". It was funded through a Memorandum of Understanding between the USFS-RMRS in Boise and the Utah Crop Improvement Association (UCIA), initiated in the fall of 2003 and renewed with additional funds in the fall of 2004 and fall of 2007. A new joint venture agreement titled "Stock Seed Production of Native Plants for the Great Basin" was completed on August 17, 2009. Seed has been distributed during this time period using the Buy-back option, a mechanism for returning a portion of the seed increased by private growers back to the UCIA for redistribution to the original and additional seed growers for further seed increase.

<u>Project Status</u>
A synopsis of the Stock Seed Buy-Back Program follows, applicable to the period Jan. 1, 2010-Dec. 31, 2010. Table 1 lists new (2010) seed distributions and their field status. Table 1 also lists forb and grass seed acquisitions, distributions, inventory, field status, and whether seed has been harvested, for specific germplasms included in the UCIA Stock Seed Buy-back Program from 2002-2009. This list includes the previous AOSCA program which is now being administered by the UCIA. It is expected that in 2011 several additional forbs and grasses will be included in the program. Table 2 lists the Standardized Market Price for contract negotiations for each species included in the program, updated at the beginning of 2010. However, some of the species planted in the fall of 2008 and during 2009 and 2010 do not have a market record, and more investigation and negotiation is underway to complete monetary details of buy-back contracts.

Table 1. 2010 Utah Crop Improvement Association (UCIA) Great Basin Native Plant Selection and Increase Project Stock Seed Buyback Program. Forb and grass seed acquisition, distribution and field planting status for species germplasms planted in 2009 and 2010. Also listed are 2002-2008 plantings with activity in 2010.

Kind & Variety / Germplasm	Source	Lot / Origin	Seed acquisition & production status	Generation	lb Added to Inventory	date	lb distributed from Inventory	date	State distributed to	Field Status
					bulk		bulk			
2010										
Poa secunda	PoaSec01-BSE-06	NBS-RR8-MTH-1		G1	466.00	5/21/10	100.00	5/25/10	WA	Anticipate planting Aug 2011
Mountain Home Germ.		NBS-RR9-MTH-1		G1	534.00	5/21/10	0.00	-	-	-
		SOS-RMRS-1173		G0	175	-	25	9/29/10	WA	Anticipate planting Aug 2011
Lomatium dissectum	NBR wild collected USFS	LD TD-10		G1	2.00	10/5/10	-	-	-	-
Penstemon cyaneus	PECY B6-02	2009-0570		G2	6.14	7/28/10	6.14	8/3/10	WA	-
Astragalus filipes	NBR-1	Plugs 2010								Planted Fall 2010
Astragalus filipes	BC population	Plugs 2010								Planted Fall 2010
Astragalus filipes	NBR1	Plugs 2010								Transplanted needs to thicken
Dalea ornata	Socur Summit (Spectrum Germplasm)	Plugs 2010		-	-	-	-	5/19/10	WA	Small amount of seed harvested
Dalea searlsiae	EK population	Plugs 2010		-	-	-	-	5/24/10	WA	Transplanted needs to thicken
Eriogonum heracleiodes	NGB-EH			G1	52.5	5/5/09	52.5	5/5/09	WA	Seed harvested 2010; good stand
Eriogonum heracleiodes	NGB-EU			G1	10.4	Fall 2010	10.4	Fall 2010	WA	Planted Fall 2010
2009										
Eriogonum umbellatum	Pooled ID, OR	ERUM2009	*1*2	G1	10.4	Fall 09	10.4	Fall 09	WA	Tublings in greenhouse
Eriogonum umbellatum	Pooled ID, OR	ERUM2009	*1*2	G1	10.4	Fall 09	10.4	Fall 09	OR	Planted Fall 2010
Penstemon acuminatus	Pooled ID, OR, NV	PEAC NBR	*1*2	G0	4.13	Fall 09	4.13	Fall 09	NV	Seeded Fall 08, added 0.75 acres Fall 09
Poa secunda Mountain Home Germ.	PoaSec01-BSE-06	NBS-RR8MTH-1	-	G1	300	Summer 09	300	Fall 09	WA	Established
Elymus elymoides	Little Sahara site	CU-907, GBRI 29	-	G0	200	Summer 09	200	8/28/09	WA	Seed harvested 2010; good stand
Linum lewisii	Maple Grove Germplasm	F-757, MGLF-1-08	-	G3	33.0	Spring 09	33.0	4/6/09	OR	Good stand; anticipate harvest 2011
2008										
Eriogonum heracleoides	Pooled*	ERHE2	*1*2	G0	52.5	12/5/08	52.5	12/5/08	WA	Seed harvested 2010; good stand
Leymus cinereus	Pooled*	LECI	*1*2	G1	10.00	9/9/08	10.00	9/9/08	WA	Seed harvested 2010; good stand
Astragalus filipes	Brothers	ASFI	*1*2	G1	8.00	9/28/08	8.00	9/28/08	WA	Seed harvested 2010; good stand
Lomatium triternatum	Pooled*	LOTR	*1*2	G0/G1	9.05	9/24/08	9.05	9/24/08	ID	Plowed out Fall 2010
Balsamorhiza hookeri	Elko	BAHO	*1*2	G0	0.33	11/12/08	0.33	11/12/08	UT	Fair stand
Sphaeralcea coccinea	Pooled*	SPCO	*1*2	G0	4.4	11/12/08	4.4	11/12/08	UT	Fair stand
Achnatherum thurberianum	Jordan Valley	ACTH7	*1*2	G0	1.133	11/12/08	1.133	11/12/08	UT	Fair stand
Achillea millefolium	Eagle, ID	ACMI 01	*1*2	G0	0.125	11/12/08	0.125	11/12/08	UT	Fair stand
Lomatium nudicaule	Pequop Summit	LONU2	*1*2	G0	0.68	11/6/08	0.68	11/6/08	NV	Unknown
Heliomeris multiflora var. nevadensis	Pioche	HEMUN	*1*2	G1	0.22	11/6/08	0.22	11/6/08	NV	Unknown
2002-2007										
Achillea millefolium	Eagle, ID	Wild collected USFS	-	-	-	-	-	-	OR, WA, WY	Wide use in seed industry
Balsamorhiza hookeri	Wild Collected USFS	BAHO B1-02	*1*2	G0	-	Fall 02	0.31	Fall 02	CO	Plowed out 2010
Balsamorhiza sagittata	Wild Collected USFS	BASA U32-02	*1*2	G0	1.62	4/15/04	1.19	4/16/04	UT	6th year immature stand
Lomatium dissectum	NBR Wild Collected USFS	Pooled	*1*2	G0	2.00	10/31/06	2.00	11/22/06	UT	2lbs. seed harvested 2010
Penstemon acuminatus	Wild Collected USFS	PEAC2 B4-02	*1*2	G0	0.22	Fall 02	0.22	Fall 02	ID	Plowed out 2010
Penstemon cyaneus	PECY2 B6-02-CO	2006.0413	*1*3	G1	5.00	12/5/06	5.00	3/1/07	WY, ID	Small scale use in seed industry
Penstemon pachyphyllus	PEPA2 U6-99-OR	A5-4-P1	*3	G1	38.03	6/7/05	7.3	Fall 05	ID	3rd year immature stand
Penstemon palmerii 'Cedar'	Wild Collected UCIA	CPP KL-05-1, GBRI 16	-	F	133	10/24/05	46.54	2006-09	CO, ID, WY	Small scale use in seed industry
Poa secunda Mountain Home Germ.	Rainier Seed WA	557-215-31A	*3	G2	0.7	11/4/03	50.0	9/15/03	ID, UT, WA, WY	Wide use in seed industry
Poa secunda Mountain Home Germ.	Wild Collected USFS	Poa Sec01-BSE-06	*1	G0	6.5	9/10/06	6.5	9/11/06	WA	Plowed out Fall 2010
				Total	**2077.4**		**957.5**			

Table 2. Standardized Market Price for Contract Negotiation, Great Basin Native Plant Selection and Increase Project-Utah Crop Improvement Association Buy-back Program. Based on end user marketprice and suggested PMC stock seed prices for applicable growers

Scientific Name	**Common Name**	**5 Year average**
Forbs		
Achillea millefolium	Western yarrow	$10.00
Agoseris heterophylla	Annual agoseris	
Astragalus filipes	Basalt milkvetch	
Balsamorhiza hookeri	Hooker's balsamroot	$26.00
Balsamorhiza sagittata	Arrowleaf balsamroot	$25.00
Chrysothamnus spp.	Rabbitbrush	$40.00
Cleome serrulata	Beeplant	$12.00
Crepis acuminata	Tapertip hawksbeard	$140.00
Crepis intermedia	Hawksbeard	
Dalea ornata	Blue Mountain prairie clover	
Eriogonum heracleoides	Parsnipflower buckwheat	
Eriogonum umbellatum	Sulfur-flower buckwheat	$37.00
Heliomeris mutliflora var. *nevadensis*	Nevada goldeneye	
Linum lewisii	Lewis flax	$12.00
Lomatium dissectum	Giant lomatium (parsley or biscuitroot)	$65.00
Lomatium nudicaule	Barestem biscuitroot	
Lomatium triternatum	Nineleaf lomatium	$80.00
Lupinus spp.	Lupine	$55.00
Penstemon acuminatus	Sharpleaf penstemon	$60.00
Penstemon cyananthus	Wasatch penstemon	$52.00
Penstemon cyaneus	Blue penstemon	$60.00
Penstemon deustus	Hot-rock penstemon	$40.00
Penstemon eatonii	Firecracker penstemon	$50.00
Penstemon pachyphyllus	Thickleaf penstemon	$62.00
Penstemon palmeri	Palmer penstemon	$20.00
Sphaeraclea coccinea	Scarlet globemallow	$65.00
Sphaeralcea grossulariifolia	Gooseberry-leaved globemallow	$57.00
Sphaeralcea munroana	Munro's globemallow	$57.00
Grasses		
Achnatherum hymenoides	Indian ricegrass	$11.00
Achnatherum thurberianum	Thurber's needlegrass	$56.00
Elymus elymoides	Bottlebrush squirreltail	$20.00
Elymus wawawaiensis	Snake River Wheatgrass	$10.50
Festuca idahoensis	Idaho Fescue	$8.50
Leymus cinereus	Basin Wildrye	$9.00
Poa fendleriana	Muttongrass	$75.00
Poa secunda	Sandberg bluegrass	$12.00
Pseudoroegneria spicata	Bluebunch wheatgrass	$10.50

Project Synopsis

Great Basin Native Plant Selection and Increase Project (GBNPSIP) and Utah Crop Improvement Association (UCIA) Stock Seed Buy-back Program. This program encourages and allows seed growers to benefit economically in a timely manner as an incentive to participate in the UCIA Stock Seed Buy-back Program. The program helps accelerate the increase in stock seed supplies and ultimately increase seed supplies on the open market for commercial revegetation use.

The objectives of the UCIA Stock Seed Buy-back Program, funded through the GBNPSIP, is to: a) facilitate development of a seed market for specific germplasm accessions, pooled accessions, and/or formal germplasm releases developed through GBNPSIP; b) reward initial seed growers financially for the risks they have assumed to participate in the program; c) document germplasm identity through the seed increase process by utilizing seed certification protocols; and d) increase stock seed available for potential secondary seed growers. This program is administered through the Utah Crop Improvement Association.

The mechanisms for purchasing stock seed from growers and redistributing it for further increase are as follows:

1. UCIA offers for free or for sale (depending on seed generation and availability) stock seed to seed growers. A UCIA Stock Seed Contract (Appendix I) is completed at this time that formalizes the seed production agreement (number of pounds, price per pound, any special arrangements for reimbursement for establishment costs, etc.).
2. After harvest of the first seed production year, the grower is required to return to the UCIA (for inventory reserve) the amount of stock seed specified in the contract. More may be returned if mutually negotiated. The grower will be compensated 125% of the standardized market price (SMP, see Table 2) for all seed returned to UCIA. SMP will be updated yearly and/or adjusted as needed.
3. UCIA may negotiate to buy all or part of the seed from any subsequent years of seed production back from seed grower at 125% SMP.
4. UCIA offers the grower the option to immediately buy back the seed sold to the UCIA (except for the inventory reserve) at 100% SMP. The grower thus realizes an immediate 25% premium incentive to expand plantings and remain in the program. This seed must be planted for seed production and entered into the local seed certification program either by original seed grower or another seed grower recruited by the original seed grower. If this seed is instead sold commercially, the UCIA reserves the right to recover the 25% premium paid for the seed, and the grower may be ineligible for further GBNPSIP seed distribution.
5. All seed offered to the UCIA, bought, or sold shall be certified or certified eligible.
6. UCIA agrees to pay for shipping and seed analysis costs. Seed purchasing, shipping, and seed analysis costs are to be reimbursed to the UCIA through GBNPSIP program funds.
7. If seed is unconditioned when purchased by the UCIA, the seed grower may be charged for conditioning costs, or in certain circumstances these costs may be paid by the UCIA and reimbursed by GBNPSIP.

Notes:

1. Seed quantity and quality (lbs PLS) of original stock seed provided to the seed grower will be determined on a case by case basis in order to determine the amount of seed that must be returned to the UCIA from the first harvestable crop by the seed grower.
2. When the original seed grower sells to the UCIA and/or buys back seed (as in points 3 and 4 above) the amount of seed (lbs PLS) will typically be verified through the applicable state seed certification agency. Some instances may require special negotiation.

Publications:

Young, S. A. 2010. Plant germplasm handling protocols: provenance, collection, development release, distribution and production. Procedural white paper for Great Basin Native Plant Seed Increase Project.

Young, S. A. 2010. Seed certification tracks the natives from wildlands to restoration. Ecological Restoration and Sustainable Development: Establishing Links Across Frontiers; 7th SER European Conference on Ecological Restoration, 2010 August 23-27, Avignon, France. Abstract.

Young, S.A.; Bouck, M. 2010. Stock seed production of native eplants for the Great Basin. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 71-75. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

Young, S. A. Plant germplasm handling protocols as proposed by the GBNPSIP PDQ Committee. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Young, S. A. Using buy-backs to jumpstart native seed inventories. Workshop: seed production of native grasses and forbs; 2010 February 23; Ontario, OR. http://www.fs.fed.us/rm/boise/research/shrub/projects/Ontario2010.html

Young, S. A. How to be a seed connoisseur. National Native Seed Conference; 2010 May 7-21; Snowbird, UT.

Young, S. A. Seed Certification Tracks the Natives From Wildlands to Restoration. 7th SER European Conference on Ecological Restoration; 2010 August 23-27; Avignon, France. http://www.fs.fed.us/rm/boise/research/shrub/projects/2010SEREurope.HTML

Management Applications:

For most of the species being studied by GBNPSIP cooperators, wildland seed collection is insufficient to provide for reclamation planting needs. Thus, accessions consisting of limited quantities of seed obtained from defined wildland stands, or pooled from defined geographic areas, must be increased in commercial fields or nurseries in order to be available in the marketplace in sufficient quantities to supply reclamation projects of the scope called for in the Great Basin. The UCIA Buy-Back project provides a bridge between a) small-quantity initial accessions and b) commercial marketplace production, by working with specialized growers who are willing to provide land, time, and expertise to produce increased amounts of stock seed from the former, and with UCIA facilitation, makes it available for the latter. This process has been more successful for some species than others, but in general, great progress has been made in defining seed accession groupings, knowledge of agronomic seed production techniques, and understanding the reality of the commercial seed marketplace.

Project Title: Coordination of GBNPSIP Plant Materials Development, Seed Increase and Use

Project: Eastern Oregon Stewardship Services, Prineville, Oregon

Principal Investigators and Contact Information:

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Project Description:

Objectives

1. Collaborate with the GBNPSIP, BLM field offices and native seed growers to increase native plant materials from the Great Basin for research and commercial production.
2. Facilitate private seed grower capacity to produce seed of native Great Basin forbs and grasses.
3. Augment seed collections of needed GBNPSIP research materials and new plant materials for BLM field offices within the Great Basin.

Methods

Native seed farms growing forbs for the GBNPSIP in the Columbia Basin and Treasure Valley were visited and fields were monitored. Where seed stocks from the Great Basin were not immediately available, we spent the 2010 field season collecting relatively large quantities of seed to transfer to growers. A trip to Nevada was taken to locate new sites for research collections of Thurber's needlegrass (*Achnatherum thurberianum*) and bottlebrush squirreltail (*Elymus elymoides*). We also collected seed for the GBNBSIP, USDA-ARS, OSU Malheur Experiment Station, USDA-FS and USDI BLM Seeds of Success programs.

Results

Six native seed growers from Oregon, Washington and Idaho were contracted to grow twelve forb species (table 1). New growers were recruited. This year the number of growers involved in “Buy-Back” increased as well as the number of forb species they are propagating. Thirty-three seed lots from twelve species were collected by EOSS for GBNPSIP growers (table 2). Forty-three research collections from eight species were made for USDA-ARS, USDA-FS and OSU Experiment Station scientists. Seed lot weights varied between less than a pound to over 20 pounds. A new Buy-back spreadsheet was created with information concerning origin of genetic material, growers, testing results and outcome of production. EOSS sponsored and helped organize the “Seed Production of Native Grasses and Forbs Workshop” February 23, 2010, in Ontario, OR. Over 120 participants, mostly from private industry, heard from fourteen GBNPSIP collaborators about new restoration species entering the market, genetics and seed zones, seeding rates, stand establishment, irrigation requirements, weed control, pollinators and seed predators, native seed certification and BLM contracting. EOSS also organized a special session at the European Society for Ecological Restoration Conference. Our session was entitled

"Farming for Restoration: Building Bridges for Native Seed", five GBNPSIP cooperators gave presentations and collaborated with European colleagues.

Publications:

Shaw, N.L.; Youtie, B.; Olwell, P. 2010. Building bridges between agencies, researchers, farmers and non-governmental organizations to create collaborative native seed programs. Proceedings 7th European Conference on Ecological Restoration. 2010 August 23-27; Avignon, France.

Youtie, B. 2010. Coordination of GBNPSIP plant materials and development, seed increase and use. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 76-79. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

Shaw, N.; Youtie, B. Building bridges between NGO's, Researchers and Farmers to develop a collaborative native seed program. 7th SER European Conference on Ecological Restoration; 2010 August 23-27; Avignon, France. http://www.fs.fed.us/rm/boise/research/shrub/projects/2010SEREurope.HTML

Youtie, B. 2010. Coordination of GBNPSIP plant materials and development, seed increase and use. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Management Applications:

Increased communication and collaboration has led to better seed distribution to growers for seed development of new forb species that may be used in BLM seed buys and restoration projects in the future. The Seed Production Workshop transferred technical information to farmers growing native forbs and grass species and also assisted in recruiting new farmers to grow native seed for the Great Basin.

Products:

Table 1. Forb species for seed production buy-back in Oregon, Washington and Idaho

Scientific name	Common name	Scientific name	Common name
Achillea millefolium	Western yarrow	*Lomatium triternatum*	Nineleaf desert parsley
Achnatherum thurberianum	Thurber's needlegrass	*Machaeranthera canescens*	Hoary tansyaster
Astragalus filipes	Basalt milkvetch	*Penstemon acuminatus*	Sharpleaf penstemon
Chaenactis douglasii	Douglas' dusty maiden	*Penstemon cyaneus*	Blue penstemon
Eriogonum heracleiodes	Wyeth buckwheat	*Penstemon speciosus*	Royal penstemon
Eriogonum umbellatum	Sulphur-flower buckwheat	*Sphaeralcea munroana*	Munro's globemallow

Table 2. Research Collections (R) and Bulk Seed Lots collected in the 2010 field season by Eastern Oregon Stewardship Services.

Species and Site No.	***Site Details***	***Collection Date*** *mm/dd/yy*	***No. Plants***
ACHY1BY10-R	Crowley Road, Malheur Co., OR	7/2/10	100
ACTH1BY10-R	Diamond Craters, Harney Co., OR	6/27/10	50
ACTH1NBY10-R	Ruby Valley, Elko Co., NV	7/6/10	35
ACTH7NBY10-R	Battle Mt, Izzenhoodgap, Lander Co., NV	6/25/10	50
ACTH9NBY10-R	Bog Hot & Hwy 140, Humbolt Co., NV	6/25/10	35
ACTH8NBY10-R	Hwy140, Denio Summit, Humbolt Co., NV	7/6/10	75
ACTH2BY10-R	Sutton Mt, Wheeler Co., OR	7/3/10	60
CHDO1BY10-R	Leslie Gulch, Malheur Co., OR	7/25/10	200
CHDO3BY08	Twin Springs, Malheur Co., OR	7/11/10	100
CHDO2BY10-R	Diamond Craters, Harney Co., OR	7/14/10	50
CHDO3BY10	Malheur Field Station View, Harney Co., OR	7/19 & 7/23/10	130
CHDO8BY10-R	Riddle Mt, Harney Co., OR	7/14/10	45
CHDO6BY10-R	Sunset Valley, Harney Co., OR	7/18/10	50
CHDO7BY10-R	Hwy 26 between Redmond and Sisters, Deschutes Co., OR	8/5/10	50
CLLU1BY10	South of Adrian, Malheur Co., OR	7/12 & 7/24/10	300
CLLU2BY10	Mikey Hot Springs, Harney Co., OR	7/7–7/8/10	200+
CLLU3BY10	Twin Springs, Malheur Co., OR	7/11/10	50
DAOR3BY08-R	Twin Springs, Malheur Co., OR	7/11/10	300
ELEL1BY10-R	Hoodoo Ridge, Malheur Co., OR	6/22/10	50
ELEL2BY10-R	Bruneau, Owyhee Co., ID	6/23/10	40
ELEL1NBY10-R	Austin, Lander Co., NV	6/25/10	25
ELEL2NBY10-R	Battle MT, Lander Co., NV	6/25/10	45
ELEL3NBY10-R	Winnemucca, Humboldt Co., NV	6/25/10	30
ELEL21BY10-R	Leslie Gulch, Malheur Co., OR	7/25/10	35
ELEL8BY10-R	Rome, Malheur Co., OR	7/4/10	35
ELEL9BY10-R	Owyhee Overlook, Malheur Co., OR	7/4/10	35
ELEL5BY10-R	Burns Junction, Malheur Co., OR	7/8/10	35
ELEL13BY10-R	Catlow Valley, Harney Co., OR	7/17/10	50
ELEL4NBY10-R	Hwy140, Wilder Creek Rd, Humboldt Co., NV	7/6/10	35
ELEL4BY10-R	Drewsey, OtisValley, Harney Co., OR	7/4/10	35

Species and Site No.	***Site Details***	***Collection Date*** *mm/dd/yy*	***No. Plants***
ELEL15BY10-R	Hwy 395 Silvies Valley, Harney Co., OR	7/18/10	25
ELEL16BY10-R	Hwy 26 Rock Creek, Grant Co., OR	7/20/10	25
ELEL7BY10-R	Riddle Mt., Harney Co., OR	7/14/10	35
ELEL14BY10-R	Harney Lake, Harney Co., OR	7/18/10	35
ELEL10BY10-R	Diamond Craters, Harney Co., OR	7/14/10	35
ELEL11BY10-R	Ridge E. Castle Rock, Malheur Co., OR	7/16/10	35
ELEL12BY10-R	Ridge above Westfall, Malheur Co., OR	7/16/10	35
ELEL3BY10-R	Overstreet-Adrian, Malheur Co., OR	6/24/10	35
ELEL6BY10-R	Owyhee Reservoir, Malheur Co., OR	7/9/10	35
ELEL17BY10-R	Steens Mt., Harney Co., OR	7/26/10	35
ELEL18BY10-R	Steens Mt. High, Harney Co., OR	8/10/10	35
ELEL19BY10-R	Pass between Antelope & Clarno, Jefferson Co., OR	8/2/10	35
ELEL20BY10-R	Succor Creek near Hwy 95, Malheur Co., OR	7/25/10	35
ERLA1BY10	Leslie Gulch, Malheur Co., OR	7/3/10	100
ERLA2BY10	Crowley Road, Malheur Co., OR	7/5/10	200
ERLA4BY10	Owyhee Reservoir, Malheur Co, OR.	6/26/10	25
ERUM2BY08	Brothers, Deschutes Co., Or	8/5–8/10/10	5000+
ERUM 13-R	Hwy 20 mile 203-204, Malheur Co., OR	8/16/10	50
HECO1BY10-R	Crowley Road, Malheur Co., OR	6/22/10	100
HECO2BY10-R	Owyhee Reservoir Road, Malheur Co., OR	6/24/10	100
LONU 05	Stinking Water, mile 163-4, Harney Co., OR	7/5/10	300+
LONU1BY10	Drewsey, Otis Valley, Harney Co., OR	6/24/10	100+
LONU2BY10	Castle Rock Road, Malheur Co., OR	7/4/10	200
LONU3BY10	Road to Westfall, Malheur Co., OR	7/16/10	75
LOTR1BY08	Leslie Gulch, Malheur Co., OR	7/2/10	75
LOTR1BY10	Riddle Mt, Harney Co., OR	7/14 & 7/17/10	700
LOTR2BY10	Road to Westfall, Malheur Co., OR	7/16/10	30
MACA1BY10	Walgren's Ontario, Malheur Co., OR	10/1/10	150
MACA2BY10-R	Drewsey, Otis Valley, Harney Co., OR	10/4/10	50
MACA1ABY09-R	Wrights Point, Harney Co., OR	9/26/10	50
PEAC11	Keeney Pass, Malheur Co., OR	7/15/10	500
PEAC38	Owyhee Reservoir Road, Malheur Co., OR	7/22/10	500
PEAC1BY10	Alvord Well Road, Harney Co., OR	7/28/10	200

Species and Site No.	***Site Details***	***Collection Date*** *mm/dd/yy*	***No. Plants***
PESP1BY08	Sunset Valley, Harney Co., OR	8/4/10	200
PESP5BY10	Hwy 205, Harney Co., OR	8/3/10	90
PHHA1BY10	Owyhee Reservoir, Malheur Co., OR	7/23/10	200
PHHA2BY10	Upper Leslie Gulch, Malheur Co., OR	7/24/10	150
PHHA4BY10	Hwy 20 - mile 156, Harney Co., OR	7/25/10	45
PHHA5BY10	Drewsey, Otis Valley, Harney Co., OR	7/20/10	95
PHLI4BY10	Powerline Exclosure, Harney Co., OR	7/19 & 7/22/10	400
SPMU1BY10	Overstreet, Malheur Co., OR	7/3/10	154
SPMU2BY10	Owyhee Reservoir, Malheur Co., OR	6/27 & 7/9/10	375
SPMU4BY10	Crowley Ranger District, Malheur Co., OR	7/5/10	500
SPMU5BY10	Harney Lake, Harney Co., OR	7/18/10	100+
SPMU6BY10	Burns Junction, Malheur Co., OR	7/8/10	100+
SPMU8BY10	Twin Springs, Malheur Co., OR	7/11/10	100

Project Title: The Role of Native Annual Forbs in the Restoration of Invaded Rangelands

Project Location: University of Nevada, Reno, Nevada
USDA ARS, Reno, Nevada

Principal Investigators and Contact Information:

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Project Description:

<u>Background</u>

In Western rangelands, invasion by the exotic annual grass *Bromus tectorum* is altering fire regimes, community composition, and ecosystem function. Communities with well-established perennial grasses may be more resistant to invasion by *B. tectorum*, making post-disturbance restoration with native perennial grasses desirable. However, restoration with these later-succesional species is often unsuccessful. Greater restoration success may be achieved with seed mixes that mimic natural succession in Great Basin systems, which includes native annuals as a key component of the post-disturbance community.

<u>Objectives</u>

The objectives of this study were to 1) determine the effect of select native annual forbs on the performance of *Bromus tectorum* and *Elymus multisetus* and 2) determine if the presence of native annual forbs increases the performance of *E. multisetus* when grown in competition with *B. tectorum*.

Methods

In greenhouse and field competition experiments, seedlings of the native perennial grass, *Elymus multisetus*, were grown with native annual forbs both in the presence and absence of *B. tectorum*. We recorded the number of green leaves on *E. multisetus* plants at three separate times after planting to assess treatment effects on growth rate, and collected aboveground tissue at harvest to determine treatment effects on biomass. Seedlings of *B. tectorum* were also grown with each of the native forbs to determine competitive effects of native annual forbs on *B. tectorum* performance (biomass and seed production).

Results

In the greenhouse, *E. multisetus* growth and seasonal biomass production were lower when grown with *B. tectorum* than with any of the native annuals. Additionally when in competition with *B. tectorum*, *E. multisetus* performed best when *M. veatcheana* was also present and growth rates were significantly greater when any annual forbs were also present. *Amsinckia tesselata* and *A. intermedia* were the most competitive native annuals against *B. tectorum*, and although *A. tesselata* was beneficial in the greenhouse, under field conditions, *Amsinckia* species had a negative effect on *E. multisetus* performance. However, over time, these negative effects decreased and could potentially lead to facilitation of *E. multisetus* later in the season.

Conclusions

The results of our greenhouse and field experiments support the idea that the presence of certain native annual forbs can enhance the establishment of *E. multisetus* in *B. tectorum* invaded rangelands. Future studies are needed to examine the longer-term consequences of early season interactions between native annual forbs and exotic annuals. Additionally, more work is needed to further understand germination strategies and competitive abilities of native annual forbs so that recommendations can be made to seed growers and land managers regarding which species to invest in.

Publications:

Forbis, T.; Leger, E.A.; Goergen, E.; Meyer, S.E. 2010. Investigations of seed and seedling ecology and competitive ability of native annual forbs of the Western Great Basin. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 127-135. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

Forbis, T. 2010. Germination phenology of some Great Basin native annual forb species. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Goergen, E., Leger, E. A., and Forbis, T. 2010. Can indirect competition with annual forbs increase establishment of native perennial grasses in *Bromus tectorum* invaded systems? Ecological Society of America Annual Meeting; 2010 August 1-6; Pittsburgh, PA.

Management Applications and Seed Production Guidelines:
This research examines an ecologically and economically rational strategy for management of *B. tectorum* invaded rangelands. By utilizing principles of natural succession of Great Basin rangelands, two goals are met: 1) restoring rangelands to their proper functioning using native plant materials and 2) an ecological and economic benefit to land managers through increased restoration success. Understanding if native annual forbs can increase establishment of *E. multisetus* in degraded rangelands will allow managers and seed producers to take the following steps to maintain healthy systems: 1) include highly competitive annual forbs in restoration seed mixes to promote establishment of early successional perennial grasses such as *E. multisetus*, 2) target annual forbs that have the greatest positive effect on *E. multisetus* and negative effect on *B. tectorum* biomass and reproduction for seed increase programs, and 3) manage and maintain sites with high annual forb diversity, as these populations may be a vital component for successful restoration of disturbed rangelands.

Products:
Outreach presentation to the public on the use of native annual forbs in restoration of invaded rangelands, sponsored through the Galena Creek Visitor Center's discussion series "Chin-wagging and Wine".

Project Title: Evolution of Native Plants in Cheatgrass Invaded Systems

Project Location: University of Nevada, Reno, Nevada

Principal Investigators and Contact Information:

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Project Description:

Objectives

In this experiment, we examined populations of five common native perennial grass species (*Poa secunda*, *Elymus multisetus, Hesperostipa comata, Achanatherum hymenoides* and *A. thurberianum*) from four locations where paired invaded/uninvaded sites were found in close proximity, addressing the following questions:

1. Which species are the most tolerant of *B. tectorum* competition?
2. Which species exert the strongest competitive effect on *B. tectorum*?
3. Does native plant phenology differ between invaded and uninvaded populations?
4. Are tolerant and/or competitive plants present in higher frequencies in invaded communities?

Methods

Three hundred and twenty adult plants were collected from invaded and uninvaded communities from four locations near Reno, Nevada, USA. Each plant was divided in two and transplanted into the greenhouse. One clone was grown with *B. tectorum* while the other was grown alone, and we measured tolerance (ability to maintain size) and the ability to reduce size of *B. tectorum* for each plant.

Table 1. Site and species characteristics of the four sampled locations

	Bedell Flats	Little Hill	McClellan Peak	Tule Peak
Lat Long	39°49'58.10"N 119°45'56.10"W	39°52'51.20"N 119°42'55.60"W	39°14'21.30"N 119°44'34.70"W	39°54'0.10"N 119°42'4.90"W
Elevation (m)	1513	1335	1750	1470
Mean Precip⁺ (in)	7.5	7.5	10.4	7.5
Soil Type†	Haybourne loamy sand	Washoe gravelly sandy loam	Indiano-Nosrac-Old Camp Association	Oppio cobbly sandy loam
Parent Material†	Alluvium derived from granitic rocks	Mixed alluvium	Residuum and colluvium derived from volcanic rock	Residuum derived from volcanic rock
% Sand†	73	67	47	35
Size of uninvaded area relative to invaded area	Small	Large	Equivalent	Large
Species collected	*Achnatherum hymenoides*[1,4] *Hesperostipa comata*[2,5] *Poa secunda*[1,3]	*Achnatherum hymenoides*	*Achnatherum thurberianum*[2,4] *Elymus multisetus*[1,4] *Poa secunda*	*Elymus multisetus*

⁺Precipitation data from Carson City Station (261485) for McClellan Peak and from Sutcliff Station (267953) for Bedell Flats, Little Hill, and Tule Peak (Western Regional Climate Center, www.wrcc.dri.edu). †Soil data from Natural Resources Conservation Services, (websoilsurvey.nrcs.usda.gov). [1]Short-lived or [2]long-lived species, and [3]apomictic, [4]selfing, or [5]outcrossing mating system.

Results

Plants from invaded populations consistently had earlier phenology than those from uninvaded populations, and in two out of four sites, invaded populations were more tolerant of *B. tectorum* competition than uninvaded populations. *Poa secunda* and one population of *E. multisetus* had the strongest suppressive effect on *B. tectorum*, and these two species were the only ones that flowered in competition with *B. tectorum*.

Conclusions

Our study indicates that response to *B. tectorum* is a function of both location and species identity, with some, but not all, populations of native grasses showing trait shifts consistent with evolution in response to *B. tectorum* invasion within the Great Basin.

Publications:

Forbis, T.; Leger, E.A.; Goergen, E.; Meyer, S.E. 2010. Investigations of seed and seedling ecology and competitive ability of native annual forbs or the Western Great Basin. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 127-135. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

Leger, E. A. 2010. Native species evolution in response to cheatgrass (*Bromus tectorum*) invasion. Seminar, USDA ARS Northern Plains Agricultural Research Laboratory, 2010 January 15, Sydney, MT.

Leger, E. A. 2010. Native species evolution in response to cheatgrass (*Bromus tectorum*) invasion. Departmental Seminar, Chico State University, 2010 April 8, Chico, CA.

Leger, E. A. 2010. The role of genetics in seedling establishment in invaded systems. National Native Seed Conference, 2010 May 18, Snowbird, UT.

Leger, E. A., Espeland, E. K., Goergen, E. M. 2010. Can we improve restoration success in highly invaded communities? Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Leger, E. A.; Goergen, E. M.; Espeland, E. K.; Kulpa, S. M.; Rowe, C. J. 2010. Persistence and evolution of native plants in cheatgrass invaded systems: implications for the health and management of Great Basin rangelands, Society for Range Management Annual Meeting, 2010 February 9, Denver, CO.

Management Applications and Seed Production Guidelines:
This study and others indicate that native species may be responding to selection from the presence of invasive plants, and further, that there are both species- and population-level differences in the way native species perform with an invasive competitor. In addition to examining the evolutionary effects of species invasion, these studies provide valuable information on potential restoration of invaded rangelands. In order to find the most tolerant and/or competitive genotypes in the Great Basin, we recommend wide-scale collections be undertaken from heavily invaded areas, as this and other studies have shown that these populations may be evolving in response to *B. tectorum*. Additionally, field performance in highly invaded areas should be a criterion for deciding which populations will be used for restoration.

Products:
- Continued our lab's contribution to understanding the mechanisms of native plant persistence in invaded systems.
- Data will be used for USDA grant application in 2011.
- Research highlighted in the media: http://scienceline.org/2011/02/native-plants-evolve-to-fight-off-invading-species/

Project Title: Evaluating Strategies for Increasing Plant Diversity in Crested Wheatgrass Seedings

Project: University of Nevada Cooperative Extension, Elko, Nevada

Principle Investigator and Contact Information:

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Project Description:

Objectives of this research include:

1. Determine the effect of crested wheatgrass (*Aropyron desertorum*) control methods on wheatgrass density and cover.
2. Determine the effect of crested wheatgrass control methods and revegetation on establishment of seeded species.

Methods

The study site, approximately 15 miles southeast of Elko, NV, is located within the 8 – 10" p.z. in sandy loam soil (Orovada Puett association) and formerly dominated by Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*). The area was seeded to crested wheatgrass during the 1970s. Located within the boundaries area of South Fork State Park, the site has had the necessary cultural resources clearance from the Nevada State Historic Protection Office (SHPO) and is fenced to eliminate livestock grazing.

Crested Wheatgrass Control and Revegetation Treatments. The following strategies are being tested in a randomized block, split-split plot design: (1) untreated crested wheatgrass; (2) partially controlled crested wheatgrass; and (3) completely controlled crested wheatgrass. The study site is comprised of five 5-acre blocks.

Within the main (1-acre) plots in each block, the following methods of control (mechanical and chemical) and revegetated vs. non-revegetated strategies are being compared:

1. Untreated crested wheatgrass plots receiving no chemical or mechanical treatment, but divided into unseeded and seeded sub-plots.
2. Partially controlled crested wheatgrass plots split into 3-way disked or herbicide-treated plots, divided into unseeded and seeded sub-plots.
3. Completely controlled crested wheatgrass plots split into combined 3-way disked and herbicide-treated plots or combined spring and fall herbicide-treated plots, divided into unseeded and seeded sub-plots.

Treatment Implementation. During November 2007, "disked only plots" were 3-way disked. In May, 2008 "spring-applied herbicide plots" and "combined disk + herbicide plots" were sprayed with 66 oz. glyphosate (Roundup ®)/ac. In early October 2008, "combined spring + fall-applied herbicide plots" were sprayed with 66 oz. glyphosate/ac. Sub-plots targeted for seeding were seeded at NRCS-recommended rates in late October 2008 by personnel from the NRCS Aberdeen Plant Materials Center with a Truax Rough Rider rangeland drill. For small-seed species, seed tubes were pulled so that seed fell on the soil surface; drill disks were raised, no furrows made, and a brillion-type cultipacker was attached to the rear of the drill to press broadcasted seeds into the soil surface. The seed mixture used is identified in table 1.

Table 1. Final seeding mix for South Fork study plots, Elko County, NV, in sandy loam soil (Orovada Puett association), approximately 8" precipitation zone.

Species	Kind/Variety	Seeding Rate (PLS lb/acre)	Total No. lb (for 12.5 acres)
Indian ricegrass[1] (*Achnatherum hymenoides*)	'Nezpar'	2.0	25
Bottlebrush squirreltail[1] (*Elymus elymoides*)	'Toe Jam Creek'	2.0	25
Needle-and-thread grass[2] (*Stipa comata*)		2.0	25
Basin wildrye[3] (*Elymus cinereus*)	'Magnar'	2.0	25
Bluebunch wheatgrass[3] (*Psuedoroegneria spicata*)	'Secar'	1.0	12.5
Sandberg bluegrass[4] (*Poa secunda*)		0.75	9.4
Munro globemallow[4] (*Sphaeralcea munroana*)		0.50	6.25
Lewis flax[3] (*Linum lewisii*)	'Appar'	0.75	9.4
Western yarrow[4] (*Achillea millefolium*)		0.20	2.5
Wyoming big sagebrush[3] (*Artemisia tridentata wyomingensis*)		0.20	2.5
Spiny hopsage[5] (*Grayia spinosa*)		0.50	6.25
Totals		**11.9**	**148.8**

1 From Granite Seed Co.
2 From BFI Native Seeds
3 From Comstock Seed Co.
4 From FS Collection
5 From Native Seed Co.

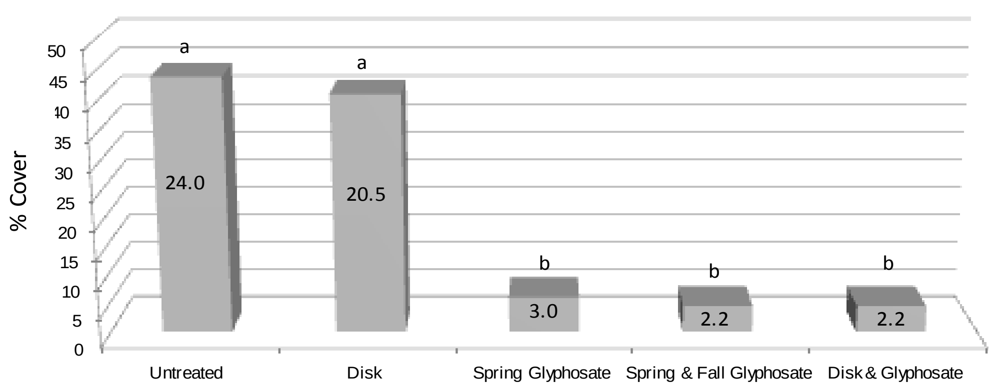
Preliminary Results

During the summers of 2009 and 2010, we measured cover and density of crested wheatgrass, as well as nested frequency of crested wheatgrass seedlings. We also measured density of seeded species. All parameters were measured for each sub-plot within ten 0.5 m^2 quadrats placed randomly on each of five transects and perpendicular to each transect.

2009. Complete (100%) control/mortality of crested wheatgrass was not obtained with any of the control treatments. However, as shown in figure 1, spring-applied glyphosate, combined spring + fall-applied glyphosate, and combined disk + glyphosate treatments all significantly reduced crested wheatgrass cover ($p<0.05$) as compared to untreated plots, with no significant differences among these treatments ($p>0.05$). Similarly, these same three treatments all significantly reduced crested density ($p<0.05$), again with no significant differences among treatments (fig. 2). However, crested wheatgrass density was significantly greater on disked plots ($p<0.05$) than on the untreated plots and plots receiving the other treatments (fig. 2), whereas cover was not significantly different ($p>0.05$) between disked and untreated plots (fig. 1).

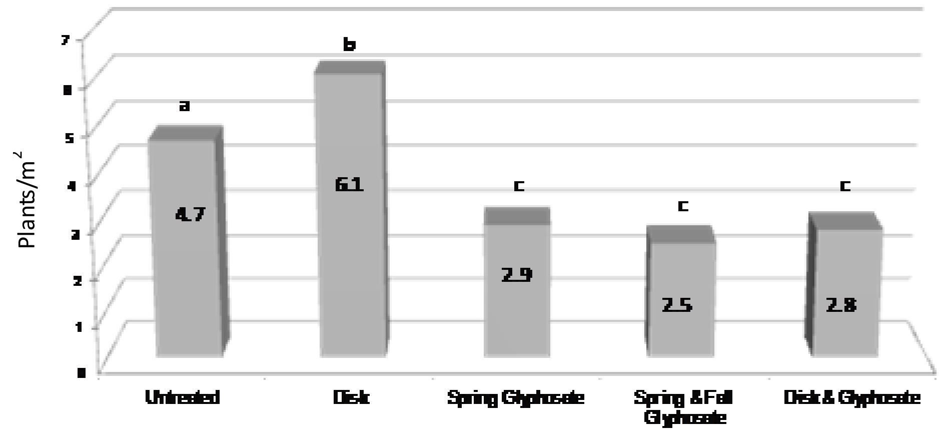
Preliminary observations showed the following: (1) four of the six seeded native grass species established, including basin wildrye, bluebunch wheatgrass, bottlebrush squirreltail, and Indian ricegrass; (2) each of the seeded forb species, i.e., western yarrow, Lewis flax, and Munro globemallow also established; and (3) of the two seeded shrub species, establishment of Wyoming big sagebrush was very spotty and spiny hopsage establishment was not documented. Seeded native grasses germinated on plots both with and without crested wheatgrass control, but were much taller and more robust in plots where crested wheatgrass was suppressed. Spring growing conditions were nearly ideal, with an extremely wet June. Some grass and forb plants produced seed in this first growing season.

Figure 1. Effects of Treatments on Crested Wheatgrass Cover, 2009*



*Means with differing letters are significantly different ($p<0.05$)

Figure 2. Effects of Treatments on Crested Wheatgrass Density, 2009*



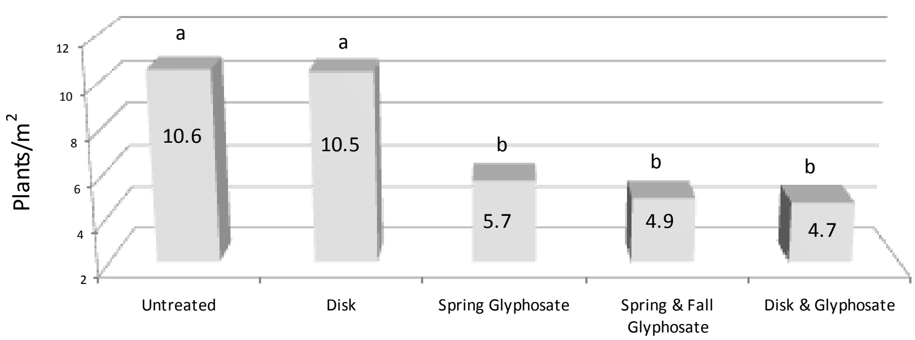
*Means with differing letters are significantly different (p<0.05)

<u>2010</u>

During 2010, density of crested wheatgrass seedlings continued to be significantly higher ($p<0.05$) in the untreated plots and disked plots (fig. 3). Density of seeded native grasses was highest in plots that received the combination of disking + spring glyphosate treatment, significantly greater than that of disk-treated plots ($p<0.05$), but not significantly different than either the spring-treated glyphosate plots or the spring + fall-applied glyphosate plots (fig. 4).

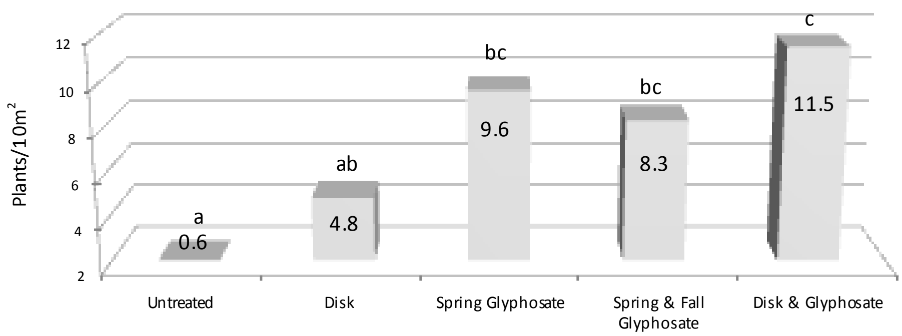
Forb densities were highest in the spring + fall-applied glyphosate plots and the disk + glyphosate plots, but because of large standard errors, only the latter treatment was significantly greater ($p<0.05$) than the untreated plots and the disked only plots (fig. 5). For all seeded species combined, the spring + fall-applied glyphosate treatment and disk + glyphosate treatment produced significantly higher seeded species densities than the disked only treatment ($p<0.05$).

Figure 3. Effects of Treatments on Crested Wheatgrass Density, 2010*



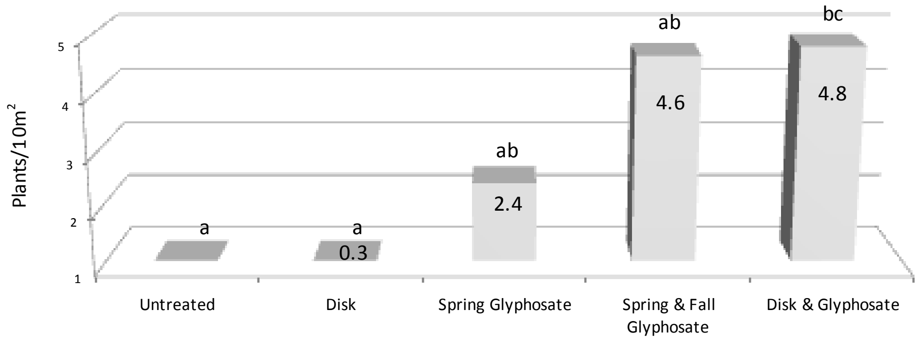
*Means with differing letters are significantly different (p<0.05)

Figure 4. Effects of Treatments on Density of Seeded Native Grasses, 2010*



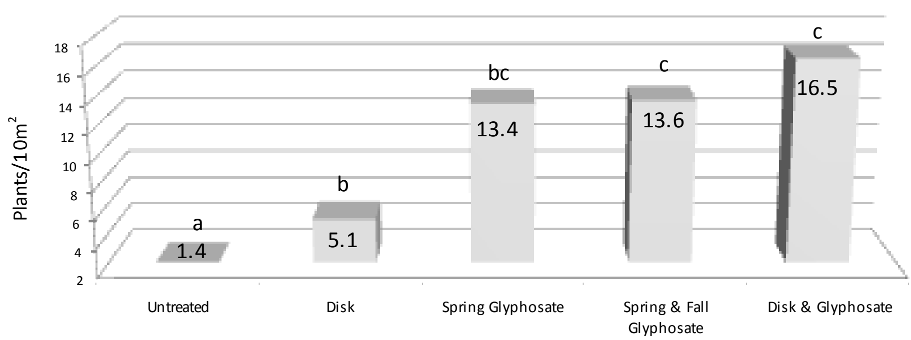
*Means with differing letters are significantly different (p<0.05)

Figure 5. Effects of Treatments on Seeded Forb Densities, 2010*



*Means with differing letters are significantly different (p<0.05)

Figure 6. Effects of Treatments on Density of All Seeded Species, 2010*



*Means with differing letters are significantly different (p<0.05)

New Treatments

During May 2010, another treatment trial was implemented within the same general study area and using the same randomized block, split-split plot design. Crested wheatgrass suppression treatments consisted of (1) imazapic (Panoramic 2SL®); (2) chlorsulfuron + sulfometuron methyl (Landmark XP ®); glyphosate (Roundup ®) full rate; glyphosate half-rate; and (4) untreated. The study site was comprised of five 5-acre blocks, with each 1-acre treatment plot divided into 0.5-acre seeded and unseeded sub-plots. All treatments were seeded during late October 2010, using the same seed mixture (table 1), rates, and methodology described above.

Sampling and Analysis

During summer 2011, we will continue to collect vegetation data, as described above, for both treatment trails (third-year data for first trial, first-year data for second trial). Data will be analyzed using mixed model analysis, with blocks and years considered random and other treatments considered fixed.

Publications:

McAdoo, K. 2010. Evaluating strategies for increasing plant diversity in crested wheatgrass seedings. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 136-140.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

McAdoo, K. 2010. Increasing plant diversity in crested wheatgrass seedings. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

McAdoo, K.; Swanson, J.; Poulsen, C.; Schultz, B.; Shaw, N. Evaluating strategies for increasing plant diversity in crested wheatgrass seedings. Joint Meeting, Society for Range Management and Weed Science Society of America. Denver, CO. (Abstract)

Management Applications:

The relative success and/or failure of revegetation strategies and methodologies used in this research will be communicated in appropriate venues for the benefit of both public and private land managers and resource users. This research will add to the body of knowledge regarding the rehabilitation, functionality, and restoration of Great Basin rangelands.

Products:

We will conduct a field tour on July 7, 2011 to look at results of applying crested wheatgrass reduction methodologies and seeding native species.

Project Title: Effect of Herbicide Application Timing on Crested Wheatgrass Control and Subsequent Native Plant Reestablishment Success

Project: USDA-ARS, Dubois, Idaho

Principal Investigators and Contact Information:

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Project Description:
Crested wheatgrass stands in much of the western United States are stable in near monocultures that are resistant to native plant reestablishment. Attempts to modify these stands, to increase diversity, will require a reduction in crested wheatgrass so other seeded species can become established. Experiments were initiated in the spring 2008 to determine whether: (1) glyphosate efficacy differs among combinations of crested wheatgrass physiological state (timing of application) and disturbance, and (2) establishment of seeded native plants is improved when crested wheatgrass control treatments are more effective.

Methods

Effect of crested wheatgrass phenological stage on herbicide efficacy. Two experiments are being conducted at the U.S. Sheep Experiment Station (USSES) headquarters property near Dubois, Idaho to determine the relationships among total nonstructural carbohydrate (TNC) trend, phenological stage, and efficacy of glyphosate to control crested wheatgrass. The first experiment will characterize the TNC trend in relation to plant phenology. The experiment is a completely randomized design. A factorial combination of year (2 levels), and date (~10 levels) were assigned completely at random to each plant (10 replications). Plants were collected and dried in the laboratory. Growth stages were classified for each plant, and root crowns and stem bases were excised for TNC analysis.

The second experiment is a completely randomized design in a split-plot arrangement with repeated measures. A factorial combination of year (2 levels; 2008 or 2009) and date (8 levels) was assigned to main plots (1 x 2 m) completely at random. Within each main plot a random half (1 x 1 m) was assigned to a clipping treatment. The clipped half was generally clipped 2 weeks prior to the main plot spray date. In mid June (2009) it was clear that a 2-week delay between clipping and spraying didn't give the crested wheatgrass time for significant regrowth, so subsequent spray dates were delayed to 28 or 56 days after clipping. At the time these plots were selected, corners of the main plot were permanently marked with fiberglass rods. At clipping, herbicide application, 2 weeks after application, and in mid June the year after herbicide application, digital photographs will be taken from 2 m above ground. In mid June, the year after herbicide application, crested wheatgrass biomass will be clipped and weighed. The photographs will be analyzed for crested wheatgrass cover. Analysis of variance will be used to determine whether year, timing of herbicide application, or clipping prior to application had an effect on crested wheatgrass cover and biomass.

Large scale seeded plot experiment. The large scale plot experiment is being conducted within a 50-ha, well established crested wheatgrass seeding near Aberdeen, Idaho. The site is mapped to two soil map units, the Portino silt loam, 4 to 8 percent slopes (Coarse-silty, mixed, superactive, mesic Xeric Haplocalcids) and the Portneuf silt loam, 2 to 4 percent slopes (Coarse-silty, mixed, superactive, mesic Durinodic Xeric Haplocalcids). Both soil units are correlated with the Loamy 8-12 ARTRW8/PSSP ecological site. The historical plant composition for this site included bluebunch wheatgrass, Thurber's needlegrass, western wheatgrass, arrowleaf balsamroot, Wyoming big sagebrush, Sandberg bluegrass, green rabbitbrush, and bottlebrush squirreltail.

The large scale plot experiment is a split-plot arrangement of a completely randomized design with repeated measures. A factorial combination of treatment year (2 levels; 2008 or 2009), spring disking (2 levels; yes or no), and glyphosate treatments (4 levels; none, vegetative stage, reproductive stage, or autumn regrowth application) was assigned completely at random to 80 main plots (61 x 43 m). A random half of each main plot (30.5 x 21.5 m, subplots) was seeded with a native mix (Table 1). Between adjacent main plots there is a minimum 12-m buffer in all directions. Sampling, within each subplot, is conducted on a central 24 x 37 m core sampling area.

For all herbicide treatments, the recommended rate (3.2 l/ha) of glyphosate was applied with a tractor pulled sprayer. For the disking treatments a tractor pulled disk was used in the spring before the soils had dried.

The seeded subplots were seeded with a mix of native grasses, forbs, and shrubs common to the sites historical plant community. Seeding each year occurred in early November. A Truax Rough Rider rangeland drill was used for the seeding.

Table 1. Seed mix

Species	kg-PLS/ha
Broadcast	
Maple Grove Lewis flax	0.45
Mtn. Home Sandberg bluegrass	0.22
Blue Penstemon	0.45
Wyoming big sagebrush	0.06
Rubber rabbitbrush	0.17
Drilled	
Anatone bluebunch wheatgrass	3.59
Magnar basin wildrye	0.90
Bannock thickspike wheatgrass	0.67
Thurber's needlegrass	0.67

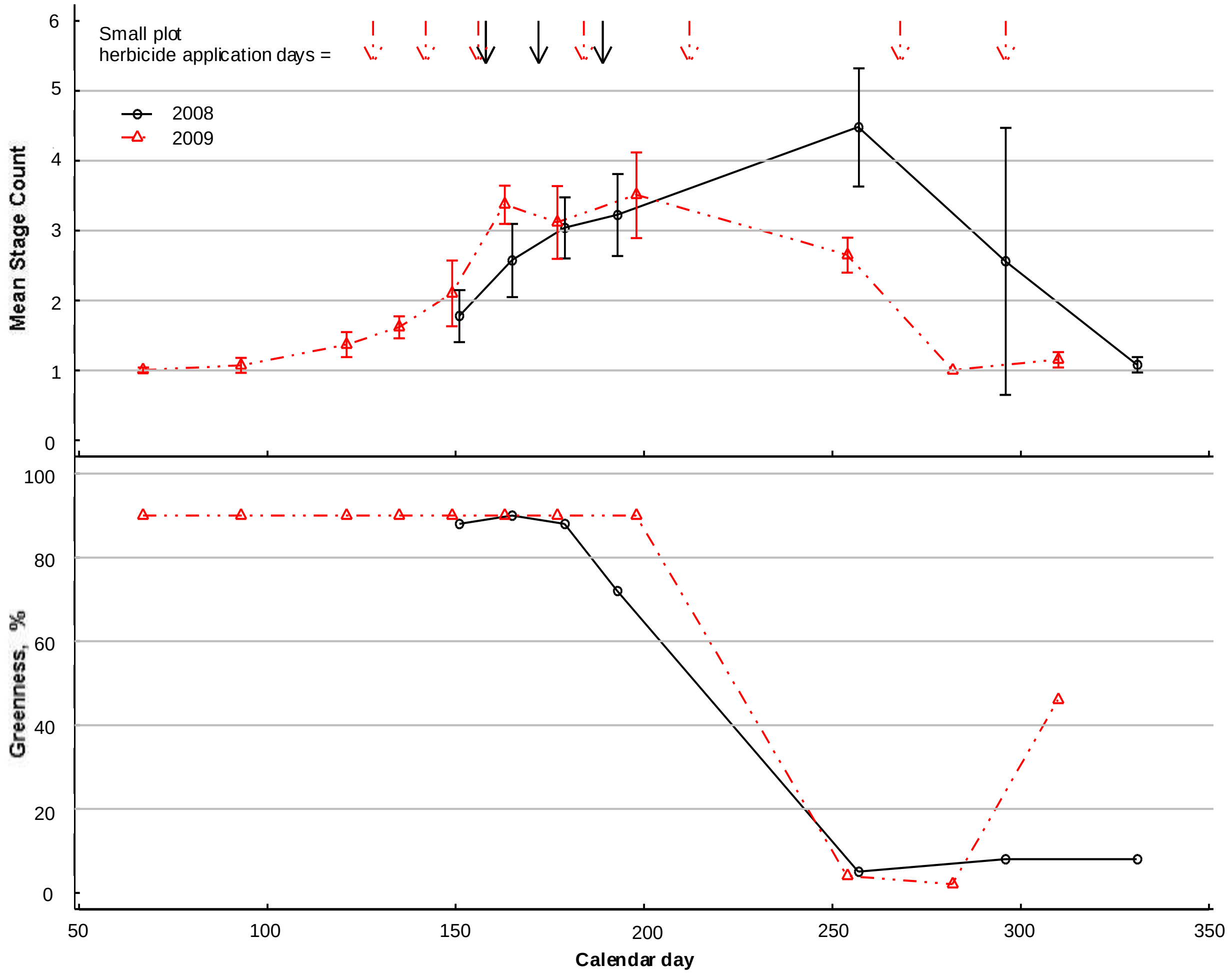

Figure 1. Mean stage count and greenness for crested wheatgrass plants collected over two years. Mean stage count classes are for green tillers and follow the classification system described by Moore et al. (1991). Greenness is plotted as the mean of the greenness class midpoint for ten sampled plants. Greenness classes for the plants were classified into 1 of 6 categories based on the percentage of green tillers (0, 1 to 20, 21 to 40, 41 to 60, 61 to 80, or 81 to 100 percent). Calendar days when herbicide was applied to adjacent small plots are also indicated for 2008 and 2009.

Reseeding success is evaluated for two growing seasons after each treatment and seeding year. Data collection includes cover and density of seeded species, crested wheatgrass, and invasive plants. Cover will be determined by line point intercept. Density will be determined by counting plants in sample quadrats or appropriately sized belt transects.

Results from 2009 and 2010

Effect of crested wheatgrass phenological stage on herbicide efficacy. Crested wheatgrass plants were collected in 2008 and 2009 and greenness and phenological stages were classified for each sample date (Figure 1). When sampling began, in late May 2008 (d 151), most of the crested wheatgrass tillers were green and in a vegetative stage. By mid July 2008 (d 193), some tillers were beginning to senesce and the green tillers were mostly in a reproductive stage. By mid September 2008 (d 257), almost all tillers were senesced and the few remaining green tillers were in seed development and seed ripening stages. With little or no autumn green-up, no herbicide applications were made in the late summer and autumn of 2008. Growth was initiated earlier in 2009 than in 2008, likely due to an earlier April 4 (d 94) thaw, whereas in 2008 snow remained on the site until April 25 (d 116). By late May 2009 (d 149), tillers were predominately in an elongation stage, whereas in late May 2008 (d 151) tillers were predominately in a vegetative stage. In 2009, 98 mm of June precipitation (218% of normal) helped to extend the time when most tillers were green beyond mid July (d 198). In 2008, plants were beginning to exhibit senescence by late May (d 148).

Shoots were predominately vegetative or nonexistent in plants subjected to clipping 2 weeks prior to sampling (data not shown). In 2008, the only sample period with abundant regrowth on clipped plants was mid June (d 165). By the late June sampling (d 179), few new tillers had emerged and all were in the early vegetative stage. By mid July (d 193) and throughout mid August (d 226), no tillers were emerging from clipped plants and no phenological stage ratings could be made. By late October (d 296), some tillers were emerging from clipped plants and the emerged tillers were in early vegetative stages. In 2009, tillers had emerged from the clipped plants at the sampling times beginning with the first clipped plant sampling May 1 (d 121) through the late June (d 177) sampling. In mid July (d 198), the clipped plants had few emerged tillers and all were in the early vegetative stage. The clipped plants that were sampled in early November (d 310) were clipped in mid July (d 198) and many tillers had finally emerged, but development was slow and they were all in the early vegetative stage.

Timing of herbicide application in 2008 had a significant effect on glyphosate efficacy. Crested wheatgrass biomass was 231 g m^{-2} in unsprayed plots. Crested wheatgrass biomass was <1 g m^{-2} in plots sprayed June 6 (d 158) at 2X the recommended herbicide application rate. Crested wheatgrass biomass was less, compared with the unsprayed control plots, when plots were sprayed at the recommended herbicide application rate on June 20 (d 172, 46 g m^{-2}), but not for plots sprayed on July 7 (d 189, 217 g m^{-2}).

For plots treated in 2009, the effect herbicide application timing had on crested wheatgrass biomass in 2010 was large, but varied depending on clipping. Plots not sprayed in 2009 produced 382 g m^{-2} of crested wheatgrass by late June 2010. For unclipped plots, glyphosate application, at the recommended rate on all 2009 spray dates except September 25, significantly reduced crested wheatgrass production. Spraying the herbicide on July 31 and October 23 reduced crested wheatgrass biomass (119 and 299 g m^{-2}, respectively), but to a much lesser extent than the 4 spray dates between May 8 and July 3 (range 9 to 41 g m^{-2}). The effect of spraying was, in most cases, not affected by clipping 2 weeks prior to spraying. Crested wheatgrass biomass in 2010 on plots clipped May 22 and sprayed June 5 (128 g m^{-2}) was, however, intermediate to the unsprayed control and the June 5 sprayed, but unclipped, plots. Likewise, plots clipped July 3 and sprayed July 31 had crested wheatgrass biomass (281 g m^{-2}) that was intermediate to the unsprayed control and the July 31 sprayed, but unclipped, plots. The efficacy of glyphosate application was increased by clipping before spraying in only one case. Plots that were clipped September 25 and sprayed October 23 had less crested wheatgrass biomass the following June (180 g m^{-2}) than the unclipped plots sprayed October 23.

Large scale seeded plot experiment. Precipitation was less than normal in 2008, above normal in 2009, owing to above normal June precipitation, and near normal in 2010. Crested wheatgrass control treatments in 2009 were begun earlier than in 2008, with the exception of the 2nd herbicide application and seeding which were completed on about the same date as in 2008.

Mature crested wheatgrass density in 2009 was reduced by disking in late May 2008. In 2010, however, there seem to be no effect of disking in mid May 2009. Mature crested wheatgrass density in 2009 was less in plots sprayed with the recommended rate of glyphosate on June 9, 2008 or June 19, 2008 compared with unsprayed plots or plots sprayed on October 24, 2008. The effect of spring disking did not interact with spraying and seeding had no effect on mature crested wheatgrass density. The effect of disking and spraying on crested wheatgrass cover depended on year. Disking and early season spraying in 2008 effectively reduced crested wheatgrass cover measured in 2009. Late May herbicide application in 2009, without mid May disking, was the only treatment effective for reducing crested wheatgrass cover in 2010. Regardless of year, seeding caused a modest, but statistically significant increase in crested wheatgrass cover.

Cheatgrass cover, regardless of treatment or year, was less than 1%. Cheatgrass density was generally low in 2009 (3.5 plants m^{-2}). In 2010, cheatgrass density increased significantly to 5 plants m^{-2}.

Emergence and first growing season survival of seeded forbs and shrubs was poor regardless of the crested wheatgrass control treatments or year. Total seeded forb seedling density was less than 1 plant m^{-2} and total seeded shrub seedling density was less than 0.01 plant m^{-2}. Emergence and first growing season survival of seeded grasses was greater in 2009 than in 2010. In 2009, seeded grass density was 27.2 plant m^{-2}, but in 2010 density was 9.7 plant m^{-2}. Across both years, the disking treatment tended to reduce emergence and first growing season survival of seeded grasses. Total seeded grass density was 19.7 plants m^{-2} in undisked plots compared with 16.4 plant m^{-2} in disked. The reduction in seedling density due to disking was significant for needlegrass (1.4 vs. 0.7 m^{-2}), significant for Sandberg bluegrass (1.2 vs. 0.4 m^{-2}), but non-significant for the wheatgrass/wildrye group.

Plans for 2011

Large plot cover and density will be measured for the second year on the 2009 treatment plots.

Publications:

Moffet, C. 2010. Effect of herbicide application timing on crested wheatgrass control and subsequent native plant reestablishment success. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 141-145. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

Moffet, C. 2010. Eastern Idaho crested wheatgrass diversification study update. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Management Applications: When this study is complete, land managers can use this information to choose efficacious crested wheatgrass control practices and increase the likelihood that subsequent native seeding efforts are successful.

Literature Cited:

Moore, K. J.; Moser, L. E.; Vogel, K. P.; Waller, S. S.; Johnson, B. E.; Pededsen, J. F. 1991. Describing and quantifying growth stages of perennial forage grasses. Agronomy Journal 83: 1073–1077.

Project Title: Recruitment of Native Vegetation into Crested Wheatgrass Seedings and the Influence of Crested Wheatgrass on Native Vegetation

Project: USDA Agricultural Research Service, Eastern Oregon Agricultural Research Center, Burns, Oregon

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Project Description:
Preliminary results suggest that over a 12 year period, crested wheatgrass density increased 40-fold while native bunchgrass density remained the same or decreased. This suggests that when seeded together, crested wheatgrass recruits new individuals into the plant community, while native perennial bunchgrasses do not and that crested wheatgrass may be displacing some of the native perennial bunchgrasses.

The objectives of our study were to 1) determine what factors (management, site/environmental characteristic, etc) promote native plant recruitment in crested wheatgrass plant communities and 2) determine if crested wheatgrass displaces native vegetation from plant communities.

<u>Methods</u>
In 1998, experimental plots were set up with known, even densities of crested wheatgrass and seven native perennial bunchgrasses. Since 1998, no management activities have occurred on these experimental plots. In 2010, we counted total density of perennial bunchgrasses by species in ten 37.2 m^2 plots.

<u>Results</u>
Over a period of 12 years, crested wheatgrass density increased 40-fold and native grass densities either remained the same or decreased (fig. 1). The preliminary results of this study suggest that, when seeded together, crested wheatgrass recruits new individuals into the plant community, while native perennial bunchgrasses do not. Thus, crested wheatgrass may be displacing some of the native perennial bunchgrasses or is better adapted to recruit new individuals into the population. This study did not address changes in forb and shrub

composition over time and it is possible that reestablishment of shrubs and forbs may be more successful.

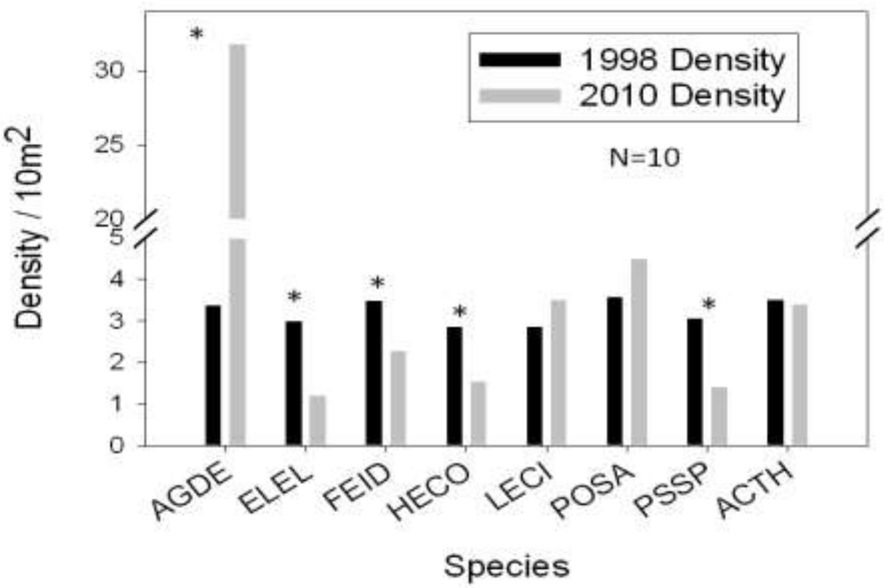

Figure 1. Density per 10 m^2 of crested wheatgrass (AGDE = crested wheatgrass) and each of 7 native perennial bunchgrass species: PSSP = bluebunch wheatgrass; LECI = basin wildrye; FEID = Idaho fescue; ELEL = bottlebrush squirreltail; HECO =needle and thread grass; POSE = Sandberg bluegrass; ACTH = Thurber's needlegrass. *Indicates statistical difference at P < 0.01.

<u>Future Plans</u>

In 2011, we will extensively sample the 1998 co-planting plots and located crested wheatgrass plant communities across the northern Great Basin. Private and public land managers will be contacted to locate crested wheatgrass plant communities. In 2012, we plan to begin sampling crested wheatgrass plant communities to determine what factors promote native plant recruitment in crested wheatgrass plant communities. Site, environmental, and management characteristics will be collected to determine their relationships with native plant recruitment into crested wheatgrass communities.

Management Applications:

Results are still preliminary, but they do suggest that crested wheatgrass is better able to recruit new individuals into the plant community than native bunchgrasses. The ability of crested wheatgrass to increase, while native bunchgrass densities remained the same or decreased, should be considered before co-planting crested wheatgrass and native bunchgrasses.

Project Title: Revegetation Equipment Catalog

Project Location: Texas Tech University, Lubbock, Texas

Principal Investigator and Contact Information:

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Project Description:
The Revegetation Equipment Catalog is an online repository of descriptions, photos, and company information for equipment that is used for revegetation efforts in the US. With pages on topics ranging from “All-terrain Vehicles” through “Fertilizing and Mulching” to “Transport Trailers”, the catalog is an important reference for information about revegetation equipment.

<u>2010 Activities and Results</u>
Prior to 2009, the catalog was hosted on websites at the Texas A&M University. During 2009, the catalog was shifted to being mirrored at Texas Tech University. During 2010, the TTU-hosted site was fully updated, and revised. All links were checked and corrected, if necessary, and the site was converted to a more “modern” format utilizing frames.

<u>Future Plans</u>
During 2011, the catalog will again be updated and maintained, but will also be redesigned in a more complete way, to modernize the approach.

Project Title: GPS Datalogger for Rangeland Drills

Project Location: USDA Forest Service, Missoula Technology and Development Center (MTDC), Missoula, Montana

Principal Investigator and Contact Information:

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Project Description:

Objectives

A durable GPS datalogger is needed to provide a quality control tool for monitoring rangeland drill operation and contracts. The aim is to create a device that is capable of: 1) operating for over a month at a time; 2) temporarily attaching to a drill (drills are often owned by cooperators); 3) operating at low temperatures; 4) utilizing user-friendly software that can be used to track drill speed, area covered, effectiveness in avoiding leave areas (archaeological sites, rare plant habitat, rock piles, etc.), and operating time. Software should be capable of superimposing the data on satellite maps and providing a record of operating time, drill speed, distance traveled, site coverage, elevation changes and avoidance of archaeological sites and other leave areas.

Progress

Several GPS dataloggers and associated software were tested until one device that seemed to have the required capabilities was identified. The device has enough memory to log a data point every five seconds, 24 hours a day, for more than 23 days. With the aid of a modified battery pack (eight 1.5V D-cell batteries), the device can run for up to 40 days of continuous operation. The device is housed inside a waterproof, lockable case that is secured temporarily to the drill by rare Earth magnets.

The software provides the ability to program the device to Power On and begin logging data at pre-programmed intervals set by the device owner or representative of the owner. This ability to program the device extends the number of days the device will remain operable. For instance, pre-programming 10-12 hour workdays will improve the longevity of the device by allowing for more data collection before the memory or battery maxes out.

The software can also be programmed to set the frequency with which GPS points are taken. A vibration detector ensures that the datalogger will stop taking points when the drill is not in motion. An alarm sounds if the drill exceeds a specified speed which would reduce planting efficiency.

Management Applications:

The low cost GPS unit is suitable for use on rugged terrain in remote areas during low temperature periods. Its features allow owners to monitor whether specifications outlined in a contract were followed.

Product:
The unit is still in the testing phase. The current version costs about $200 and includes a GPS datalogger and software, a waterproof/lockable case with five rare Earth magnets, 2 battery cases, 8 D-cell batteries, and a modified mini USB power cable.
(http://rtec.rangelands.org/GPSdatalogger.htm)

Collaborators on the project:

- Truax Company, Inc., New Hope, Minnesota
- USDA Forest Service Rocky Mountain Research Station, Boise, ID
- Glade Jones, Hindsite Co., La Barge, WY.

Project Title: Calibration of Drills for Rehabilitation and Restoration Seedings on Western Wildlands

Project Location: USDA Forest Service, Missoula Technology and Development Center (MTDC), Missoula, Montana

Principal Investigator and Contact Information:

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Project Description:

Native and diverse plant communities are essential for the health and vitality of our nation's rangelands. Reestablishing plants after wildland fires, increasing an area's resistance to weed invasion, and enhancing roadways, as well as other rangeland restoration projects, require the use of rangeland drills. This equipment is designed to distribute seeds of different sizes and shapes at appropriate rates and depths in compatible combinations.

The standard rangeland drill and some newer drills are currently in use. Operators must be familiar with this equipment and know how to calibrate it to improve seeding success and reduce waste, thus decreasing costs. Project 2400 9E92E89: "Calibrating Your Rangeland Drill" was completed in 2010. The DVD describes: the history of rangeland drill development, the essential features of rangeland drills, the basic seed and seed testing terminology, the calculation of seeding rates for multispecies seeding mixes using one or more seed boxes, and the three methods of drill calibration (the wheel circumference, the seed per row-foot, and the small bag per land area methods). It also demonstrates how the output of seed boxes can be adjusted. Included on the DVD are a glossary of standard terms and a "Drill Calibration Summary" to print for field use.

Collaborators on the project include: USDI Bureau of Land Management Vale Equipment Shop, Vale, OR; USDA NRCS Aberdeen Plant Materials Center, Aberdeen, ID; Truax Company, Inc., New Hope, MN; USDA Forest Service Rocky Mountain Research Station, Boise, ID; and the Oregon State University Malheur Experiment Station, Ontario, OR.

Single copies of the DVD may be ordered from:
U.S. Forest Service
Missoula Technology and Development Center
5785 Highway 10 West
Missoula, MT 59808-9361
Phone (406)329-3978, Fax (406)329-3719
email: wo_mtdc_pubs@fs.fed.us

Project Title: Development of Seeding Equipment for Establishing Diverse Native Communities

Project: Truax Company, Inc., New Hope, Minnesota

Principal Investigators and Contact Information:

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Project Description:
Changes were made in the telescoping seed delivery tubes and boot casing of the Roughrider in the summer of 2010; in attempts to overcome the plugging that has been experienced when the Roughrider has been used in the snow.

The seed-way passage was modeled using Solidworks software and ¼ inch cross-sections of the boot and tube were printed from the ground up. It became apparent that a restriction of 37% in the boot casing was the probable cause of the plugging. An oblong area of the boot casing was removed with a CNC plasma cutter, allowing the tumbling seed to fall against the rotating disc blade and then be carried to the ground (fig. 1). Another change was made to the telescoping seed tube to provide an escape for the seed if plugging does occur in the boot casing. Oblong holes were cut into the seed tubes to allow seed to escape if plugging occurs lower down in the boot. Heavy bristle brushes (fig. 2) provide a door to allow the seed to escape if plugging occurs and keep it flowing under normal use.

Figure 1. Boot casing. Oblong opening, left, permits seed to fall against disc blade

Figure 2. Bristle brushes reduce plugging

The only way to confirm whether this modification solves the plugging of the Roughrider's seed tubes is to use the equipment under weather conditions that provide us with the variable snow conditions. To date the jury is still out because we have not had snow at the location where a modified Roughrider is located.

Publications:

Truax, J. 2010. Development of seeding equipment for establishing diverse native communities. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 167-169. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentation:

Shaw, N.; Cox, R.; Truax, J. et al. 2010. Post-fire Seeding Strategies and Native Plant Materials for the Northern Great Basin. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Consultations:

Provided recommendations for USDA FS Missoula Technology and Development Center efforts to produce a GPS unit for monitoring rangeland seedings.

Assisted with University of Nevada Extension, Elko, Nevada/NRCS Aberdeen Plant Materials Center to install a crested wheatgrass diversification study near Elko, NV.

Assisted the USDA FS Rocky Mountain Research Station and their cooperators to install a seeding study near Mountain Home, ID.

Project Title: Establishment of Native Forbs Following Mechanical Soil Disturbance in Wyoming Big Sagebrush Communities in the Great Basin

Project: Utah Division of Wildlife Resources, Great Basin Research Center, Ephraim, Utah

Principal Investigators and Contact Information:

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Project Description:
Currently, seed mixes used for restoration generally do not include native forbs, mainly due to their high cost. Because these species have not been included in past restoration efforts there is a lack of information about planting and establishing native forbs in wildland settings. As these native forbs become more available on the market, the lower costs will facilitate land manager's ability to include these species in seed mixes used for restoration. This creates a need to determine the best methods of establishing native forbs in wildland settings. The main objective of this study is to evaluate native forb establishment in Wyoming big sagebrush communities using four different mechanical planting methods.

<u>Methods</u>
This study was established on two sites (referred to as North and South) in Tooele County, Utah. Each site has four complete treatment blocks. Two blocks were treated in the fall of 2008 and two were treated in the fall of 2009. Each block includes five randomly placed treatments. The five treatments included an untreated control, broadcast seeding followed by a Lawson aerator, broadcast seeding followed by a Dixie harrow, broadcast seeding followed by an Ely chain, and a rangeland drill seeding using a Truax Rough Rider no-till drill. The seed mix used for the study consisted of only native forbs (table 1).

Table 1. Seed mix used on the project.

Species	Bulk lbs/acre)	PLS lbs/acre	Seeds/ft^2
Munro's globemallow (*Sphaeralcea munroana*)	0.5	0.38	4.32
Blue flax (*Linum lewisii*)	1.0	0.90	6.04
Northern sweetvetch (*Hedysarum boreale*)	1.0	0.77	0.60
Silvery lupine (*Lupinus argenteus*)	1.5	0.55	0.27
Palmer penstemon (*Penstemon palmeri*)	0.5	0.39	4.86
Utah milkvetch (*Astragalus utahensis*)	0.6	0.39	2.03
Arrowleaf balsamroot (*Balsamorhiza sagittata*)	2.0	1.81	2.28
Firecracker penstemon (*Penstemon eatonii*)	0.29	0.23	3.18
Tapertip hawksbeard (*Crepis acuminata*)	0.16	0.10	0.48
Total	**7.55**	**6.02**	**24.04**

Data Collection

Data from the blocks treated in 2008 was collected in June 2009 and data from all of the blocks was collected in June 2010. Five permanently established 100 ft. belts were placed in a stratified random design along a 100 ft transect in each treatment plot. A total of 100 subsamples were collected from along these lines in each plot. Percent cover of all shrubs, grasses, and forbs was collected using a modified Daubenmire cover class method. Density data of all perennial species was also collected. Line intercept cover data was also collected for the shrub species. Data will be collected each year for 3-5 years following treatment. We are in the process of doing the statistical analysis on the 2010 data so only a summary of the results are available at this time.

Results

Density data was converted to germination using the seeding rates. By presenting the data this way we needed to omit Munro's globemallow (*Sphaeralcea munroana*) from the first two charts because it was already abundant on the south site and present on the north site. We were unable to tell if plants came from our seeding or not so this made it difficult to convert the Munro's globemallow density into germination. Germination of the seeded species varied by site and by treatment. On the first set of plots that were treated in 2008, there was a big difference between the two sites (fig. 1). The south site had very few seeds germinate when compared to the north site, as well as very little difference between treatments. On the north site, however, there were some big differences between treatments; the chaining resulted in the best germination and establishment, followed by the harrow and then the aerator. The trend was similar for the second year of growth but with more plants germinating than the year before.

There was not a big difference between the two sites on the plots treated in 2009, however there was a big difference in germination when comparing them to the first growing season of the plots treated in 2008 (fig. 2). After seeing the large difference between years we looked at precipitation for that area and found that during May 2009 precipitation was only 42% of normal whereas during May 2010 precipitation was 177% of normal. We also looked at the Palmer Drought Severity Index and found that the 2009 growing season was considered to be severe to moderate drought where as the 2010 growing season was considered to be normal to slightly wet.

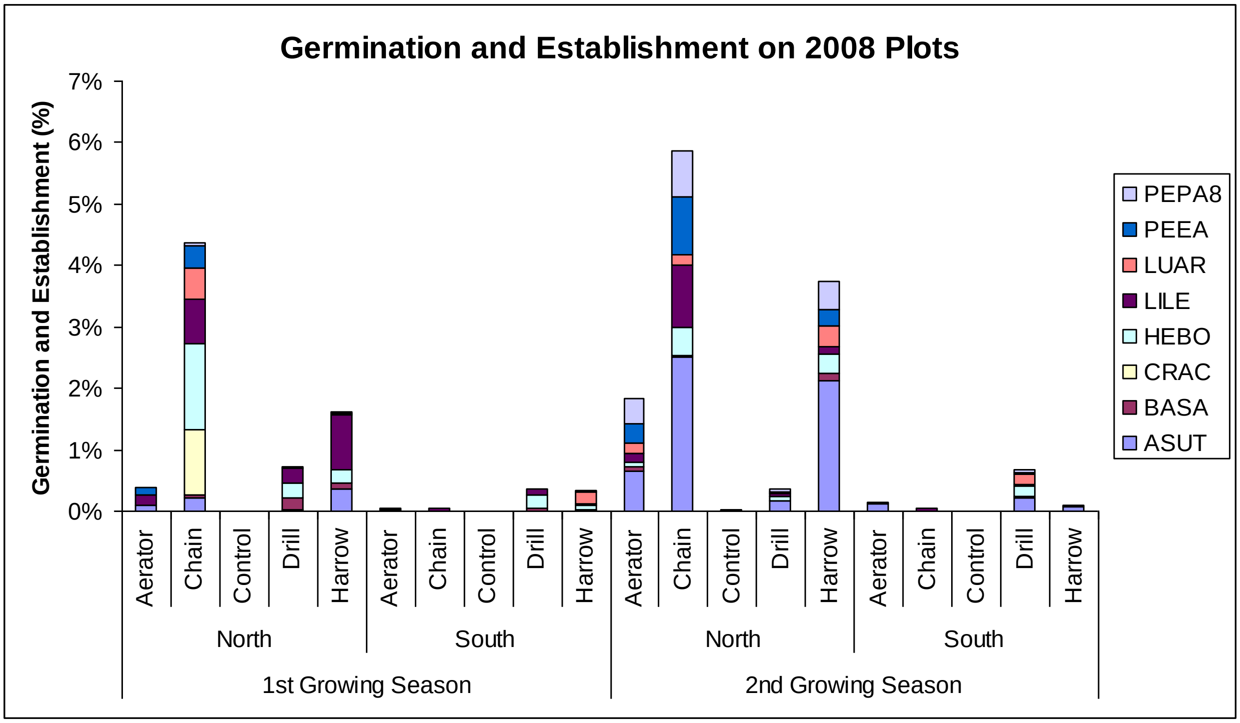

Figure 1. Germination during the first growing season and germination and establishment during the second growing season for all of the seeded species, except Munro's globemallow, separated out by site and treatment.

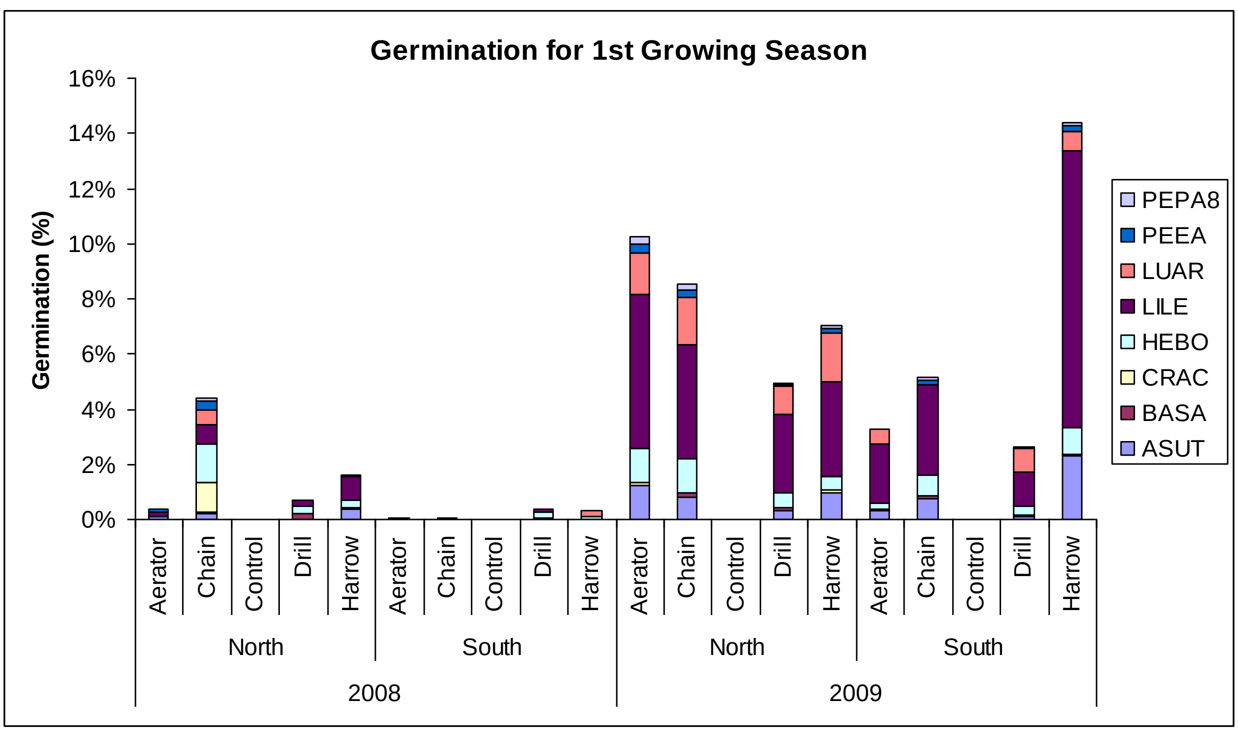

Figure 2. Germination results from the first growing season for all seeded species, except Munro globemallow, separated out by the year it was treated, site, and treatment.

While establishing native forbs into a Wyoming sagebrush community was the main objective of this project it is also important to look at how the mechanical treatments affected other components in the community. Average sagebrush cover on the control plot was 12.6%. After treating with the mechanical treatment, aerator, chain, drill, or harrow, the average cover of sagebrush decreased to 3.8%, 6.8%, 10.1%, and 3.9% respectively. Conversely, the average percent cover of bare ground went from 44.9% on the control plots to 54.9% on the aerator plots, 52.5% on the chained plots, 41.1% on the drill plots, and 58.1% on the harrow plots. The difference in the cover of annual species also varied by site (fig. 3a). The cover of annual species on the control and drill plots on the south site was quite high compared to the north site. This was due to a control plot and a drill plot being almost completely dominated by cheatgrass (*Bromus tectorum*) even before the treatment. By excluding the data from the block that was the outlier we can get a better idea of how the annual species will respond on similar sagebrush sites (fig. 3b). The harrow treatment resulted in the biggest increase in cover for annual species. Plots treated with the chain had the second highest annual species cover. The aerator treatment appears to result in a slight increase and the drill had essentially no effect on annual cover.

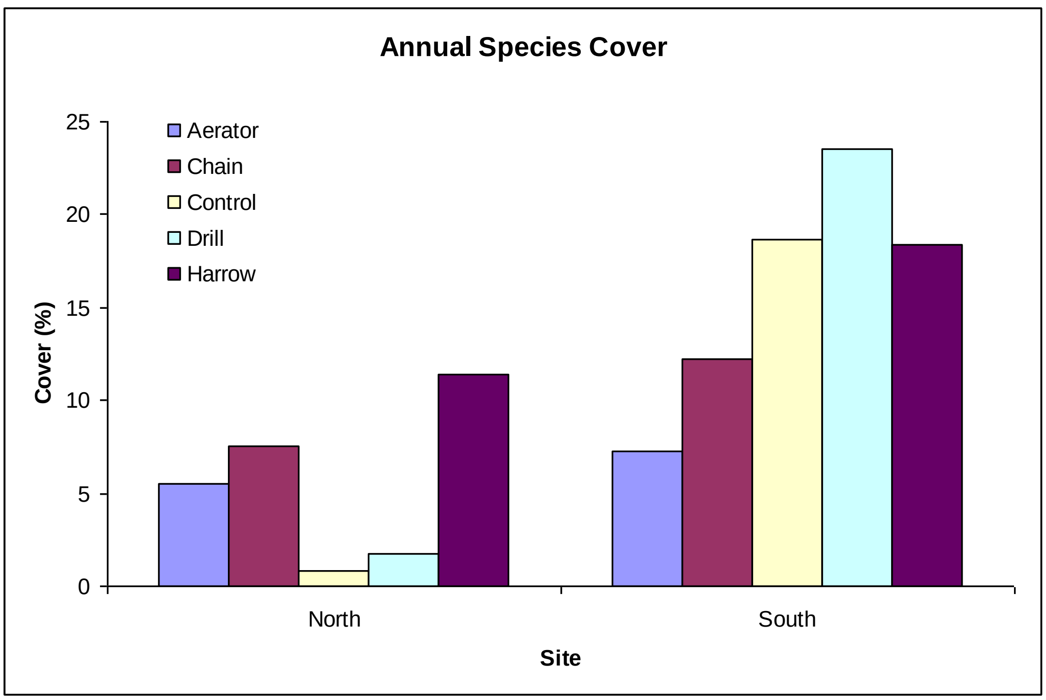

Figure 3a. Cover of all annual species from all plots, separated by site in 2010.

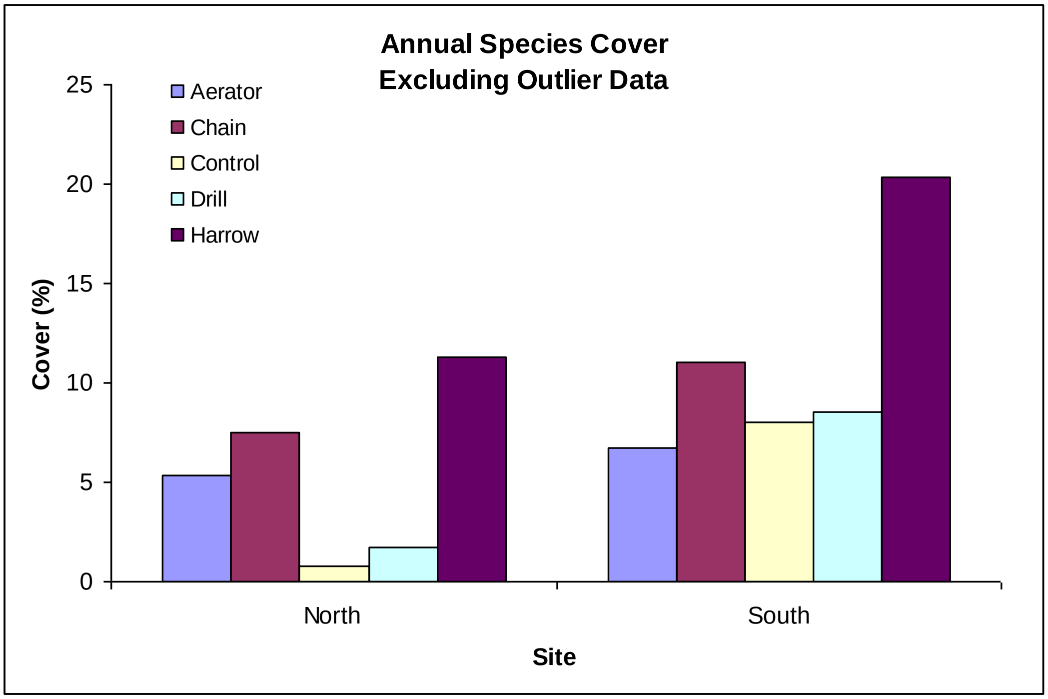

Figure 3b. Cover of all annual species from all plots, excluding the plots from block 1 on the south site, separated by site in 2010.

Management Applications:
It is still early in the study to make many management recommendations. However, by looking at the trend of the density data for the seeded species, the broadcast treatment followed by the Ely chain appears to be the most successful at establishing native forbs. When selecting a mechanical implement to reseed native forbs into a Wyoming sagebrush community you also have to consider how much of the sagebrush you want to remove. The other management implication that can be drawn from the data at this point is that more disturbance can result in high annual species cover. The mechanical treatment that caused the most disturbance was the Dixie harrow treatment so this may not be the most ideal treatment method if there are a lot of annuals present on the site. From the second year of data collection it is apparent how important precipitation is in establishing native forbs. With above normal precipitation no specific planting method stood out as being better than another. This data can also assist in deciding which species you can expect to be more successful when seeding similar sites. In the first growing season the species that performed the best was blue flax (*Linum lewisii*); however it didn't seem to persist into the second growing season. The other species that were the most successful were Utah sweetvetch (*Hedysarum boreale*), Utah milkvetch (*Astragalus utahensis*), which did even better the second growing season, and silvery lupine (*Lupinus argenteus*). We didn't see either *Penstemon* species until the second growing season but by then they were as abundant as the other top four species. As we continue to collect more data over the next several years the results will provide us with better guidelines for seeding native forbs in Wyoming sagebrush communities.

Publications:

Whittaker, A.; Summer, D. 2010. Establishment of native forbs following mechanical soil disturbance in Wyoming big sagebrush communities in the Great Basin. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 170-172. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Presentations:

Whittaker, A.; Summers, D.; Vernon, J.; Davis, B. 2010. Will it grow? A comparison of wildland planting methods for native forbs. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Whittaker, A.; Summers, D.; Vernon, J.; Davis, B. 2010. Will it grow? A comparison of wildland planting methods for native forbs. 16th Wildland Shrub Symposium, 2010. Logan, UT May 18-20, 2010. (poster)

Products:

This study will provide guidelines for planting native forbs in Wyoming big sagebrush communities. Results will be reported through symposia, workshops and through appropriate publications.

Project Title: Native Plant Selection, Seed Biology, and Seeding Equipment and Technology

Project Location: USDA Forest Service, Rocky Mountain Research Station, Boise, Idaho

Principal Investigators and Contact Information:

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Project Description:

1. Plant Materials

Seed Collection

81 collections were made in 2010, this included seed of 23 species. Collection was completed with the assistance of one Seeds of Success intern.

Distribution of Seed to Growers

Seeds of 11 species were distributed to 7 private sector seed growers, either through the Buy-Back program or for seed increase for commercial sales (table 1).

Seed Distribution

81 collections were distributed to the USDA Agricultural Research Service Western Regional Plant Introduction Station/Seeds of Success Program for addition to the GRIN system (appendix II).

Stock seed of pooled *Lomatium grayi* (0.41kg; Snake River Plain) and *Lomatium dissectum* (3.45kg; Snake River Plain) were provided to the Utah Crop Improvement Association for distribution to interested growers.

79 collections were distributed to cooperators and other users (appendix III).

Table 1. Seed lots distributed to private growers in 2010.

Species	Common name	Ecoregion*	Source type	Kg.	No. of growers
Chaenactis douglasii	Douglas' dustymaiden	NBR	Pooled	1.05	2
Eriogonum umbellatum	Sulphur-flower buckwheat	NBR	Pooled	2.42	2
Eriogonum umbellatum	Sulphur-flower buckwheat	SRP/ IB	Pooled	1.48	1
Eriogonum umbellatum	Sulphur-flower buckwheat	NGB	Pooled	2.27	2
Lomatium dissectum	Fernleaf biscuitroot	SRP	Pooled	0.81	1
Lomatium grayi	Gray's biscuitroot	SRP	Pooled	0.98	1
Lomatium nudicaule	Barestem biscuitroot	NBR	Pooled	1.06	1
Lomatium triternatum	Nineleaf biscuitroot	NBR	Pooled	1.00	1
Machaeranthera canescens	Hoary tansyaster	NGB	Pooled	0.32	2
Penstemon acuminatus	Sharpleaf penstemon	SRP	Pooled	2.91	4
Penstemon cyaneus	Blue penstemon	SRP	Single	7.46	3
Penstemon speciosus	Royal penstemon	NBR	Pooled	1.21	1
Penstemon speciosus	Royal penstemon	SRP	Pooled	0.54	1
Sphaeralcea munroana	Munro's globemallow	NBR	Pooled	0.60	2
Sphaeralcea munroana	Munro's globemallow	SRP	Single	0.08	1

* **IB** = Idaho Batholith, **NBR** = Northern Basin & Range, **NGB** = Northern Great Basin, **SRP** = Snake River Plain

2. Reestablishing Diverse Native Wyoming Big Sagebrush Communities: A comparison of seeding equipment and techniques.

Collaborators: Robet Cox, Texas Tech University, Lubbock, TX; Nancy Shaw, USDA FS Rocky Mountain Research Station, Boise, ID; Loren St. John, USDA NRCS Aberdeen Plant Materials Center, Aberdeen, ID: Dan Ogle, USDA NRCS Idaho State Office, Boise, ID; Mike Pellant, USDI BLM, Boise, ID; Tom Warren, USDI BLM, Elko, NV.

<u>Objectives and Methods</u>
The study was conducted to evaluate the capabilities of the Kemmerer Rangeland drill and the Truax RoughRider Minimum-till drill to plant seeds of diverse sizes and shapes at appropriate depths to reestablish grasses, forbs and shrubs on Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) sites following wildfire. Seedings were conducted in 2006 on recent burns (E. Humboldt and Gopher) near Elko, NV and evaluated in 2007 and 2008. Methods, study sites, and seeding mixes were described in the 2009 report (Shaw et al. 2010).

<u>Results and Conclusions</u>
Results differed at the two study sites. Drill seedings at both locations were successful in 2007, with seeded plots supporting higher densities of drill seeded species than unseeded plots at both

locations (fig. 1). Density of drill seeded species was greater at E. Humboldt than at Gopher where greater quantities of cheatgrass (*Bromus tectorum*) seed remained on the soil surface following the wildfire, and generally did not vary among seeded treatments at either site. By 2008 density of drill seeded species was greater on seeded compared to unseeded plots at E. Humboldt, but not at Gopher where cheatgrass and recovering squirreltail (*Elymus elymoides*) density were greater than at E. Humboldt (data not shown).

Density of broadcast (small seeded) species was greater for minimum-till than rangeland drill treatments in 2007 and did not differ between the two sites (fig. 2). By 2008 this difference was lost, and density of broadcast-seeded species across all treatments was greater at Gopher than at E. Humboldt. Seedling loss between the first and second growing seasons are common, but may have been exacerbated by lower than normal precipitation in 2007 and 2008 (fig. 3).

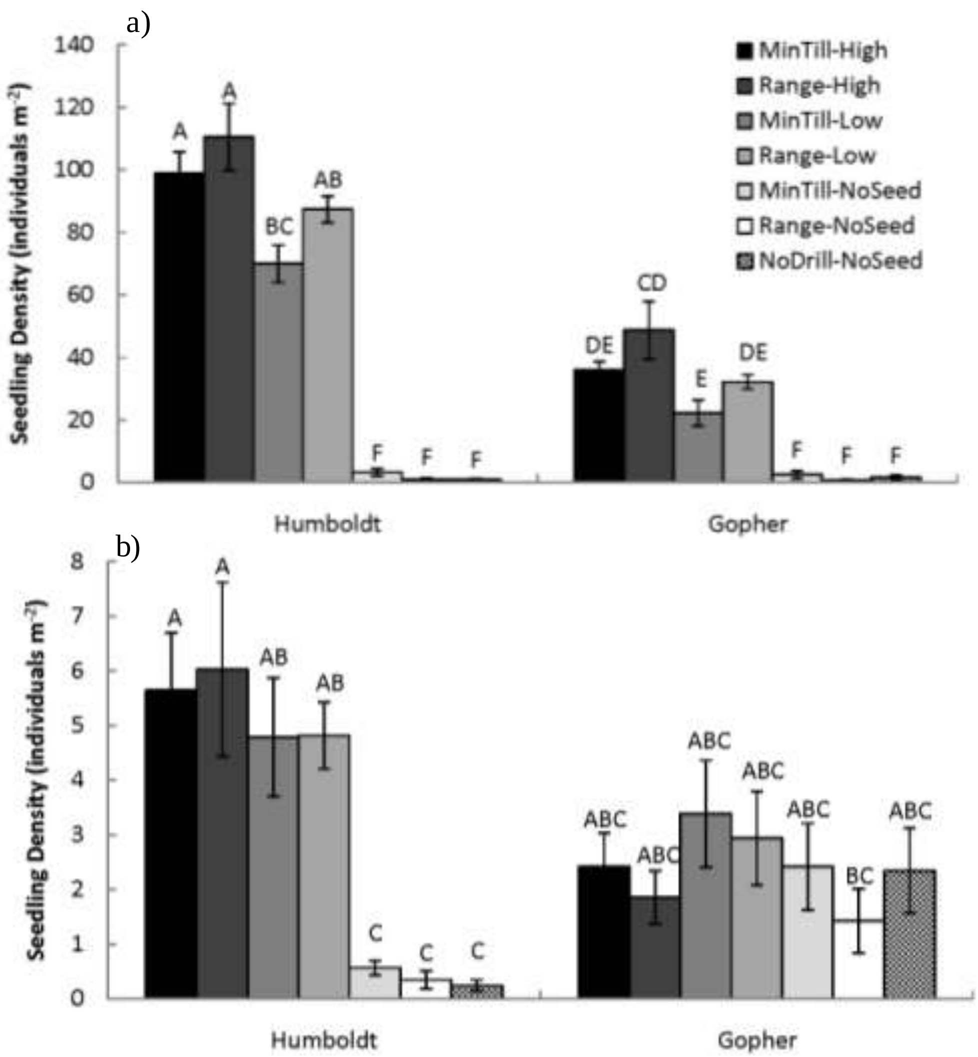

Figure 1. Total density of drill seeded species at E. Humboldt and Gopher in 2007 and 2008.

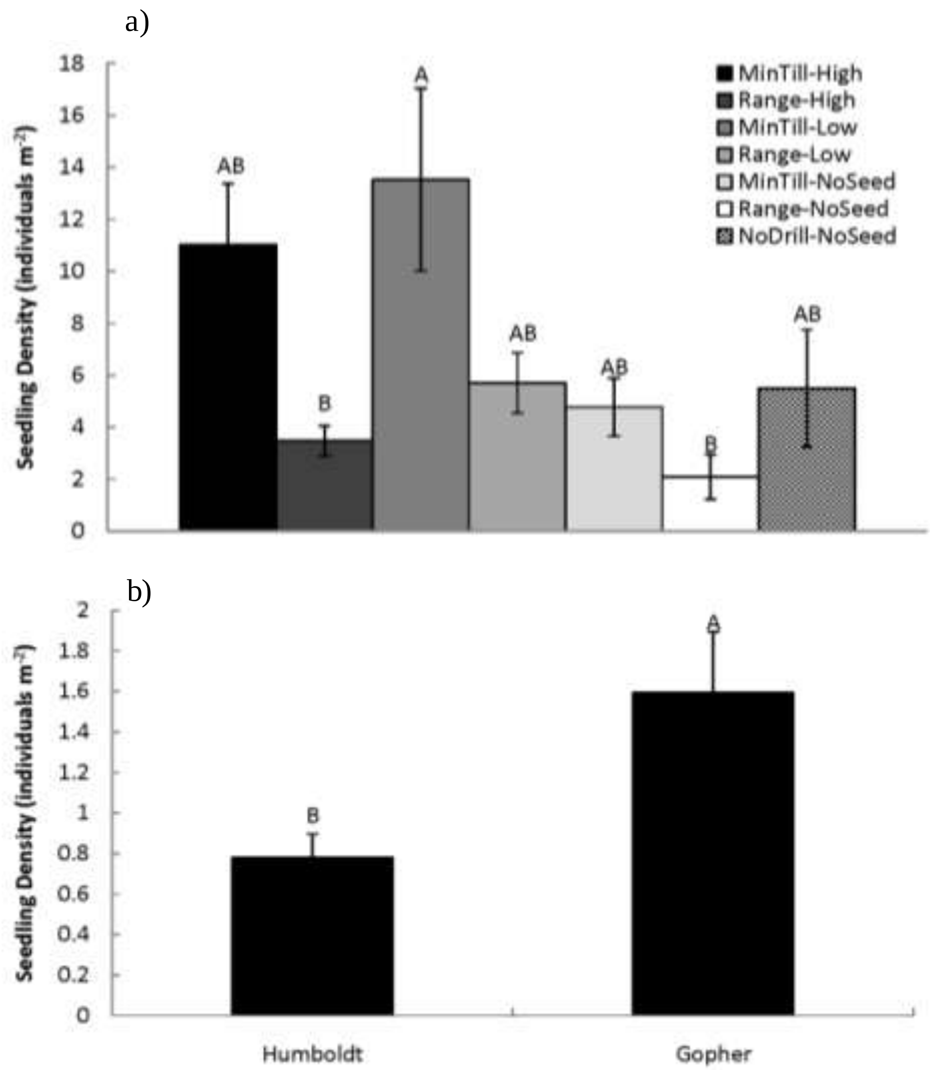

Figure 2. Broadcast (small seeded) species density in 2007 and 2008 at E. Humboldt and Gopher.

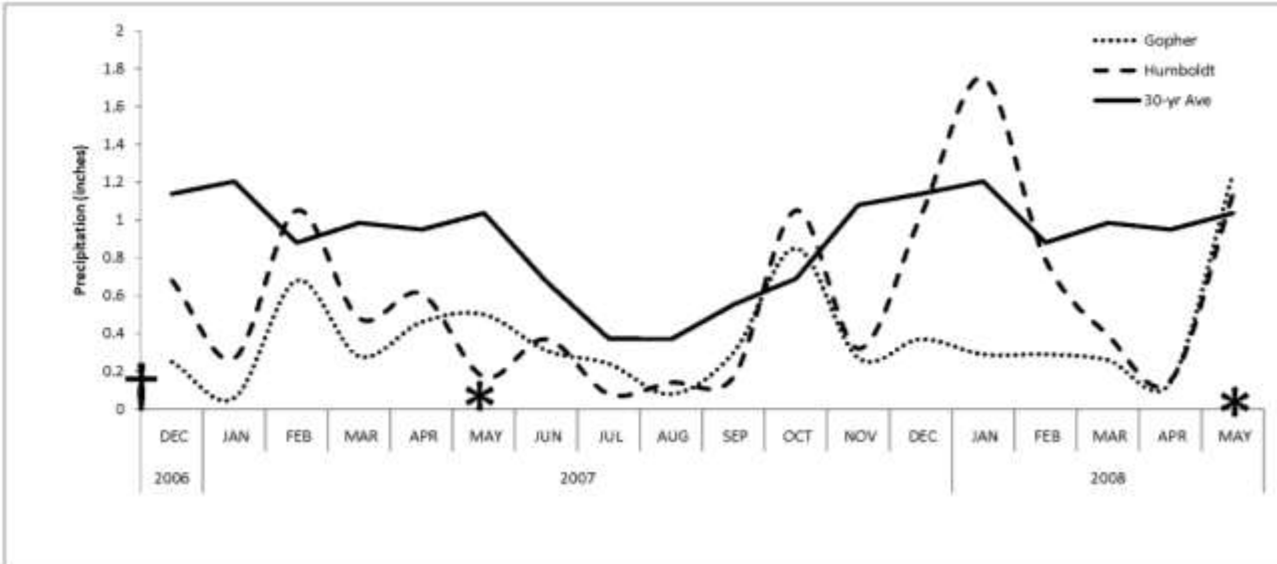

Figure 3. December 2006-May 2008 precipitation at E. Humboldt and Gopher and 30-year average.

Management Applications:
Establishment of seedings on semi-arid rangelands is dependent upon favorable precipitation and temperature conditions during germination and establishment, and failures are common. Weather conditions cannot be predicted in the Interior West. Factors that can be controlled include season of planting, selection or creation of seedbeds with minimal weed competition, and use of genetically appropriate seed sources. Seeding strategies that provide appropriate seedbed conditions for small-seeded species are lacking. This study indicates that use of the minimum-till drill fitted with impacter units to cover small-seeded species may improve their initial emergence.

3. Equipment and strategies to enhance the post-wildfire establishment and persistence of Great Basin native plants (Funding provided by the Joint Fire Science Program and GBNPSIP)

Collaborators: Nancy Shaw, USDA FS Rocky Mountain Research Station, Boise, ID; Robert Cox, Texas Tech University, Lubbock, TX; Loren St. John, USDA NRCS Aberdeen Plant Materials Center, Aberdeen, ID: Dan Ogle, USDA NRCS Idaho State Office, Boise, ID; Mike Pellant, USDI BLM, Boise, ID; Beth Newingham, University of Idaho, Moscow, ID; Amy Ganguli, North Dakota State University, Fargo, ND.

This study examines approaches for reestablishing Wyoming big sagebrush communities following wildfire. It compares the ability of the standard rangeland drill and the minimum-till drill to plant grass, forb, and shrub seeds at different rates and depths. Methods for planting small seeded species are compared and seeding rates for Wyoming big sagebrush examined.

The study was previously established on recently burned Wyoming big sagebrush sites at three locations: Mt. Home, Idaho (2006), Glass Butte, Oregon (2006), and Scooby, Utah (2008). A fourth and final replication was planted near the Mountain Home Air Force Base, Saylor Creek

Training Range in fall 2010. There are 13 treatments (table 1) with 5 replications. Experimental plots are approximately 0.2 ha in size (70 m x 30 m) and fenced to exclude grazing for a minimum of 5 years.

Unfenced plots are established at each site to evaluate long-term impacts of grazing on native seedings. These include 3 treatments (Control, minimum-till 5X, and rangeland drill 5X) with 5 replications. Plot size for the grazed plots is about 0.6 ha (70 m x 90 m).

Table 1. Seeding treatments for fenced plots. All plots seeded in November, except winter broadcast, which was made over snow in January.

Drill	Seeding Rate
No drill (control)	No seed
Minimum till	No seed
Minimum till	Standard
Minimum till	5X ARTRW
Minimum till	10X ARTRW
Minimum till	Fall broadcast (5X)
Minimum till	Winter broadcast (5X)
Rangeland drill	No seed
Rangeland drill	Standard
Rangeland drill	5X ARTRW
Rangeland drill	10X ARTRW
Rangeland drill	Fall broadcast (5X)
Rangeland drill	Winter broadcast (5X)

The second season of monitoring was completed at the Scooby site in 2010. This seeding is located in Box Elder Co., Utah (4700 ft elevation; 41° 51'23.28"N, 113° 03'00.66"W; 226mm annual precipitation; soil: Hiko Peak – gravelly loam; ecological site: semidesert gravelly loam, Wyoming big sagebrush). Seeding mixes for this site are provided in table 2. Monitoring included density of seeded species and cheatgrass plus presence of nonseeded species, gap measurements (>20 cm), and cover estimates (line-point intercepts) in 2009 and 2010.

Table 2. Broadcast and drill seed mixes applied at the Scooby site in November 2008.
* Standard, 5X and 10X broadcast seeding mixes vary only in the application rate of Wyoming big sagebrush seed.

Standard broadcast mix		Pounds PLS/acre	PLS seeds/lb	Seeds ft^{-2}	Seeds m^{-2}
Wyoming big sagebrush	*Artemisia tridentata* ssp. *wyomingensis*	0.10	2,109,032	4.84	52.10
Rubber rabbitbrush	*Ericameria nauseosa*	0.50	695,000	7.98	85.84
Western yarrow (Eagle)	*Achillea millefolium*	0.15	2,700,000	9.30	100.04
Sandberg bluegrass (Mt. Home)	*Poa secunda*	0.40	926,000	8.50	91.49
Blue penstemon	*Penstemon cyaneus*	0.09	3,429,810	7.09	76.25
Total broadcast				**37.71**	**405.72**

5X broadcast mix		Pounds PLS/acre	PLS seeds/lb	Seeds ft^{-2}	Seeds m^{-2}
Wyoming big sagebrush	*Artemisia tridentata* ssp. *wyomingensis*	0.45	2,109,032	21.79	234.43
Rubber rabbitbrush	*Ericameria nauseosa*	0.50	695,000	7.98	85.84
Western yarrow (Eagle)	*Achillea millefolium*	0.15	2,700,000	9.30	100.04
Sandberg bluegrass	*Poa secunda*	0.40	926,000	8.50	91.49
Blue penstemon	*Penstemon cyaneus*	0.09	3,429,810	7.09	76.25
Total 5X broadcast				**54.65**	**588.06**

10x broadcast mix		Pounds PLS/acre	PLS seeds/lb	Seeds ft^{-2}	Seeds m^{-2}
Wyoming big sagebrush	*Artemisia tridentata* ssp. *wyomingensis*	0.95	2,109,032	46.00	494.92
Rubber rabbitbrush	*Ericameria nauseosa*	0.50	695,000	7.98	85.84
Eagle yarrow	*Achillea millefolium*	0.15	2,700,000	9.30	100.04
Sandberg bluegrass	*Poa secunda*	0.40	926,000	8.50	91.49
Blue penstemon	*Penstemon cyaneus*	0.09	3,429,810	7.09	76.25
Total 10X broadcast				**78.86**	**848.54**

Drill seeding mix		Pounds PLS/acre	PLS seeds/lb	Seeds ft^{-2}	Seeds m^{-2}
‘Rimrock' Indian ricegrass	*Achnatherum hymenoides*	1.00	205,000	4.71	50.64
Munro globemallow	*Sphaeralcea munroana*	0.50	750,000	8.61	92.63
‘Anatone’ germplasm bluebunch wheatgrass	*Pseudoroegneria spicata*	2.00	135,153	6.21	66.77
‘Toe Jam’ germplasm bottlebrush squirreltail	*Elymus elymoides*	1.00	190,000	4.36	46.93
Sulphur-flower buckwheat	*Eriogonum umbellatum*	0.24	184,153	1.01	10.92
Total drilled				**24.90**	**267.89**

Results and Discussion

Emergence and growth of seeded species were favored by good rainfall in spring 2009 and 2010. Density of seeded forbs and Wyoming big sagebrush following the second growth season are reviewed here.

Drill seeded forbs. Combined density of drill seeded Munro’s globemallow and sulphur-flower buckwheat were similar among all treatments where seeded. However, density of these two species exceeded the controls (no drill/no seed and drill/no seed) only in plots seeded with the minimum till drill (fig. 1).

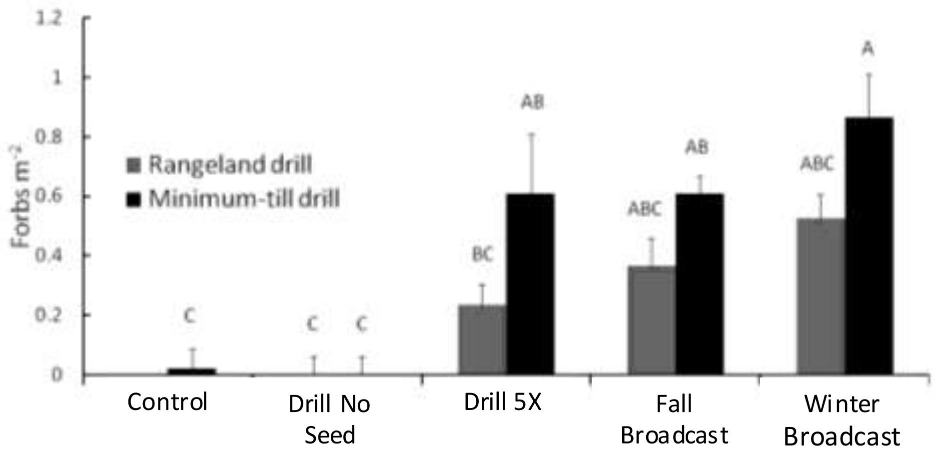

Figure 1. Density of drill seeded forbs (Munro's globemallow and sulphur-flower buckwheat) in 2010, Scooby seeding, northern Utah ($p<0.05$).

<u>Broadcast seeded forbs.</u> When seeded through the minimum till drill in November, combined density of western yarrow and blue penstemon exceeded the density of these species in the control and minimum till drill/no seed treatments, but was similar to the density in the rangeland drill/no seed treatment (fig. 2). Seeding these species through the rangeland drill in November did not increase their density relative to the controls. Hand broadcasting western yarrow and blue penstemon in fall over plots seeded with the minimum-till drill or in winter over plots seeded with the rangeland drill resulted in increased density relative to the three nonseeded treatments. Hand broadcasting in fall over plots seeded with the minimum-till drill was more effective than broadcast seeding over plots seeded with the rangeland drill. Densities of these two forbs in plots hand broadcast in winter over plots seeded with either drill were similar.

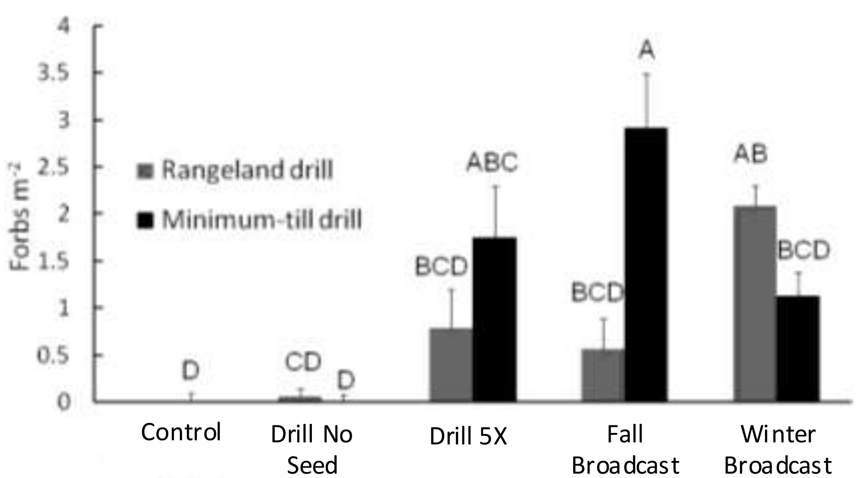

Figure 2. Density of broadcast seeded forbs (western yarrow and blue penstemon) in 2010 by treatment, Scooby seeding, northern Utah ($p<0.05$).

It is possible that the sloughing of the rough surface created during the drilling process with the rangeland drill caused the small seeds to be buried too deeply when broadcast in fall.

Wyoming big sagebrush. Density of Wyoming big sagebrush seedlings was improved only when seeded through the drills at the 10X rate and did not differ between drills at any seeding rate (fig. 3). Densities obtained when seeding through the minimum till drill at the 10X rate exceeded those obtained by all other treatments except the 10X rangeland drill treatment.

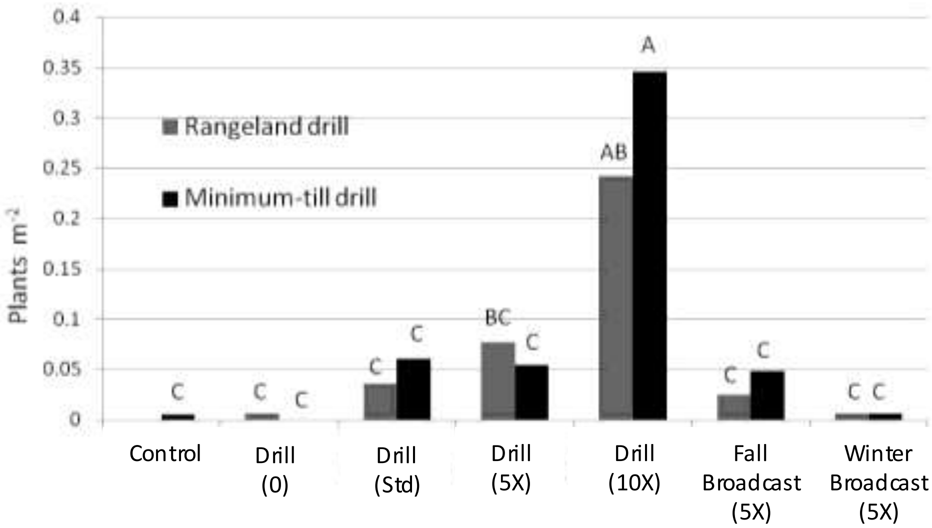

Figure 3. Density of Wyoming big sagebrush in 2010 by treatment, Scooby seeding, northern Utah, ($p<0.05$).

Future direction

Results of the first three seedings (Mt. Home, Glass Butte, and Scooby) are being summarized for a report. Data will be collected at Saylor Creek for two years before publications are written.

Publications:

Cox, R. D.; Shaw, N. L.; Pellant, M. Diverse seed mixes for post-wildfire reseeding: conditional importance of seeding method. Rangeland Ecology and Management. Submitted.

Hardegree, S. P.; Jones, T. A.; Roundy, B. A.; Shaw, N. L.; Monaco, T. A. 2011. Assessment of range planting as a conservation practice. In: D. D. Briske, ed. Conservation benefits of rangeland practices: assessment, recommendations, and knowledge gaps. Lawrence, KS: Allen Press. In press.

Kosberg, L.; Cox, R. D.; Shaw, N.; Hardegree, S. Effect of fungicides on Wyoming Big Sagebrush seed germination. Native Plant Journal. Submitted.

Parkinson, H.; Zabinski, C; Shaw, N. Impact of native and exotic grasses on Great Basin forb seedling growth. Rangeland Ecology and Management. Submitted.

Shaw, N.L; Cox, R.D.; Truax, J. 2010. Native plant selection, seed biology and seeding equipment and technology. Great Basin Native Plant Selection and Increase Project FY2009 Progress Report. p. 150-166.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2009_Progress_Report.pdf

Shaw, N. L.; Youtie, B.; Olwell, P. 2010. Building bridges between agencies, researchers, farmers and non-governmental organizations to create collaborative native seed programs. Proceedings 7th European Conference on Ecological Restoration, Avignon, France, 23-27 August 2010. SER Europe Knowledge Base on Ecological Restoration.

Tishew, S.; Youtie, B.; Kirmer, A.; Shaw, N. In press. Farming for restoration: building bridges for native seeds. Ecological Restoration.

USDA Forest Service, Rocky Mountain Research Station, USDI Bureau of Land Management, Idaho State Office, Utah State University Agricultural Experiment Station, Logan, UT, University of Idaho, Agricultural Experiment Station, Moscow, ID. Notice of release for source identified Eagle Germplasm Western Yarrow (natural population). Submitted.

USDA Forest Service, Rocky Mountain Research Station, USDI Bureau of Land Management, Idaho State Office, Utah State University Agricultural Experiment Station, Logan, UT, University of Idaho, Agricultural Experiment Station, Moscow, ID, United States Air Force, Mountain Home Air Force Base. Notice of release for source identified Mountain Home Germplasm Sandberg Bluegrass (natural population). Submitted.

Presentations:

Shaw, N. 2010. Great Basin Native Plant Selection and Increase Project. National native need conference, 2010 May 17-21, Park City, UT.

Shaw, N; Cox, R; Truax, J; Denney, E; Fisk, M; Williams, N. 2010. Post-fire seeding strategies and native plant materials for the northern Great Basin. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2010 January 26-27; Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2010.shtml

Shaw, N. L.; Jensen, S.; Richardson, B. 2010. A collaborative science-based program to provide native plant materials and restoration technology for the Great Basin. All scientists meeting, 2010 March 23-25, U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Shaw, N.; Youtie, B. 2010. Building bridges between NGO's, researchers and farmers, SER2010 7th European Conference on Ecological Restoration, 2010 August 23-2, Avignon, FR. http://www.fs.fed.us/rm/boise/research/shrub/projects/2010SEREurope.HTML

<u>Exhibit</u>

Great Basin Native Plant Selection and Increase Project:

- Society for Range Management Annual Meeting, 2010 February 7-11, Denver, CO.
- National Native Seed Conference, 2010 May 17-21, Park City, UT.
- Oregon State University Malheur Experiment Station Field Day, July 2010, Ontario, OR.

<u>Meetings and Workshops</u>

Organizer, Great Basin Native Plant Selection and Increase Project Annual Meeting, 2010 January 26-27, Salt Lake City, UT.

Co-organizer, Workshop: Native Grass and Forb Seed Production, 2010 February 23, Ontario, OR. Other organizers were the Eastern Oregon Stewardship Services and Oregon State University Malheur Experiment Station. Attendees included more than 100 representatives of the native seed industry: seed growers, wildland seed collectors, employees of seed regulatory agencies (seed certification, seed testing laboratories and foundation seed organizations), and university and agency researchers from seven western states. The program focused on plant materials being developed for native seedings in the Great Basin, genecology and seed zone development, and cultural practices for producing native grasses and forbs in seed fields.

Co-organizer, Special session: Seed zones, climate, and propagation of native plants for ecological restoration. Fourth World Conference on Ecological Restoration, 2011 August 21-25, Merida, Yucatan.

<u>Equipment</u>
Calibrating your rangeland drill (DVD). Prepared by Missoula Technology and Development Center (MTDC) in response to a proposal (2400 9E92E89 Drill calibration video training) submitted by N. Shaw, Mike Pellant, and Vicky Erickson. (see report by Lisa Outka-Perkins, Project Leader, MTDC, this document).

GPS Datalogger for Rangeland Drills. Prepared by Missoula Technology and Development Center in response to a proposal submitted by N. Shaw, Mike Pellant, and Vicky Erickson. (see report by Damien Hoffman, Project Leader, MTDC, this document).

References:
Shaw, N.; Fisk, M.; Williams, N.; Denney, E. 2010. Native plant selection, seed biology and seeding equipment and technology. In: N. Shaw; M. Pellant, eds. Great Basin Native Plant Selection and Increase Project: FY2009 Progress Report. p. 150-166.

Appendix I.

Utah Crop Improvement Association

4855 Old Main Hill
Logan, Utah 84322-4855

Email ucia@mendel.usu.edu
Website www.utahcrop.org

Phone (435) 797-2082
Fax (435) 797-0642

Stock Seed Production Contract

This agreement is entered into by and between the **Utah Crop Improvement Association** located in Logan, Utah hereinafter referred to as UCIA and **(fill in name)** hereinafter referred to as Seed Grower. This agreement entered into on (date). This contract shall be in force for period of (00) years. Commencing (date), and ending (date).

SEED GROWER: EMAIL

ADDRESS CONTRACT NUMBER: UCIA 0001

CITY/STATE PHONE

STOCK SEED DETAILS:

Species	
Common Name	
Variety Name/Germplasm ID	
Certification Class or PVG Category and Generation	
Stock Seed Lot # and Quantity (lb)	

Note: As a prerequisite for accepting the stock seed listed above the seed grower acknowledges the following terms, conditions, and agreements for seed production and buy-back by UCIA for distribution as stock seed for the purpose of additional seed field production. **Specific alterations or options as noted in the following Terms and Agreements may be listed in the Addendum section and duly initialed by both parties.**

TERMS AND AGREEMENTS:

UCIA agrees to:

1. Provide stock seed or other propagative materials for planting of seed field. Sale price of stock seed will be determined by UCIA with input from the entity providing the seed, and may in some cases be provided free of charge.
2. Purchase ___________lb PLS of seed produced by the Seed Grower at $________ /lb PLS. If the total amount of seed produced in the first harvest is less than that specified in this contract, the seed grower shall provide at least 50% of the seed produced from each year's production until the amount specified is met. To account for price differences from year to year the price may be renegotiated. The renegotiated price must be within 25% of the UCIA Standardized Market Price (SMP*).
3. Allow the Seed Grower the first option to purchase up to ___% of the seed sold to UCIA so long as it shall be used to expand the Seed Grower's seed fields or for seed production elsewhere. Such seed may not be downgraded and/or sold commercially.
4. Pay for shipping and seed analysis costs. If the seed is not conditioned when purchased by the

UCIA the Seed Grower may be charged for conditioning costs.

5. Negotiate on a case by case basis the payment of establishment costs for species that require more than one year after seedling establishment for plants to produce seed, or require special processes for establishment (e.g., greenhouse seedling production and/or transplanting). The establishment advance shall be deducted from the purchase price when seed is sold to the UCIA unless other arrangements are specifically negotiated.

The **SEED GROWER** agrees to

1. Plant the seed provided within one year of delivery, or return it to UCIA. Late summer planting is preferred but seed may be dormant seeded or spring planted (or other specified planting method) if mutually agreed by UCIA and Seed Grower.
2. Plant the seed at the recommended, appropriate rate for seed production, unless it is mutually agreed that the suggested seeding rate is not reasonable, needed or possible.
3. Ensure that the field is entered into certification through the applicable official Seed Certification Agency and pay all associated fees (e.g., seedling inspections, crop inspection, seed sampling, testing, and tagging).
4. Make a reasonable effort to ensure that the seed crop meets certification standards and requirements, such as (but not limited to) planting in rows, controlling weeds and volunteer crops, roguing off types, maintaining proper isolation distances, avoiding contamination during harvest and conditioning, etc.
5. Provide the UCIA, upon request, any and all applicable seedling or other field inspection reports, conditioning reports, seed sample analysis reports, etc. completed during the certification and conditioning process.
6. Be timely in irrigation, weed control, harvesting, and all other agronomic practices required for seed production within the Seed Growers control.
7. Accept the risk associated with seed production, including the additional risk associated with growing forb, shrub or grass species for which agronomic practices may not be fully defined.
8. Contact UCIA regarding seed availability for UCIA purchase under this contract before seed is otherwise offered for sale or otherwise utilized.
9. Make all reasonable efforts to preserve the lowest numeric generation possible while producing the seed. If the generation of seed produced cannot be maintained at the next sequential level of the original stock seed due to volunteers, loss of stand, or isolation requirements, the seed grower shall inform the UCIA. If one or more generations are lost due to these conditions the above purchase price may be renegotiated.
10. Notify UCIA of any intentions to remove field from production before such action is taken, in order to allow for reasonable renegotiation of contract; it is anticipated that the stand life of any perennial species seed field will be for at least the number of years specified in the contract.

It is **MUTUALLY AGREED** that:

1. UCIA may purchase additional seed as needed and available. Amount and purchase price of additional seed may be renegotiated, but must be within 25% of the UCIA SMP.
2. Seed produced in excess of the contracted purchase amount may be sold commercially as the eligible or downgraded class or generation of certified seed.
3. Seed quality standards for individual species including purity, viability, weed seed, and diseased seed may be mutually defined by the two parties before signing of this contract. Seed not meeting such standards may be purchased at the discretion of the UCIA.
4. Failure to abide by the terms of this contract can disqualify the grower from receiving consideration for additional seed lots.

Performance:
The Seed Grower, without consent of the UCIA, may not assign performance of this contract. This contract is binding upon heirs, successors, and administrators or assignees as the original parties are now bound.

Crop Failure:
In the event there is a crop failure the Seed Grower waives compensation for his services and use of the land. Neither Seed Grower nor UCIA will be liable for failure to perform the contract if crop failure is due to acts of God, inclement weather, fires, or other causes beyond reasonable control.

Payment:
Payment for seed grown by the Seed Grower shall be made upon completion of final seed conditioning, testing, and delivery. Payment shall be made within 30 days after delivery of seed to UCIA. Negotiated establishment costs (item UCIA 5. above) will be paid within 30 days of the determination of stand establishment.

***SMP** is updated yearly (5 year average) by UCIA with a survey of estimated prices obtained from seed growers, conditioners, dealers, and buyers that provide a representative estimate of current end use seed prices, as well as consideration of NRCS-PMC stock seed prices.

Signatures:

________________________________ (Seed Grower) __________ Date

________________________________ (UCIA) __________ Date

ADDENDUMS:____
____
____
____
____
____

Initialed by Seed Grower _______ Date ________ UCIA ______Date ________

Appendix II. Germplasm conservation samples contributed to the Seeds of Success Program/ARS Western Regional Plant Introduction Station in 2010 by USDA FS Rocky Mountain Research Station, Boise, ID.

Symbol	Scientific Name	Common Name	Ecoregion	Ecoregion Name	County	State
ACHY 14	*Achnatherum hymenoides*	Indian ricegrass	80f	Owyhee Uplands and Canyons	Malheur	OR
ACHY 40	*Achnatherum hymenoides*	Indian ricegrass	80f	Owyhee Uplands and Canyons	Malheur	OR
ACHY 41	*Achnatherum hymenoides*	Indian ricegrass	12j	Unwooded Alkaline foothills	Owyhee	ID
ACHY 42	*Achnatherum hymenoides*	Indian ricegrass	13b	Shadscale-Dominated Saline Basins	Box Elder	UT
ACMI 01	*Achillea millefolium*	common yarrow	12j	Unwooded Alkaline foothills	Ada	ID
ACMI 04	*Achillea millefolium*	common yarrow	13m	Upper Humbolt Plains	Elko	NV
ACMI 05	*Achillea millefolium*	common yarrow	13n	Mid Elevation Ruby Mountains	Elko	NV
ACMI 07	*Achillea millefolium*	common yarrow	16f	Foothill Shrublands-Grasslands	Boise	ID
ACTH 01	*Achnatherum thurberianum*	Thurber's needlegrass	12h	Mountain Home Uplands	Ada	ID
ACTH 29	*Achnatherum thurberianum*	Thurber's needlegrass	80f	Owyhee Uplands and Canyons	Gem	ID
AGGL 28	*Agoseris glauca*	pale agoseris	80g	High Lava Plains	Harney	OR
AGHE 01	*Agoseris heterophylla*	annual agoseris	16f	Foothill Shrublands-Grasslands	Boise	ID
ARPU 01	*Aristida purpurea*	purple threeawn	16f	Foothill Shrublands-Grasslands	Boise	ID
ARPU 02	*Aristida purpurea*	purple threeawn	12h	Mountain Home Uplands	Ada	ID
ARPU 03	*Aristida purpurea*	purple threeawn	12j	Unwooded Alkaline foothills	Ada	ID
ARTRV 01	*Artemisia tridentata* ssp. *vaseyana*	mountain big sagebrush	16k	Southern Forested Mountains	Boise	ID
ARTRV 02	*Artemisia tridentata* ssp. *vaseyana*	mountain big sagebrush	16f	Foothill Shrublands-Grasslands	Ada	ID
ARTRW 01	*Artemisia tridentata* ssp. *wyomingensis*	Wyoming big sagebrush	12h	Mountain Home Uplands	Ada	ID
ASER 03	*Astragalus eremiticus*	hermit milkvetch	12h	Mountain Home Uplands	Ada	ID
ASER 01	*Astragalus eremiticus*	hermit milkvetch	16f	Foothill Shrublands-Grasslands	Ada	ID
BAHO 04	*Balsamorhiza hookeri*	Hooker's balsamroot	12h	Mountain Home Uplands	Ada	ID
BAHO 08	*Balsamorhiza hookeri*	Hooker's balsamroot	12h	Mountain Home Uplands	Ada	ID
BAHO 19	*Balsamorhiza hookeri*	Hooker's balsamroot	12c	Camas Prairie	Camas	ID

Symbol	Scientific Name	Common Name	Ecoregion	Ecoregion Name	County	State
CHDO 12	*Chaenactis douglasii*	Douglas' dustymaiden	11i	Continental Zones Foothills	Malheur	OR
CRAC 104	*Crepis acuminata*	tapertip hawksbeard	80a	Dissected High Lava Plateau	Malheur	OR
CROC 07	*Crepis occidentalis*	largeflower hawksbeard	12j	Unwooded Alkaline foothills	Gem	ID
DAOR 03	*Dalea ornata*	Blue Mountain prairie clover	12j	Unwooded Alkaline foothills	Malheur	OR
DAOR 05	*Dalea ornata*	Blue Mountain prairie clover	80f	Owyhee Uplands and Canyons	Malheur	OR
DEAN 01	*Delphinium andersonii*	Anderson's larkspur	13b	Shadscale- Dominated Saline Basins	Box Elder	UT
ERHE 06	*Eriogonum heracleoides*	parsnipflower buckwheat	16k	Southern Forested Mountains	Boise	ID
ERHE 10	*Eriogonum heracleoides*	parsnipflower buckwheat	16k	Southern Forested Mountains	Boise	ID
ERHE 14	*Eriogonum heracleoides*	parsnipflower buckwheat	19f	Semiarid Foothills	Cache	UT
ERHE 16	*Eriogonum heracleoides*	parsnipflower buckwheat	80f	Owyhee Uplands and Canyons	Owyhee	ID
ERHE 17	*Eriogonum heracleoides*	parsnipflower buckwheat	80f	Owyhee Uplands and Canyons	Harney	OR
ERHE 19	*Eriogonum heracleoides*	parsnipflower buckwheat	12f	Semiarid Foothills	Adams	ID
ERHE 20-09	*Eriogonum heracleoides*	parsnipflower buckwheat	12f	Semiarid Foothills	Elmore	ID
ERHE 20-10	*Eriogonum heracleoides*	parsnipflower buckwheat	12f	Semiarid Foothills	Elmore	ID
ERLA 01	*Eriophyllum lanatum*	common woolly sunflower	80f	Owyhee Uplands and Canyons	Malheur	OR
ERLA 02	*Eriophyllum lanatum*	common woolly sunflower	80f	Owyhee Uplands and Canyons	Malheur	OR
ERLA 03	*Eriophyllum lanatum*	common woolly sunflower	80f	Owyhee Uplands and Canyons	Malheur	OR
EROV 70	*Eriogonum ovalifolium*	cushion buckwheat	12j	Unwooded Alkaline foothills	Owyhee	ID
ERPU 03	*Erigeron pumilus*	shaggy fleabane	13r	Central Nevada High Valleys	Eureka	NV
ERUM 62	*Eriogonum umbellatum*	sulphur-flower buckwheat	12f	Semiarid Foothills	Adams	ID
ERUM 65	*Eriogonum umbellatum*	sulphur-flower buckwheat	80d	Pluvial Lake Basins	Deschutes	OR
HECO 01	*Hesperostipa comata*	needle and thread grass	80f	Owyhee Uplands and Canyons	Malheur	OR
HECO 02	*Hesperostipa comata*	needle and thread grass	80f	Owyhee Uplands and Canyons	Malheur	OR
MACA 08	*Machaeranthera canescens*	hoary tansyaster	12a	Treasure Valley	Malheur	OR
OECA 01	*Oenothera caespitosa*	tufted evening primrose	12j	Unwooded Alkaline foothills	Malheur	OR
PEAC 11	*Penstemon acuminatus*	sharpleaf penstemon	12j	Unwooded Alkaline foothills	Malheur	OR
PEAC 13	*Penstemon acuminatus*	sharpleaf penstemon	80l	Salt Shrub Valley	Harney	OR
PEAC 14	*Penstemon acuminatus*	sharpleaf penstemon	12h	Mountain Home Uplands	Elmore	ID
PEAC 35	*Penstemon acuminatus*	sharpleaf penstemon	16k	Southern Forested Mountains	Owyhee	ID

Symbol	Scientific Name	Common Name	Ecoregion	Ecoregion Name	County	State
PEAC 36	*Pestemon acuminatus*	sharpleaf penstemon	12a	Treasure Valley	Malheur	OR
PEAC 38	*Pestemon acuminatus*	sharpleaf penstemon	80f	Owyhee Uplands and Canyons	Malheur	OR
PEAC 45	*Penstemon acuminatus*	sharpleaf penstemon	12j	Unwooded Alkaline foothills	Owyhee	ID
PEAC 56	*Pestemon acuminatus*	sharpleaf penstemon	12j	Unwooded Alkaline foothills	Owyhee	ID
PEAC 08	*Penstemon acuminatus*	sharpleaf penstemon	12h	Mountain Home Uplands	Elmore	ID
PECY 01	*Penstemon cyaneus*	blue penstemon	12b	Lava Fields	Lincoln	ID
PEDE 02	*Penstemon deustus*	hotrock penstemon	16f	Foothill Shrublands-Grasslands	Boise	ID
PEDE 05-09	*Penstemon deustus*	hotrock penstemon	12f	Semiarid Foothills	Adams	ID
PEDE 05-10	*Penstemon deustus*	hotrock penstemon	12f	Semiarid Foothills	Adams	ID
PEDE 09-09	*Penstemon deustus*	hotrock penstemon	16k	Southern Forested Mountains	Boise	ID
PEDE 09-10	*Penstemon deustus*	hotrock penstemon	16k	Southern Forested Mountains	Boise	ID
PEDE 29	*Penstemon deustus*	hotrock penstemon	16f	Foothill Shrublands-Grasslands	Boise	ID
PEDE 35-09	*Penstemon deustus*	hotrock penstemon	11i	Continental Zone Foothills	Baker	OR
PEDE 35-10	*Penstemon deustus*	hotrock penstemon	11i	Continental Zone Foothills	Baker	OR
PEDE 48	*Penstemon deustus*	hotrock penstemon	80j	Semiarid Foothills	Harney	OR
PHHA 01	*Phacelia hastata*	silverleaf phacelia	80f	Owyhee Uplands and Canyons	Malheur	OR
PHHA 02	*Phacelia hastata*	silverleaf phacelia	80f	Owyhee Uplands and Canyons	Malheur	OR
PHHA 05	*Phacelia hastata*	silverleaf phacelia	16k	Southern Forested Mountains	Boise	ID
PHLI 01	*Phacelia linearis*	threadleaf phacelia	80f	Owyhee Uplands and Canyons	Malheur	OR
POSE 01	*Poa secunda*	Sandberg bluegrass	80a	Dissected High Lava Plateau	Owyhee	ID
SPMU 11	*Sphaeralcea munroana*	Munro's globemallow	12j	Unwooded Alkaline foothills	Payette	ID
SPMU 13	*Sphaeralcea munroana*	Munro's globemallow	80f	Owyhee Uplands and Canyons	Malheur	OR
SPMU 14	*Sphaeralcea munroana*	Munro's globemallow	80f	Owyhee Uplands and Canyons	Malheur	OR
SPMU 15	*Sphaeralcea munroana*	Munro's globemallow	80f	Owyhee Uplands and Canyons	Malheur	OR
SPMU 17	*Sphaeralcea munroana*	Munro's globemallow	80g	High Lava Plains	Harney	OR
SPMU 18	*Sphaeralcea munroana*	Munro's globemallow	80a	Dissected High Lava Plateau	Malheur	OR
SPMU 9b	*Sphaeralcea munroana*	Munro's globemallow	12j	Unwooded Alkaline foothills	Payette	ID
TOFL 02	*Townsendia florifer*	showy Townsend daisy	80f	Owyhee Uplands and Canyons	Owyhee	ID
WYAM 01	*Wyethia amplexicaulis*	Mule-ears	16k	Southern Forested Mountains	Boise	ID

Appendix III. Seed lots distributed to cooperators in 2010 by USDA FS Rocky Mountain Research Station, Boise, ID.

Species	Common Name	Seed Origin (county, state)	Affiliation	kg
Achnatherum hymenoides	Rimrock Indian ricegrass	Yellowstone, MT	Agriculture Research Service	0.45
Achnatherum thurberianum	Thurber's needlegrass	Ada, Idaho	OSU Malheur Experiment Station	0.07
Agoseris spp.	agoseris	Owyhee, ID	Agriculture Research Service	0.05
Allium spp.	onion	Elko, NV	Agriculture Research Service	0.05
Artemisia tridentata ssp. *wyomingensis*	Wyoming big sagebrush	Idaho, Oregon, Utah, Nevada	Idaho Department of Fish and Game	271.5
Astragalus lentiginosus	freckled milkvetch	Northern Great Basin	USDA FS Rocky Mountain Research Station	0.4
Astragalus spp.	milkvetch	Northern Great Basin	USDA FS Rocky Mountain Research Station	1.25
Astragalus utahensis	Utah milkvetch	Eureka, NV	USDA FS Rocky Mountain Research Station	0.33
Astragalus utahensis	Utah milkvetch	Lander, NV	USDA FS Rocky Mountain Research Station	0.07
Camassia spp.	camas	Ada, ID	College of Western Idaho	0.11
Chaenactis douglasii	Douglas' dustymaiden	Owyhee, ID	USDA ARS Bee Biology and Systematics Laboratory	0.22
Crepis spp.	hawksbeard	Malheur, OR	Agriculture Research Service	0.12
Dalea ornata	Blue Mountain prairie clover	Malheur, OR	Utah State University	1.53
Dalea ornata	Blue Mountain prairie clover	Malheur, OR	Utah State University	1.26
Dalea ornata	Blue Mountain prairie clover	Malheur, OR	Utah State University	0.71
Dalea ornata	Blue Mountain prairie clover	Malheur, OR	Utah State University	0.39
Elymus elymoides	Emigrant bottlebrush squirreltail	Harney, OR	Agriculture Research Service	0.45
Ericameria nauseosa	rubber rabbitbrush	Utah	Idaho Department of Fish and Game	154.2
Erigeron glabellus	streamside fleabane	Northern Great Basin	College of Western Idaho	0.05
Eriogonum heracleoides	Parsnipflower buckwheat	Cache, UT	OSU Malheur Experiment Station	0.1
Eriogonum spp.	buckwheat	Box Elder, UT	College of Western Idaho	1.18
Eriogonum spp.	buckwheat	Northern Great Basin	Agriculture Research Service	0.3
Eriogonum spp.	buckwheat	Cache, UT	College of Western Idaho	0.23
Eriogonum spp.	buckwheat	Eureka, NV	College of Western Idaho	0.14
Eriogonum vimineum	wickerstem buckwheat	Owyhee, ID	College of Western Idaho	0.03

Species	Common Name	Seed Origin (county, state)	Affiliation	kg
Hesperostipa comata	needle and thread	Millard, UT	Agriculture Research Service	0.45
JFSP seed mixes	N/A	N/A	Idaho Department of Fish and Game	200
JFSP seed mixes	N/A	N/A	Truax Company, Inc.	27.22
Lomatium dissectum	fernleaf biscuitroot	Snake River Plain	Utah Crop Improvement Association	6.1
Lomatium dissectum	Fernleaf biscuitroot	Ada, ID	OSU Malheur Experiment Station	1.8
Lomatium dissectum	Fernleaf biscuitroot	Malheur, OR	OSU Malheur Experiment Station	1.6
Lomatium dissectum	fernleaf biscuitroot	Payette, ID	USDA FS National Seed Lab	0.06
Lomatium grayi	Gray's biscuitroot	Gooding, ID	USDA FS National Seed Lab	1.5
Lomatium grayi	Gray's biscuitroot	Snake River Plain	Utah Crop Improvement Association	0.88
Lomatium spp.	biscuitroot	Utah, UT	Agriculture Research Service	0.4
Lomatium spp.	biscuitroot	Rich, UT	Agriculture Research Service	0.36
Lomatium spp.	biscuitroot	Millard, UT	College of Western Idaho	0.32
Lomatium spp.	biscuitroot	Millard, UT	College of Western Idaho	0.2
Lupine spp.	lupine	Elko, NV	Agriculture Research Service	0.02
Penstemon acuminatus	sharpleaf penstemon	Elmore, ID	OSU Malheur Experiment Station	0.03
Penstemon acuminatus	sharpleaf penstemon	Harney, OR	USDA FS National Seed Lab	0.03
Penstemon acuminatus	sharpleaf penstemon	Malheur, OR	USDA FS National Seed Lab	0.03
Penstemon acuminatus	sharpleaf penstemon	Elmore, ID	USDA FS National Seed Lab	0.03
Penstemon acuminatus	sharpleaf penstemon	Owyhee, ID	USDA FS National Seed Lab	0.03
Penstemon acuminatus	sharpleaf penstemon	Owyhee, ID	USDA FS National Seed Lab	0.03
Penstemon cyaneus	blue penstemon	Lincoln, ID	OSU Malheur Experiment Station	0.2
Penstemon deustus	Scabland penstemon	Boise, ID	USDA FS National Seed Lab	0.15
Penstemon deustus	Scabland penstemon	Boise, ID	USDA FS National Seed Lab	0.15
Penstemon deustus	Scabland penstemon	Elmore, ID	USDA FS National Seed Lab	0.15
Penstemon deustus	Scabland penstemon	Elmore, ID	USDA FS National Seed Lab	0.15
Penstemon deustus	Scabland penstemon	Baker, OR	USDA FS National Seed Lab	0.15
Penstemon deustus	Scabland penstemon	Baker, OR	OSU Malheur Experiment Station	0.01
Penstemon spp.	penstemon	Owyhee, ID	College of Western Idaho	1.9

Species	Common Name	Seed Origin (county, state)	Affiliation	kg
Penstemon spp.	penstemon	Owyhee, ID	Agriculture Research Service	0.83
Penstemon spp.	penstemon	Owyhee, ID	Agriculture Research Service	0.68
Poa secunda	Mountain Home Sandberg bluegrass	Owyhee, ID	Agriculture Research Service	0.45
Poa secunda	Mountain Home Sandberg bluegrass	Owyhee, ID	USDA ARS Western Regional Plant Introduction Station	0.23
Pseudoroegneria spicata	Anatone bluebunch wheatgrass	Asotin, WA	Agriculture Research Service	0.45
Sphaeralcea grossulariifolia	gooseberryleaf globemallow	Owyhee, ID	USDA FS Rocky Mountain Research Station	0.11
Sphaeralcea grossulariifolia	gooseberryleaf globemallow	Owyhee, ID	USDA FS Rocky Mountain Research Station	0.05
Sphaeralcea grossulariifolia	gooseberryleaf globemallow	Box Elder, UT	USDA FS Rocky Mountain Research Station	0.03
Sphaeralcea munroana	Munro's globemallow	Malheur, OR	USDA FS Rocky Mountain Research Station	0.52
Sphaeralcea munroana	Munro's globemallow	Malheur, OR	USDA FS Rocky Mountain Research Station	0.39
Sphaeralcea munroana	Munro's globemallow	Payette, ID	USDA FS Rocky Mountain Research Station	0.2
Sphaeralcea munroana	Munro's globemallow	Harney, OR	USDA FS Rocky Mountain Research Station	0.19
Sphaeralcea munroana	Munro's globemallow	Payette, ID	USDA FS Rocky Mountain Research Station	0.19
Sphaeralcea munroana	Munro's globemallow	Malheur, OR	USDA FS Rocky Mountain Research Station	0.15
Sphaeralcea munroana	Munro's globemallow	Malheur, OR	USDA FS Rocky Mountain Research Station	0.11
Sphaeralcea munroana	Munro's globemallow	Payette, ID	USDA FS Rocky Mountain Research Station	0.11
Sphaeralcea munroana	Munro's globemallow	Malheur, OR	USDA FS Rocky Mountain Research Station	0.1
Sphaeralcea munroana	Munro's globemallow	Malheur, OR	USDA FS Rocky Mountain Research Station	0.07
Sphaeralcea munroana	Munro's globemallow	Payette, ID	USDA FS Rocky Mountain Research Station	0.07
Sphaeralcea munroana	Munro's globemallow	Payette, ID	University of Idaho	0.02
Sphaeralcea munroana	Munro's globemallow	Malheur, OR	University of Idaho	0.02
Sphaeralcea munroana	Munro's globemallow	Malheur, OR	University of Idaho	0.02
Sphaeralcea munroana	Munro's globemallow	Malheur, OR	University of Idaho	0.02
Sphaeralcea munroana	Munro's globemallow	Harney, OR	University of Idaho	0.02
Sphaeralcea munroana	Munro's globemallow	Payette, ID	USDA FS Rocky Mountain Research Station	0.02
Sphaeralcea munroana	Munro's globemallow	Payette, ID	USDA FS Rocky Mountain Research Station	0.01
			Total Seed Distributed (kg)	**684.2**