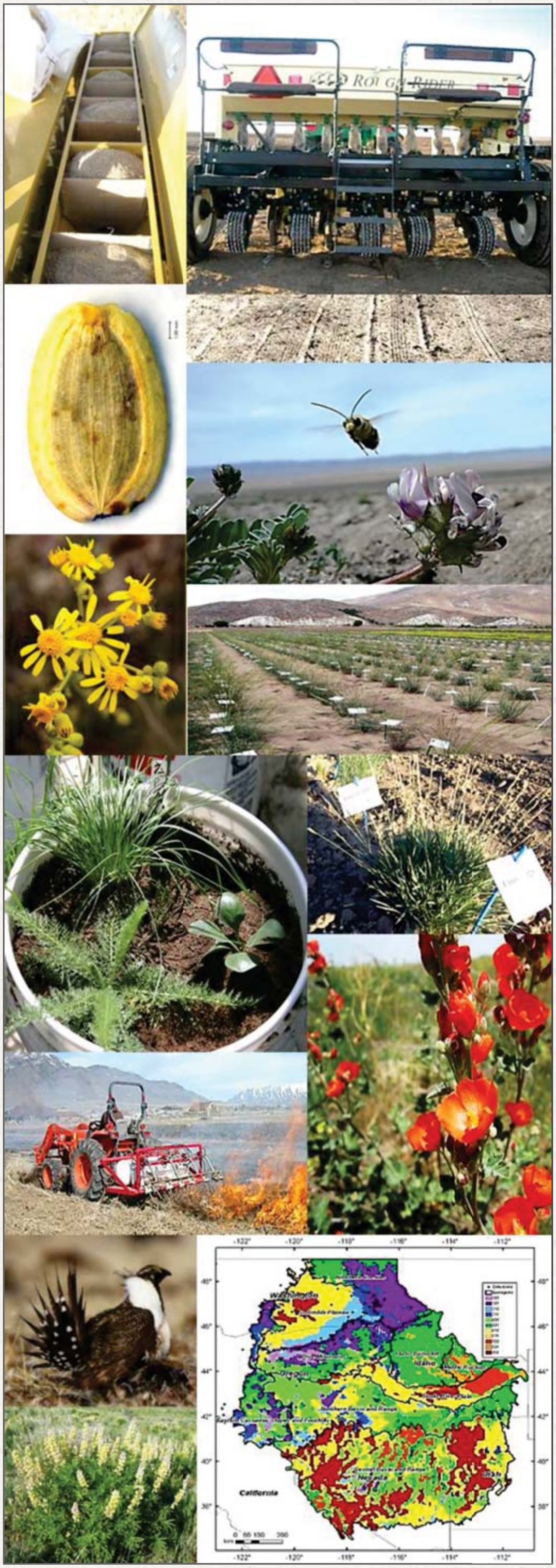


# Great Basin Native Plant Selection & Increase Project

## 2012 Progress Report

**Improving the availability of native plant materials and providing the knowledge and technology required for their use in restoring diverse native plant communities across the Great Basin.**

# Great Basin Native Plant Selection and Increase Project

## 2012 Progress Report

USDA Forest Service, Rocky Mountain Research Station
and USDI Bureau of Land Management, Boise, ID
April 2013

Cooperators

USDA Forest Service, Rocky Mountain Research Station,
Grassland, Shrubland and Desert Ecosystem Research Program, Boise, ID and Provo, UT
USDI Bureau of Land Management, Great Basin Restoration Initiative, Boise, ID
USDI Bureau of Land Management, Plant Conservation Program, Washington, DC
Boise State University, Boise, ID
Brigham Young University, Provo, UT
College of Western Idaho, Nampa, ID
Eastern Oregon Stewardship Services, Prineville, OR
Oregon State University, Malheur Experiment Station, Ontario, OR
Private Seed Industry
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University of Idaho Parma Research and Extension Center, Parma, ID
University of Nevada, Reno, NV
University of Nevada Cooperative Extension, Elko and Reno, NV
University of Wyoming, Laramie, WY
Utah State University, Logan, UT
USDA Agricultural Research Service, Bee Biology and Systematics Laboratory, Logan, UT
USDA Agricultural Research Service, Eastern Oregon Agricultural Research Center, Burns, OR
USDA Agricultural Research Service, Forage and Range Research Laboratory, Logan, UT
USDA Agricultural Research Service, Great Basin Rangelands Research Unit, Reno, NV
USDA Agricultural Research Service, Western Regional Plant Introduction Station, Pullman, WA
USDA Forest Service, National Seed Laboratory, Dry Branch, GA
USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR
USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center, Aberdeen, ID
USDI Bureau of Land Management, Morley Nelson Birds of Prey National Conservation Area, Boise, ID
US Geological Survey, Forest and Rangeland Ecosystem Science Center, Boise, ID and Corvallis, OR
Utah Division of Wildlife Resources, Great Basin Research Center, Ephraim, UT
Utah Crop Improvement Association, Logan, UT

**Great Basin Native Plant Selection and Increase Project**
**2012 Progress Report**

The Interagency Native Plant Materials Development Program outlined in the 2002 USDA and USDI Report to Congress, 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. The Great Basin Native Plant Selection and Increase Project was initiated to provide information that will be useful to managers when making decisions about selecting appropriate plant materials and technologies for restoration. The Program is supported by the USDI Bureau of Land Management's National Native Plant Materials Program and the Great Basin Restoration Initiative and administered by the USDA Rocky Mountain Research Station's Grassland, Shrubland and Desert Ecosystem Research Program.

Research priorities are to 1) provide tools for the selection and development of genetically appropriate plant materials for restoring rangelands impacted by human activities including climate change, 2) develop agricultural practices for seed increase of native forbs and grasses, 3) devise strategies for seeding native forbs and improving the establishment of multi-species native seed mixes, and 4) disseminate science and technology information to advance restoration.

We thank our many collaborators for their dedication and their institutions for their in-kind contributions. The wide array of expertise represented by this group has made it possible to address the many challenges involved in this endeavor. We especially thank Robin Bjork for the many hours she spent carefully editing and compiling this report and Jan Gurr for managing our financial reporting. Special thanks also to our resident students: Erin Denney for her artistic ability and development of outreach materials and Matt Fisk and Alexis Malcomb for managing our seed inventory and database.

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**Great Basin Native Plant Selection and Increase Project**
http://www.fs.fed.us/rm/boise/research/shrub/greatbasin.shtml

**Great Basin Restoration Initiative**
www.blm.gov/id/st/en/prog/gbri.html

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# HIGHLIGHTS FOR 2012

## GENETICS AND SEED ZONES

Genetic diversity and genecology of bluebunch wheatgrass (*Pseudoroegneria spicata*), prairie junegrass (*Koeleria macrantha*), and squirreltail (*Elymus elymoides*)
*Brad St. Clair and Francis Kilkenny*

- Bluebunch wheatgrass (*Pseudoroegneria spicata*) and prairie junegrass (*Koeleria macrantha*) populations differ substantially for traits of growth, reproduction, leaf morphology, and floral phenology.
- Moderate correlations of population means with the climates of seed sources for both bluebunch wheatgrass and prairie junegrass suggest the presence of adaptively significant genetic variation that should be considered when moving populations in restoration projects.
- Geographic genetic variation for both bluebunch wheatgrass and prairie junegrass was mapped based on the relationships between traits and climate, and seed zones have been delineated for bluebunch wheatgrass that guide the choice of adapted populations for revegetation and restoration of grasslands in the interior Pacific Northwest and Great Basin.
- A study on squirreltail (*Elymus elymoides*) has been started, and first-year data have been collected.

Conservation, adaptation and seed zones for key Great Basin species
*Richard C. Johnson, Erin K. Espeland, Matt Horning. Elizabeth A. Leger, Mike Cashman, and Ken Vance-Borland*

- Seed zones for Indian ricegrass (*Achnatherum hymenoides*) have been developed, mapped, and published.
- Sandberg bluegrass (*Poa secunda*) data analysis revealed substantial genetic variation, indicating a good potential for developing seed zones based on genetic and source climate interactions.

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

Molecular genetics of big sagebrush

- Phylogenetic analyses of 24 genes (12,000 base pairs of DNA sequence) suggest diploid *Artemisia tridentata* ssp. *vaseyana* (mountain big sagebrush) and *A. t.* ssp. *tridentata* (basin big sagebrush) are distinct (monophyletic) subspecies.
- *A. t.* ssp. *wyomingensis* (Wyoming big sagebrush) is not a monophyletic subspecies, originating from different diploid lineages of *tridentata* and *vaseyana*.
- *A. t.* ssp. *wyomingensis* is a tetraploid complex with varying affinities to diploid *tridentata* and *vaseyana*.
- Tetraploid lineages are likely formed locally or regionally from nearby populations of diploid *A. t.* ssp. *tridentata* and ssp. *vaseyana*.

Big sagebrush common gardens

- Final growth measurements were completed for three years.
- Flower phenology analyses suggest day length and warm temperatures control flowering date: populations with longer summer days and colder temperature flower earlier than short summer days and warmer temperature.
- Estimates of total seed yield and seed weights are being calculated for the populations in two gardens. This will provide an overall estimate of plant fitness and comparison of seed weights among subspecies.
- The Ephraim, Utah common garden has substantially more mortality than other gardens. Possible factors are discussed.

Selecting sagebrush seed sources for restoration in a variable climate: Ecophysical variation among genotypes

*Matthew J. Germino*

- Physiological performance of different seed sources for big sagebrush (*Artemisia tridentata*) is under evaluation. Comparisons among the many populations (genotypes or provenances) of each subspecies being grown in common gardens will provide results that will fill crucial gaps in the data, enabling the improved development of climatic seed-transfer zones for the restoration of big sagebrush.
- Physiological variability is generally considerably greater among populations than among subspecies.
- At mid-summer, preliminary data suggest big sagebrush growing in an Idaho garden demonstrated adaptations in water use efficiency to local conditions; while populations in two other gardens did not demonstrate these trends in water use efficiency or other measured variables associated with photosynthesis or water status. For tetraploid big sagebrush, such as Wyoming big sagebrush (*A. t. wyomingensis*) grown in an Idaho common garden, carbon isotopes indicate longer-term patterns of water use efficiency are related to climate of origin.
- An experiment has been established to test sagebrush seedling response to climate and weather variability, as a function of their genotype, in post-fire settings.

Evolution of native plants in cheatgrass invaded systems

*Elizabeth A. Leger, Erin M. Goergen, and Erin K. Espeland*

- Native species and populations differ in their ability to tolerate and compete with cheatgrass (*Bromus tectorum*).
- Sandberg bluegrass (*Poa secunda*) was consistently the best suppressor of cheatgrass biomass, and one population of big squirreltail (*Elymus multisetus*) was very good at both tolerating and competing with cheatgrass.
- 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.
- We recommend screening native populations for their ability to both tolerate and compete with cheatgrass, and, in addition to considering adaptation to local climate, select restoration material based on field performance in invaded conditions.

## SEED BIOLOGY AND TECHNOLOGY

Globemallow and big sagebrush performance under varying conditions
*Anthony S. Davis*

Sagebrush

- Overwinter storage of big sagebrush seedlings can be done in a cooler (2 to 4°C); however, further study is needed to determine the optimal hardening regimes and lifting dates for freezer storage (0 to -2°C).
- Two experiments were conducted to evaluate physiological and morphological variation in Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) seedlings grown from accessions obtained from each of five locations within the range of this subspecies.

Globemallow

- Munro's globemallow (*Sphaeralcea munroana)* seeds are physically dormant and possess a water gap responsible for water uptake. Dormancy is best relieved by mechanical (93%) or boiling water (49%) scarification.
- Gibberellic acid application, stratification, or the combination of stratification and scarification failed to enhance germination compared with scarification alone, indicating an absence of additional dormancy types.
- This perennial, cool-season forb shows considerable potential for restoration use on arid sites, but it may not be the best candidate for early competition with cool season grasses during its establishment phase.
- Early growth is hindered by cool temperatures; thus, a later sowing date may improve establishment in nurseries, seed production areas, and restoration sites.

Development of protocols for germination, seed weight, purity, and seed conditioning/cleaning for Great Basin grasses and forbs: banking Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) seed
*Robert Karrfalt and Victor Vankus*

- A Wyoming big sagebrush seed storage protocol was developed that prevents loss of germination for at least 5 years. In conventional storage seeds are mostly dead after 12 to 24 months. Seeds can now be held in storage until needed for post-fire rehabilitation and restoration.
- Using the principles of equilibrium relative humidity, and measuring it using inexpensive electronic hygrometers, seed moisture can be managed to maintain high seed viability at all stages of seed handling from harvest to long-term storage.

## SEED AND SEEDLING ECOLOGY

Modeling seedling root growth of Great Basin species
*Bruce A. Roundy, Kert Young, and Nathan Cline*

- We developed thermal time models for days to 15 cm of rooting depth for 14 Great Basin plant materials (forbs, annual grasses, and perennial grasses) by conducting six constant temperature and three diurnal temperature growth chamber trials.
- Cheatgrass (*Bromus tectorum*) roots grow fastest at cooler temperatures, yet Anatone bluebunch wheatgrass (*Pseudoroegneria spicata* ssp. *spicata*) and crested wheatgrass (*Agropyron desertorum*) grew well enough to compete with cheatgrass.

- Forbs extended roots slower than most measured grasses and may not have sufficient time to extend roots before soil drying at some locations.
- We have conducted the field root trials at two locations in Utah for 2 years. We are currently analyzing these data.
- We characterized seedbeds at eight locations in the Great Basin and found that seedbeds spend a minimal amount of time at extreme (0 to 5°C and >30°C) temperature ranges where thermal time models are more variable in their response.

Pre-inoculation of Wyoming big sagebrush seedlings with native arbuscular mycorrhizae: Effects on mycorrhizal colonization and community composition after transplanting
*Marcelo D. Serpe and Bill E. Davidson*

- Pre-inoculation of Wyoming big sagebrush seedlings with native arbuscular mycorrhizae increased colonization of the roots that developed after transplanting.
- In sandy soils, the increase in mycorrhizal colonization caused by the pre-inoculation treatment led to an increase in seedling survival during periods of water deficits.

Smoke-induced germination of Great Basin native forbs
*Robert Cox*

- Extensive literature reviews for all Great Basin focal species have been conducted; species have been prioritized by germination requirements and potential for smoke response.
- The smoke response of the focal species is currently being tested.
- Future study will examine smoke response of seeds among populations within a species.
- The information can be used by land managers, seed producers and others to better plan restoration seedings which take advantage of smoke-responsive species.

## Plant Materials and Cultural Practices

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

- Hardseededness is a feature that often limits rapid, uniform germination in legume species. We conducted a greenhouse study in 2012 to determine the influence of seed scarification, soil type, and water droplet size (impact of soil crusting) on the speed of emergence of basalt milkvetch (*Astragalus filipes*), western prairie clover (*Dalea ornata*), Searls' prairie clover (*Dalea searlsiae*), and purple prairie clover (*Dalea purpurea*).
- Scarification greatly improved emergence in both western and Searls' prairie clover, but was much less effective in improving emergence of basalt milkvetch.
- Field seeding studies were established at three locations in 2012. Early spring seedings of western prairie clover were more successful than late-fall dormant seedings. The reverse was true for NBR-1, a basalt milkvetch release.
- Two natural-track selected germplasms of western prairie clover (Magestic and Spectrum) were released in 2011 for use in revegetation of semiarid rangelands in the western U.S.

Great Basin forb native forb development and cultural practices
*Jason Stettler and Alison Whittaker*

- We implemented a study to treat iron deficiency chlorosis in four cultivated native lupine species. All species responded positively to seed-applied chelated iron fertilizer.
- We planted a total of 62 sources of 20 native forb species at three farms for stock seed production and species evaluation.
- We conducted germination studies for ballhead ipomopsis (*Ipomopsis congesta*), golden princesplume (*Stanleya pinnata* var. *integrifolia*), and streambank wild hollyhock (*Iliamna rivularis*). We will use the germination data to develop propagation protocols for these species.

Provisional seed zone-based seed increase
*Scott Jensen*

To provide additional stock seed of Central Basin and Range forbs adapted to specific provisional seed zones, additional wildland seed collections were harvested and planted in seed increase plots. Existing seed increase plots were harvested to provide stock seed for growers. Major accomplishments:

- Twenty-two wildland collections of 10 species were harvested.
- Seed increase plots were installed for 10 species representing 50 source populations and 103 beds/rows.
- Seed increase plantings yielded seed of 10 species representing 26 different sites.
- Twenty-nine kg of thickleaf beardtongue (*Penstemon pachyphyllus)* were distributed for private sector seed production.

Aberdeen Plant Materials Center report of activities
*Loren St. John and Derek Tilley*

- USDA Natural Resources Conservation Service Plant Guides were completed or revised for arrowleaf balsamroot (*Balsamorhiza sagittata*), cutleaf balsamroot (*Balsamorhiza macrophylla*), Hooker's balsamroot (*Balsamorhiza hookeri*), yellow beeplant (*Cleome lutea*), tapertip hawksbeard (*Crepis acuminata*), barestem biscuitroot (*Lomatium nudicaule*), blue penstemon (*Penstemon cyaneus*) and gooseberryleaf globemallow (*Sphaeralcea grossulariifolia).* Plant guides are available at the PLANTS database (www.plants.usda.gov) and at the Aberdeen Plant Materials Center website (www.id.nrcs.usda.gov/programs/plant.html).
- The Aberdeen Plant Materials Center is progressing toward release of:
  -Douglas' dustymaiden (*Chaenactis douglasii*)
  -Hoary tansyaster (*Machaeranthera canescens*)
  -Wyeth buckwheat (*Eriogonum heracleoides*)

Bee pollination and breeding biology studies
*James H. Cane*

- The seeds of most of the cultivated wildflower species for the Great Basin are susceptible to infestation by various little-known seed beetles. These beetles are all natives, most specializing on the genus or species of wildflower. Some leave the seed after feeding, but others overwinter in the seed and could be transported. None seem able to reproduce in stored seed.

Seed production of Great Basin native forbs
*Clinton C. Shock, Erik B. Feibert, Lamont D. Saunders, Cheryl Parris, Nancy Shaw, Douglas A. Johnson, B. Shaun Bushman, and Ram K. Sampangi*

Four research projects are summarized, including:

- Irrigation requirements for seed production of five perennial species planted in 2005.
- Preliminary assessment of irrigation requirements for seed production of nine perennial species planted in 2009 and two annual species planted in 2011.
- Direct surface seeding strategies for the establishment of two native legume species: western prairie clover (*Dalea ornata*) and basalt milkvetch (*Astragalus filipes*).
- Evaluation of tolerance of sulphur-flower buckwheat (*Eriogonum umbellatum*) to herbicides.

## SEED INCREASE

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

- The Utah Crop Improvement Association (UCIA) Buy-Back project facilitates development of a seed market for specific germplasm accessions, pooled accessions, and/or formal germplasm releases developed through GBNPSIP and rewards initial seed growers financially for the risks they have assumed to participate in the program.
- Progress has been made in defining seed accession groupings, knowledge of agronomic seed production techniques, and understanding the reality of the commercial seed marketplace.
- Details on the program's stock seed inventory and distribution, and the seed increase, stock seed, and commercial availability are provided.

A strategy for maximizing native plant material diversity for ecological restoration, germplasm conservation and genecology research
*Berta Youtie*

- Use of the Provisional Seed Zone maps facilitates identification of collection gaps, planning for seed collection for research studies, seed increase or *ex situ* conservation, and identification of potential locations for *in situ* conservation.
- Fifteen collections of 10 species were made in southeastern Oregon for the Great Basin Native Plant Selection and Increase Project Research.
- Site visits were made to three farms producing eight native forbs.

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

- Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) plots recovered from chemical and mechanical thinning treatments applied to increase seed production. Data indicate the mechanical-strip kill was effective at one location; however, the same results did not occur at the second location where there were no differences among the treatments.
- Treatment effects on Wyoming big sagebrush have changed the understory plant populations.

Managing pests of native plant seed production
*Robert Hammon*

- Insect predators of globemallow (*Sphaeralcea)* and beardtongue or penstemon (*Penstemon*) were described in two Native Plant Journal publications.

## Horticultural Uses of Native Plants

Native annual species for retail nurseries and landscaping
*Heidi A. Kratsch*

- Established protocols for investigation of native annual species for retail nurseries.
- Evaluated five native annual species for native plant landscaping in western Nevada.

RMRS-CWI research and demonstration gardens and student training program
*John Dodson and Alexis Malcomb*

- The U.S. Forest Service (USFS) Great Basin Research Site in Boise, Idaho, is used for research by the USFS and several educational institutions. In cooperation with the student employee, student intern, and senior project programs of the College of Western Idaho (CWI), the site is maintained and utilized by students.
- RMRS, in collaboration with CWI has created a Demonstration Garden exhibiting plants used in Great Basin restoration, as well as serving as an educational tool for CWI horticulture students and community education.

## Species Interactions

The role of native annual forbs in the restoration of invaded rangelands
*Keirith A. Snyder, Elizabeth A. Leger, and Erin M. Goergen*

- Some native forbs such as bristly fiddleneck (*Amsinckia tessellata*) and common fiddleneck (*A. intermedia*) show promise as good competitors against cheatgrass (*Bromus tectorum*)
- The presence of certain native annual forbs, such as Veatch's blazingstar (*Mentzelia veatchiana*), can enhance the establishment and restoration of native perennial grasses, such as big squirreltail (*Elymus multisetus*) in cheatgrass-invaded rangelands
- The presence of native annual forbs provides a positive, indirect effect that promotes the establishment of *E. multisetus* in the presence of *B. tectorum*.

## Crested Wheatgrass Diversification

Evaluating strategies for increasing plant diversity in crested wheatgrass seedings
*Kent McAdoo and John Swanson*

- Preliminary results showed that density of seeded native grasses was highest in plots that received the combination of disking+spring glyphosate treatment for reduction of crested wheatgrass (*Agropyron desertorum*), significantly greater than that of disk-treated plots, but not significantly different than either the spring-treated glyphosate plots or the spring+fall-applied glyphosate plots. Forb densities were highest in the disk+glyphosate plots. 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.
- Data analysis is currently in progress for data collected in 2012. Preliminary indications are that glyphosate was more effective at reducing crested wheatgrass than either imazapic or chlorsulfuron+sulfometuron.

The ecology of native forb establishment in the Great Basin: A holistic approach
*Jeremy James*

- Low winter snow pack on rangeland reduced cheatgrass (*Bromus tectorum*) and bluebunch wheatgrass (*Pseudoroegneria spicata*) seedling survival probability by 80% or more
- Cheatgrass and bluebunch wheatgrass seedling recruitment was decreased about 20% in soils that had been disturbed, mainly due to increased physical crust formation
- Low winter snow pack on rangeland increased fungal pathogen load on native grass and cheatgrass seed with cheatgrass seed experiencing larger fungal loads than bluebunch wheatgrass under low snow pack
- Delaying seeding to winter or early spring may avoid these mortality windows in low snow years
- Non-native plant competition appears to play only a modest role in inhibiting native plant recruitment compared to other biotic and abiotic factors such as winter snow pack, attack by fungal pathogens, and physical soil crusts.

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

- We sampled 101 sites with crested wheatgrass (*Agropyron cristatum)* and a range of native vegetation establishment between May and August 2012.
- Preliminary analysis suggests native grass cover is positively associated with sites higher in silt and clay while crested wheatgrass cover is more positively associated with sites high in sand.

## RESTORATION STRATEGIES AND EQUIPMENT

Restoration of native understory plants in degraded sagebrush steppe ecosystems
*David A. Pyke, Kari Veblen, and Troy Wirth*

- Three loamy Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) project sites, one each in the Snake River Plain, Owyhee Plateau, and Great Salt Lake Major Land Resource Area, were selected and pre-project site monitoring was conducted.
- In fall 2012, two native grass and two forb species were experimentally seeded in undercanopy and gap microsites at each of these sites.
- Planting of seedlings is planned for spring 2013, and all seeds and seedlings will be monitored in June 2013.

Revegetation Equipment Catalog website maintenance
*Robert Cox*

- The Revegetation Equipment Catalog, a repository of information on types, capabilities, requirements, and company information for equipment used for revegetation efforts in the U.S., is in the process of a complete redesign. http://www.rw.ttu.edu/reveg-catalog/

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

- Effects of imazapic herbicide on cheatgrass (*Bromus tectorum*) germination and early growth was examined for two herbicide application rates in petri dish-laboratory and soil-greenhouse trials.
- In petri dish trials, imazapic reduced shoot and root length, but not germination or shoot biomass; soil trials showed significant differences in emergence, shoot length and shoot biomass. Given these results, soil trials appear useful for predicting responses of cheatgrass to this herbicide in field settings, whereas petri dish trials have limited utility for this purpose.
- No differences in plant responses were observed relative to the two imazapic application rates suggesting that a longer plant growth period is necessary or the rates tested were both above a threshold to observe differences in response.

Drill seeding with minimum-till drills
*Anne Halford and James Truax*

- As part of a collaborative research program underway at the Snake River Birds of Prey National Conservation Area, we are assessing inter-seeding treatments of early to mid-seral native shrub, grass and forb species relative to three disturbance legacies.
- Seeding was conducted in November 2012 within four 49-ha blocks. Seeding treatments were carried out with two minimum-till drills, the Truax On-The-Go and Rough Ride. Features and performance of the drills are being examined.

Influence of post-fire treatments on exotic, native residual and seeded species production at the Scooby wildfire site in Northern Utah
*Megan Taylor, Ann Hild, Urzula Norton, and Nancy Shaw*

- This research examined the impact of wildfire rehabilitation seedings on the presence of exotic annual invaders during the first three growing seasons post-fire. A second objective was to track the presence of soil biota beneath seeded perennial grasses and returning exotics to document changes in soil biotic diversity following catastrophic wildfire.
- Native grasses seeded for wildfire rehabilitation of Wyoming big sagebrush in northeastern Utah successfully limited the dominance and productivity of the exotic annuals cheatgrass (*Bromus tectorum*), halogeton (*Halogeton glomeratus*), and prickly Russian thistle (*Salsola tragus*).
- In the absence of seeding, post-fire vegetation was dominated primarily by annual exotics throughout the study period.
- Soil biota was present and diverse within the first three years post-fire but soil biotic communities did not strongly differentiate beneath native grass and exotic microsites.
- Soil communities are temporally variable within a growing season and communities beneath the same plant species may shift dramatically as soil moisture is diminished.
- Soil biotic communities should be monitored repeatedly within a growing season and microsite to obtain better estimates of their transient nature.

Use of native annual forbs and early seral species in seeding mixtures for improved success in Great Basin restoration
*Keirith A. Snyder, Elizabeth A. Leger, and Shauna M. Uselman*

- Seedling emergence and early survival of early seral native species was generally greater than that of late seral native species when seeded with cheatgrass (*Bromus tectorum*) or medusahead (*Taeniatherum caput-medusae*).
- Native grasses were more successful than native forbs and shrubs, especially in a coarse-textured soil.
- Emergence and survival of medusahead was consistently very high on divergent soil types, supporting the need for preventive measures against its further spread in the Intermountain West.
- Early seral natives show promise for improving success of rangeland restoration/rehabilitation reseeding efforts in the Great Basin.

Effects of N-sulate® fabric on germination and establishment of native seeded species
*Jason Stettler and Alison Whittaker*

- We collected and analyzed establishment data on second-year plots of the Forb Island study. We found that the N-sulate® fabric plots had increased survival rates compared to control plots.

Reducing cheatgrass: Research into *Bromus tectorum* and *Sordaria* symbiosis
*George Newcombe*

- The potential of using dung fungi in the biocontrol of cheatgrass (*Bromus tec*torum) is being examined.
- Over 1,100 fungal isolates were made from cheatgrass collections across the western U.S. Isolates of several genera of dung fungi were effective at reducing cheatgrass growth and fecundity. *Sordaria* isolate # CID 323 was selected for further testing.
- Dung fungi are spread through herbivore feces. After passage through the GI tracts, these fungi then produce spores on the animal's dung that should multiply and reduce fecundity in new generations of cheatgrass. Current work tests the assumptions that CID 323 can be freely passed from animal to plant host, and from plant to animal host. A field experiment confirmed that CID-infected cheatgrass did pass through the digestive tracts of sheep. A greenhouse experiment is underway to see if spores present on the dung will re-infect cheatgrass plants.
- Concurrent experiments test the effect of CID323 on native grasses used for restoration. The assumption is that the growth of native grasses, which have lived with these fungi for millennia, will not be negatively affected.
- A *Fusarium* isolate has been identified that also shows promise as a potential biocontrol agent.

Native plant selection and restoration strategies
*Nancy Shaw, Jeff Ott, Matt Fisk, Robin Bjork, Jan Gurr, Erin Denney, and Alexis Malcomb*

Comparison of rangeland and minimum-till drill, seeding methods, and Wyoming big sagebrush seeding rates

- Broadcasting small-seeded species through the minimum-till drill provided greater first-year density and equal cover during the first two years compared to broadcasting through the standard rangeland drill.

- Broadcasting small-seeded species through the minimum-till drill provided greater first-year density and equal cover during the first two years compared to treatments simulating aerial application (hand broadcasting in fall or in winter).
- Drilling large-seeded species with the rangeland drill resulted in greater density, but not greater cover than drill seeding them through the minimum-till drill. Cheatgrass density, but not cover was lower following seeding with the rangeland drill.
- Higher Wyoming big sagebrush seeding densities resulted when it was seeded through the minimum-till drill compared to the rangeland drill. For both drills, density increased with seeding rate over for the range tested: 52-525 PLS $m^{-2}$.

Plant Material Development and Distribution

- Forty-two seed collections were forwarded to the USDA ARS Western Regional Plant Introduction Station, Pullman, WA for ex situ conservation. Seventy-eight collections were provided to cooperators for ongoing research. Fifty-five new collections were added to the inventory for research and seed increase. Eight seed lots (G1 and G2) were added to the stock seed inventory.

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## Horticultural Uses of Native Plants

**Appendices**

**Project Title** Genetic Diversity and Genecology of Bluebunch Wheatgrass (*Pseudoroegneria spicata*), Prairie Junegrass (*Koeleria macrantha*), and Squirreltail (*Elymus elymoides*)

**Project Agreement No.** 12-IA-11221632-149

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**Project Description**

*Bluebunch wheatgrass*

Bluebunch wheatgrass (*Pseudoroegneria spicata*) 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.

<u>Objectives</u>

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 Basin, 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.

Methods

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 U.S. Forest Service (USFS) Lucky Peak Nursery near Boise, ID. Data were collected for 20 traits of growth, phenology and morphology at each of the three contrasting test sites during 2007 and 2008. Seed was collected from the common gardens in 2008 and germination tests were conducted in 2009 to evaluate population variation in germination rates. 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 seed zones have been delineated based on the results.

Results

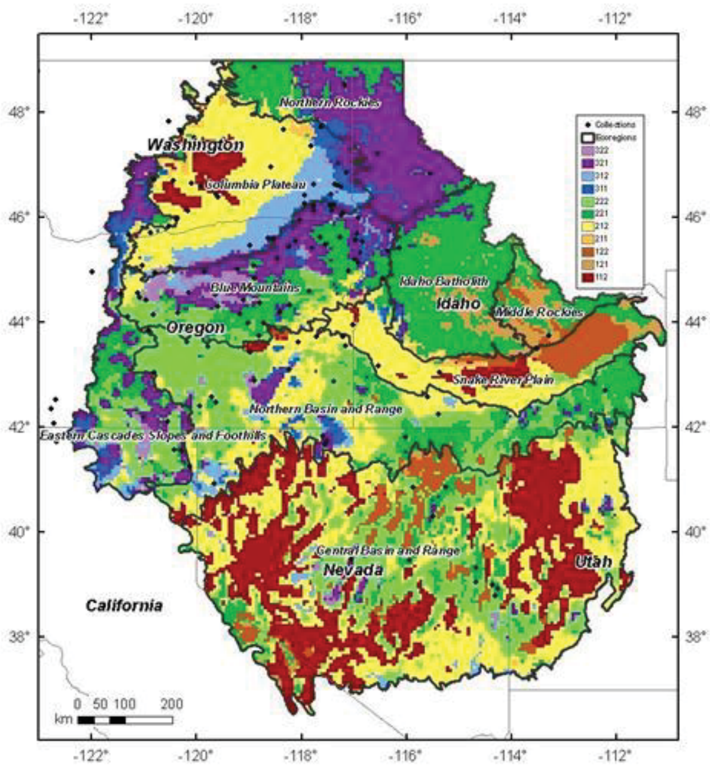
Differences among test sites and between years for traits of growth and phenology were generally large. Plants grown at the warmest and driest site, Central Ferry, were largest, whereas plants grown at the coolest, wettest site, Pullman, were smallest. Reproductive phenology was delayed at the coolest 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 among populations evaluated at each test site. Many traits showed that 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 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 population 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 moderate 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. That large population differences consistently correlated with environmental variables in meaningful ways suggests adaptively significant genetic variation 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 (Figure 1). The trait maps and seed zones largely reflect differences among Level III ecoregions (Omernik 1987), but with variation within ecoregions corresponding to temperature, precipitation and aridity.




| | | small | Intermed. | large |
|---|---|---|---|---|
| early | narrow | 1 red brown 13.4% | 3a yellow 24.7% | 6 light blue 4.0% |
| early | wide | none | 3b light orange 1.2% | 7 dark blue 2.6% |
| late | narrow | 2a dark orange 4.4% | 4 light green 17.6% | 8a light purple 1.7% |
| late | wide | 2b orange 2.5% | 5 dark green 17.1% | 8b dark purple 11.0% |

**Figure 1.** Seed zones for bluebunch wheatgrass. Seed zones are numbered 1 to 8 and are based on dividing the area into three principle components that represent small, intermediate or large plant size, early or late phenology, and narrow or wide leaves.

*Prairie junegrass*

Prairie junegrass (*Koeleria macrantha*) is a highly variable, moderately long-lived, cool season perennial bunchgrass that grows 15 to 60 cm (0.5 to 2 ft) tall. It is adapted to a wide variety of climates and soils and is an important component of many native plant communities. One of the most important uses of prairie junegrass is in seed mixes for restoration of native prairie, savanna, coastal scrub, chaparral, and open forest habitats across much of North America. Good drought tolerance and fibrous roots also make it beneficial for revegetation and erosion control on mined lands, over septic systems, and on construction sites, burns, and other disturbed areas. There is a need for greater genetic knowledge of prairie junegrass to ensure adapted populations are used for restoration and revegetation projects. Most information will be generated from two common garden studies conducted in separate contrasting environments in Oregon.

Objectives

1. Using common gardens, determine the magnitude and patterns of genetic variation among prairie junegrass populations from a wide range of source environments in Oregon, Washington and Idaho.
2. Relate genetic variation to environmental variation at collection locations.
3. Develop seed transfer guidelines.

Methods

Seed was collected from endemic stands of prairie junegrass during the summers of 2003 to 2006. Populations came from Oregon, Washington, and adjacent areas of Idaho, primarily east of the Cascade Mountains. Two families (maternal parents) were sampled from each of 114 populations, while only a single family was sampled from 12 populations, for a total of 240 families from 126 populations. Common garden studies were established in 2008 at two contrasting sites in Oregon: the USDA Natural Resources Conservation Service Plant Materials Center, Corvallis, Oregon, and Oregon State University's Agricultural Experiment Station at Powell Butte, Oregon. Plants were measured for a variety of traits including growth, morphology, phenology, and fecundity in 2009 and 2010. 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.

Results

Traits at Corvallis were significantly different from traits at Powell Butte. Plants at Corvallis were larger and had earlier phenology in both 2009 and 2010. Plants at Powell Butte flowered profusely compared to plants at Corvallis in 2009, but plants in Corvallis had a higher inflorescence number in 2010. Variation among populations for size traits was much greater when plants were grown at Corvallis in both years, and plants grown at Powell Butte had generally higher variation among populations in phenology traits for both years. The percentage of the total phenotypic variation (populations, families, and residual) that was found within populations was high for most traits, especially crown width, leaf width, leaf ratio, and dates of heading and bloom.

The population x site interaction was significant for most traits. Correlations of population means between test sites were higher in 2009 than in 2010, and correlations between years within sites were generally high. Populations that had wide crowns, more flowers, wide leaves, upright habit, and later phenology at one site were generally the same as those at the other site.

Traits that had large population variation and were correlated with climates at the source locations are biomass, crown width, inflorescence number, leaf width, leaf ratio, heading date and bloom date. As might be expected, leaf width is strongly correlated with leaf ratio ($r = -0.73$), and bloom date is strongly correlated with heading date ($r = 0.93$) though only moderately correlated with maturation date ($r = 0.46$). These traits are generally correlated with temperatures, precipitation, and aridity (as measured by the heat moisture index which is a function of the ratio of temperature to precipitation). Regression equations of traits on source climates used various combinations of temperature, precipitation or aridity variables. Regression models were used to map patterns of variation for biomass, inflorescence number, leaf ratio, and bloom date (Figure 2). $R^2$ values ranged from 0.29 to 0.36. Although the magnitudes and nature of the relationships between the source climates and traits differ somewhat between the four traits, general patterns of variation emerge. Populations from the Columbia Basin have lower biomass, narrower leaves, fewer inflorescences, and later phenology when grown together in a common environment. Populations from the Blue Mountains have greater biomass, wider leaves, more inflorescences, and earlier phenology. Populations from the northern Great Basin are similar to the Columbia Basin in having narrow leaves and lower biomass, but are more similar to the Blue Mountains in having earlier phenology. The few populations from western Oregon have wider leaves, high biomass and the latest phenology. From an adaptation perspective, we expect narrow leaves from areas of greater aridity, less precipitation, and warmer summer temperatures, and we expect earlier phenology from areas with colder winter temperatures (i.e., selection for quicker responses to springtime warming). The general patterns that emerge from this preliminary analysis are largely congruent with large-scale ecoregions, suggesting that Omernick's Level III ecoregions may be useful for seed zones. Preliminary seed zones are presented (Figure 2).

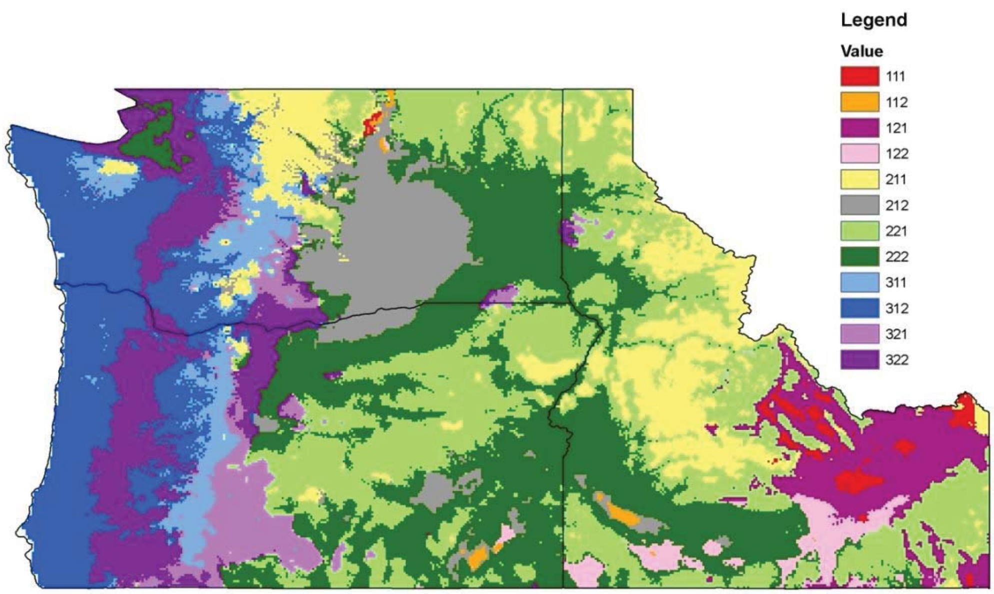



**Figure 2.** Preliminary seed zones for prairie junegrass. Seed zones are based on dividing the area into three principle components that represent small, intermediate or large plant size, early or late phenology, and narrow or wide leaves.

*Squirreltail*

Squirreltail (*Elymus elymoides*) is a cool-season, short-lived, self-pollinating perennial bunchgrass of semi-arid regions of western North America. It is found in a wide variety of habitats from the Pacific coast to the Great Plains and from Canada to Mexico, and ranges in elevation from 610 m-3,505 m (2,000 ft-11,500 ft). Squirreltail is considered a "workhorse" species in native plant restoration. Squirreltail can rapidly colonize disturbed sites, is also relatively fire-tolerant, and is a potential competitor to medusahead (*Taeniatherum caput-medusae*), wildrye (*Elyleymus*) and cheatgrass (*Bromus tectorum*). There are seven cultivars and pre-variety germplasm (PVG) collections of squirreltail and big squirreltail (*Elymus multisetus*) that have been or are being developed for restoration purposes, however only one variety, Toe Jam Creek, is currently used extensively. Previous studies indicate that there is strong ecotypic divergence in squirreltail. 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. Explore genetic variation in putative adaptive traits in squirreltail from a wide range of source environments in the inland West.
2. Explore the relationships between genetic variation in putative adaptive traits and the source environments.
3. Compare common cultivars of squirreltail to native sources.
4. Develop seed transfer guidelines.

Methods

With the help of collaborators from a variety of organizations interested in restoration using squirreltail (including the U.S. Forest Service, Bureau of Land Management, National Park Service, Fish and Wildlife Service, Department of Defense, the Nature Conservancy, Washington Department of Natural Resources, and the Yakama Nation), seed was collected from two maternal families from 110 populations from five western states, primarily from the northern and central Great Basin. In addition to the squirreltail populations, we obtained seed from cultivars and PVGs of squirreltail for inclusion in the common garden studies, including Toe Jam Creek, Fish Creek, Rattlesnake, Tusas, Antelope Creek, Pleasant Valley, and Sand Hollow (big squirreltail),. Common garden studies have been established at three contrasting sites: (1) Reno, Nevada, (2) Powell Butte, Oregon, and (3) Central Ferry, Washington.

Results

Data for the first year of the study have been collected and are currently being analyzed.

References

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,000). Annals of the Association of American Geographers 77: 118-125.

**Publications**

Kilkenny, F. F.; St. Clair, J. B.; Horning, M. [In press]. Climate change and the future of seed zones. USDA Forest Service National Nursery Proceedings 2012.

St.Clair, J. B.; Kilkenny, F. F.; Johnson, R. C.; Shaw, N. L.; Weaver, G. Genetic variation in adaptive traits and seed transfer zones for *Pseudoroegneria spicata* (bluebunch wheatgrass) in the northwestern United States. *Evolutionary Applications.* Accepted.

**Presentations**

Kilkenny, F. F.; St Clair, J. B. 2012. Climate change and the future of seed zones. USDA Forest Service Region 6 Genetics Meeting, 2012 November 15, Hood River, OR.

Kilkenny, F. F.; St. Clair, J. B.; Horning, M. 2012. Climate change and the future of seed zones. Seed Technology for Forest and Conservation Nurseries, 2012 September 11-13, Bend, OR.

St. Clair, J. B.; Kilkenny, F. F. 2012. Genecology and seed zones for bluebunch wheatgrass and prairie junegrass. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT.

**Management Applications and Seed Production Guidelines**

These studies indicate that populations of bluebunch wheatgrass and prairie junegrass differ greatly across the landscapes of the Great Basin, Columbia Basin, Blue Mountains and adjacent ecoregions for traits of plant size, flowering phenology, and leaf width. Much of that variation is associated with climates of the source locations, indicating adaptive significance. Seed zones are presented for recommendations of bulking seed collections and producing plant material for adapted, diverse and sustainable populations for revegetation and restoration. Different levels of acceptable risk may be accommodated by choosing whether or not to bulk materials from the same zones but in different Level III ecoregions. Results indicate that sources may be consolidated over fairly broad areas of similar climate and thus may be shared between districts, forests, and different land ownerships.

**Products**

- This study provides seed zones and seed transfer guidelines for developing adapted plant materials of bluebunch wheatgrass for revegetation and restoration in the Great Basin and adjacent areas.
- The research provides guidelines for conservation of germplasm within the National Plant Germplasm System.
- Results for bluebunch wheatgrass have been, and results from prairie junegrass are being, submitted to a peer-reviewed journal, and will be disseminated through symposia, field tours, training sessions, or workshops.

**Project Title** Conservation, Adaptation and Seed Zones for Key Great Basin Species

**Project No. & Location** 10-IA-11221632-023

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**Project Description**

Among the key restoration species for the Great Basin are Indian ricegrass (*Achnatherum hymenoides* [Roem. & Schult.] Barkworth), Sandberg bluegrass (*Poa secunda* J. Presl), basin wildrye (*Leymus cinereus* [Scribn. & Merr.] Á. Löve), and Thurber's needlegrass (*Achnatherum thurberianum* [Piper] Barkworth). These species are critical for wildlife habitat, livestock grazing, soil stabilization, and ecosystem function in the Western U.S. Yet current releases of these species do not specifically match natural genetic diversity within the species with local climatic variation to develop seed zones. Seed zones matching climate with genetic variation will greatly facilitate management decisions, ensuing restoration with diverse, adapted plant material while promoting biodiversity needed for future natural selection, especially with climate change.

Our objectives (Figure 1) are:

1. Collections representing the Great Basin are established in common garden studies and numerous plant traits associated with phenology, production, and morphology are measured and analyzed.
2. Plant traits with genetic variation in common gardens are linked to seed source location climates and composite plant traits are developed using multivariate statistics.
3. Regression models conflating variation in plant traits with source climates are developed and used with GIS to map seed transfer zones.

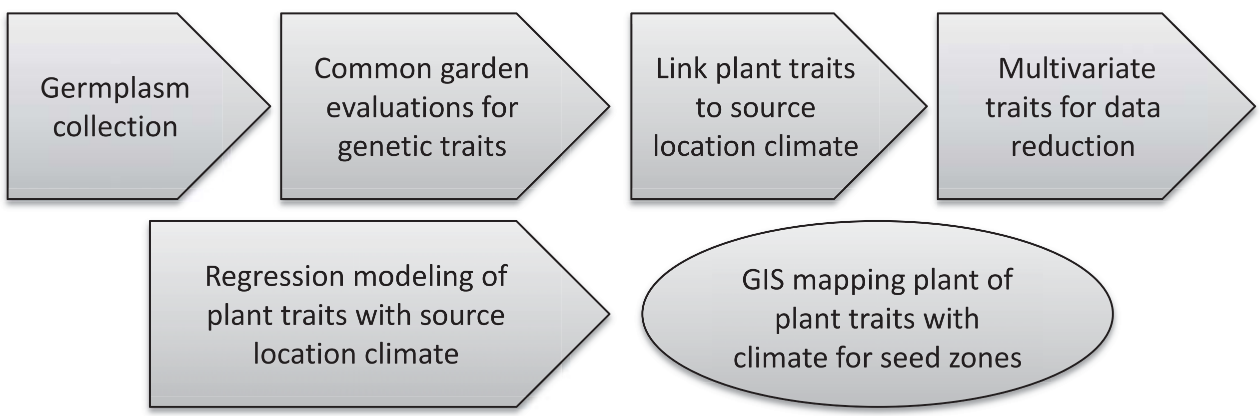


**Figure 1.** Schematic showing the steps for genecology studies to establish seed zones for a given plant species.

*Indian Ricegrass*
A genecology study of Indian ricegrass collected from across the southwestern United States including the Great Basin has been completed and published (Johnson et al. 2012). For this project plants from 106 collection locations were established in common gardens in 2006 and four phenological traits [Phen] (such as blooming date), six production traits [Pro] (such as dry weight), and eight morphology traits [Morph] (such as leaf dimensions) were measured in 2007 and 2008. Analysis of variance revealed that all of these basic garden traits differed among source locations ($p < 0.01$), indicating widespread genetic variation. Within Phen, Pro, and Morph categories, canonical correlation (SAS/STAT version 9.2, SAS Institute, Cary, NC) was completed between basic garden traits and temperature and precipitation at the source location which resulted in six significant ($p < 0.01$) canonical variates (Phen 1, Pro 1 and 2, and Morph 1, 2, and 3) representing each category of traits. Linear correlations ($r > \pm 0.25$, $p < 0.01$) consistently linked monthly temperature at collection locations with Phen 1, Pro 1, and Morph1. For precipitation, however, correlations were more dependent on month, with the strongest correlations during the spring developmental period. Using regression models between traits and climate, a map with 12 seed zones was developed representing much of the southwestern United States (Figure 2, Table 1). This generally distinguished genetic variation between cooler and warmer regions, usually separating more northern, higher elevation areas from more southern, lower elevation areas. The correspondence between climate and genetic variation suggested climate driven differences in natural selection, likely leading to adaptation. The seed zone map is recommended to guide and broaden germplasm collection and utilization for Indian ricegrass restoration.

Within the Southwestern United States we know of three Indian ricegrass ecotypes that have been developed and released: Starlake from McKinley County, NM, 'Paloma' from near Florence, CO (USDA-NRCS 2000), and Whiteriver from near Rangely, CO (Jones et al. 2010). As nearly as could be determined, they originated from within seed zones M1H2H3 and MIH2L3 (Figure 2; Table 1), which represent less than 20% of the mapped area. The largest seed zone, M1L2H3, representing major portions of the Central Basin and Range, the Wyoming Basin, and eastern Colorado, is not represented by any released germplasm. In addition, considerable portions of the Colorado and Arizona/New Mexico Plateaus (mapped in blue hues) are not represented. Thus, it appears there are substantial germplasm needs for Indian ricegrass in the southwestern United States.

*Sandberg Bluegrass*
Sandberg bluegrass common gardens were established at Powell Butte, OR, Central Ferry, WA, and Sidney, MT in 2008 with plants from 130 collection locations, two families within location, in a randomized complete block design replicated six times. Data were collected in each garden in 2009 and 2010 and analysis of variance completed (Table 2). For both years, location effects were highly significant for all traits measured, indicating substantial genetic variation among the different seed sources. Also highly significant were the garden site x location interactions for each trait. These results showed a contrasting pattern of genetic variation between Powell Butte, a relatively cool (annual average 9°C), high elevation (983 m) site, and Central Ferry, a relatively low (200 m) and warm site (annual average temperature 11.3°C ).

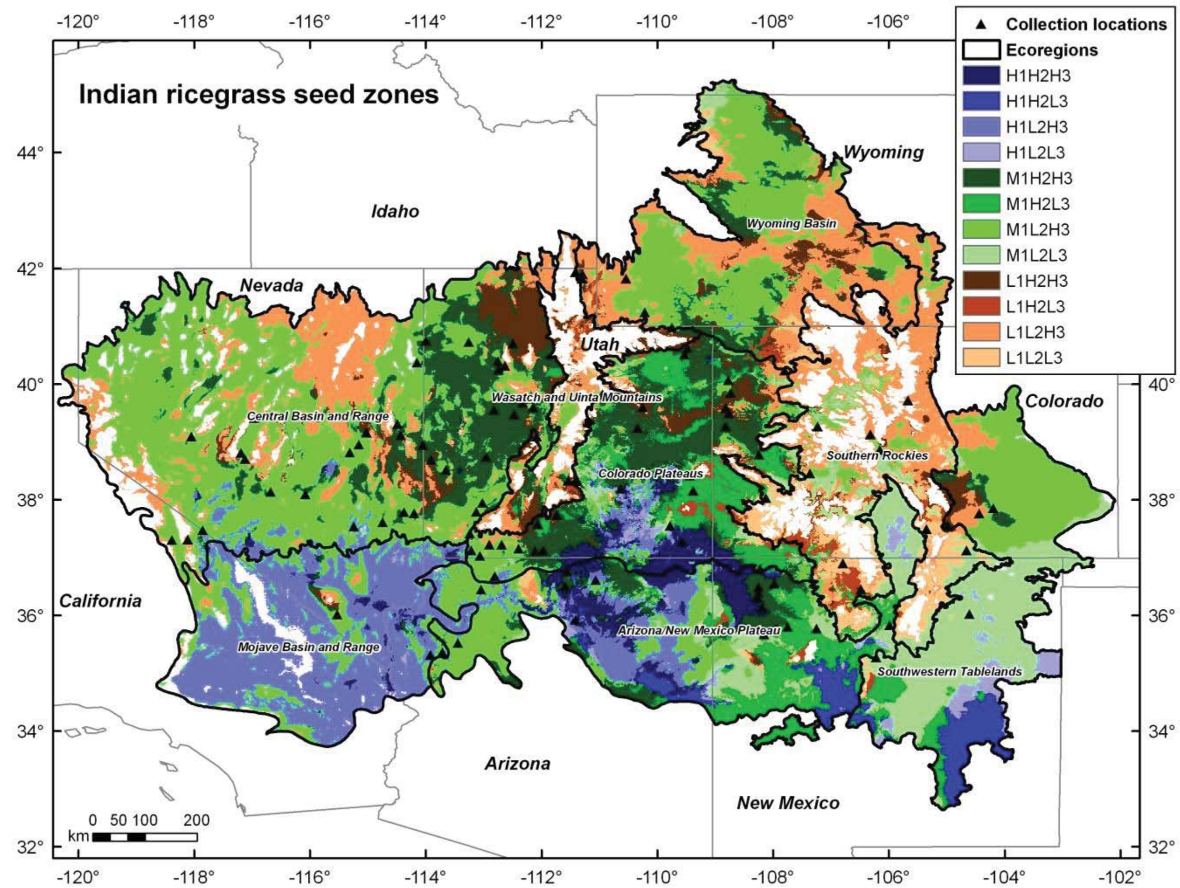


**Figure 2.** Twelve proposed seed zones for Indian ricegrass in the southwestern United States resulting from overlays of canonical variate scores (cancorr extracted) derived from phenology (Phen 1), production (Pro 1 and 2), and morphology (Morph 1, 2, 3). Model predictions outside the range for the original canonical variate scores, shown in white, were not mapped. Abbreviations H1, M1, and L1 refer to high, middle and low ranges of cancorr extract 1 scores; H2 and L2, and H3 and L3, refer to high and low ranges of cancorr extracts 2 and 3, respectively.

The substantial genetic variation indicated a good potential for successful seed zone mapping of Sandberg bluegrass. Further analysis is underway to relate this genetic variation to source location climates through regression models needed for seed zone development.

*Basin Wildrye*

Common gardens of basin wildrye were established at Pullman and Central Ferry, WA sites in 2010 with plants from 114 collection locations, two families per location. The cultivars 'Trailhead', a tetraploid (2n = 4x = 28), and 'Magnar' an octoploid (2n = 8x = 56), were also included. Plants were randomized in a complete block design with six replications. Data were collected for phenology, production, and morphology traits in 2011 and 2012, and data collection will continue in 2013.

For basin wildrye, ploidy differences are likely critical to its distribution and adaptation. Collections of basin wildrye were also made in the Columbia Plateau, WA where the octoploid form is common, whereas in the Great Basin the tetraploid predominates (Jones and Larson 2005). Ploidy for all collection locations was determined using cytometry with a Partec CyFlow® Ploidy Analyzer as described by Jakubowski et al. (2011). The analysis of field collected sources revealed 58 octoploids and 56 tetraploids. This will allow us to understand the effect of ploidy on plant traits and adaptation in relation to source location climate.

*Thurber's Needlegrass*

Thurber's needlegrass common gardens were established in fall 2011 at Central Ferry, WA, and Reno, NV. The study consists of 67 source locations predominantly from the Northern and Central Basin and Range ecoregions. Plants from each location were randomized in eight complete blocks at each garden site. Data were collected on numerous phenology, production, and morphological traits in 2012 and data collection will continue in 2013.

*Seeds of Success Activities*

Seeds of Success (SOS) and the National Plant Germplasm System (NPGS) are partnering to collect, distribute, and evaluate key native plant materials needed for conservation and restoration. More than 7,000 new native plant accessions representing diverse taxa have been acquired for the NPGS and nearly 2,400 accessions have been distributed for research at the federal, state, and private levels (Figure 3, Table 3).

**Table 1.** Area represented by each seed zone for Indian ricegrass collection locations across the southwestern U.S. and zones corresponding to released germplasm.

| Seed zone | Square kilometers | Mapped area % | Number[†] |
|---|---|---|---|
| H1H2H3 | 32,845.9 | 3.03 | 3 |
| H1H2L3 | 24,808.1 | 2.29 | 1 |
| H1L2H3 | 119,066.9 | 11.00 | 3 |
| H1L2L3 | 15,440.8 | 1.42 | 1 |
| M1H2H3 | 127,031.1 | 11.70 | 32 |
| M1H2L3 | 68,811.0 | 6.35 | 11 |
| M1L2H3 | 324,657.1 | 29.90 | 35 |
| M1L2L3 | 101,311.2 | 9.34 | 8 |
| L1H2H3 | 48,709.5 | 4.49 | 3 |
| L1H2L3 | 15,630.5 | 1.44 | 1 |
| L1L2H3 | 174,859.6 | 16.10 | 7 |
| L1L2L3 | 31,304.6 | 2.89 | 1 |
| Totals | 1,084,476.2 | 100.0 | 106 |

[†]Number of collections falling within a given seed zone.

**Table 2.** Summary of analysis of variance of common gardens traits for Sandberg bluegrass growing at Central Ferry, WA and Powell Butte, OR sites in 2009 and 2010 and representing seed collection locations across the Great Basin and surrounding areas.

| Trait | | Site | | Location | | Site x Location | |
|---|---|---|---|---|---|---|---|
| | Mean | F-value | P-value | F-value | P-value | F-value | P-value |
| Phenology | 2009 | | | | | | |
| Heading, day | 123 | 923 | <0.001 | 6.06 | <0.001 | 2.21 | <0.001 |
| Blooming, day | 138 | 902 | <0.001 | 7.43 | <0.001 | 3.39 | <0.001 |
| Maturity, day | 165 | 201 | <0.001 | 3.96 | <0.001 | 2.28 | <0.001 |
| Heading to bloom, days | 15.4 | 3.98 | 0.070 | 3.01 | <0.001 | 3.64 | <0.001 |
| Heading to maturity, days | 41.9 | 43.5 | <0.001 | 4.57 | <0.001 | 1.97 | <0.001 |
| Bloom to maturity, days | 26.4 | 35.2 | <0.001 | 3.57 | <0.001 | 2.56 | <0.001 |
| Production | | | | | | | |
| Apparent survival | 0.740 | 0.110 | 0.750 | 3.40 | <0.001 | 1.71 | <0.001 |
| Panicle number | 73.2 | 9.36 | 0.012 | 3.11 | <0.001 | 3.17 | <0.001 |
| Dry weight, g | 26.6 | 5.61 | 0.039 | 5.24 | <0.001 | 2.26 | <0.001 |
| Basal area, $cm^2$ | 54.7 | 1.63 | 0.231 | 3.93 | <0.001 | 1.59 | <0.001 |
| Morphology | | | | | | | |
| Leaf width, cm | 0.275 | 11.7 | 0.006 | 8.69 | <0.001 | 1.59 | <0.001 |
| Leaf length, cm | 6.35 | 0.020 | 0.900 | 8.09 | <0.001 | 1.49 | 0.001 |
| Leaf length x width, $cm^2$ | 1.82 | 9.32 | 0.012 | 11.4 | <0.001 | 1.57 | <0.001 |
| Plant habit, 1- 9* | 6.09 | 19.2 | 0.001 | 2.46 | <0.001 | 2.54 | <0.001 |
| Culm length, cm | 38.4 | 45.2 | <0.001 | 3.29 | <0.001 | 2.23 | <0.001 |
| Panicle length, cm | 10.8 | 9.59 | 0.011 | 4.99 | <0.001 | 2.01 | <0.001 |
| Phenology | 2010 | | | | | | |
| Heading, day | 111 | 313 | <0.001 | 8.56 | <0.001 | 2.68 | <0.001 |
| Blooming, day | 131 | 1749 | <0.001 | 8.72 | <0.001 | 2.04 | <0.001 |
| Maturity, day | 171 | 0.340 | 0.572 | 4.43 | <0.001 | 2.64 | <0.001 |
| Heading to bloom, days | 19.7 | 230 | <0.001 | 4.06 | <0.001 | 3.26 | <0.001 |
| Heading to maturity, days | 59.4 | 95.7 | <0.001 | 3.90 | <0.001 | 2.87 | <0.001 |
| Blooming to maturity, days | 39.8 | 375 | <0.001 | 4.16 | <0.001 | 3.54 | <0.001 |
| Production | | | | | | | |
| Apparent survival | 0.699 | 0.220 | 0.650 | 3.14 | <0.001 | 1.66 | <0.001 |
| Panicle number | 127 | 12.2 | 0.005 | 2.25 | <0.001 | 2.83 | <0.001 |
| Dry weight | 110 | 0.950 | 0.354 | 2.48 | <0.001 | 2.47 | <0.001 |
| Basal area** | 58.6 | 184 | <0.001 | 4.27 | <0.001 | 2.01 | <0.001 |
| Morphology | | | | | | | |
| Leaf width, cm | 0.231 | 6.46 | 0.029 | 6.38 | <0.001 | 1.33 | 0.009 |
| Leaf length, cm | 5.69 | 39.1 | <0.001 | 6.03 | <0.001 | 1.92 | <0.001 |
| Leaf length x width, $cm^2$ | 1.40 | 1.17 | 0.304 | 6.78 | <0.001 | 1.60 | <0.001 |
| Plant habit, 1- 9* | 5.54 | 65.5 | <0.001 | 2.53 | <0.001 | 2.58 | <0.001 |
| Culm length, cm | 32.4 | 7.90 | 0.018 | 3.18 | <0.001 | 3.28 | <0.001 |
| Panicle length, cm | 10.3 | 10.6 | 0.008 | 5.58 | <0.001 | 1.40 | 0.002 |

*Plant habit ranges from 1, prostrate to 9, upright.

**Estimated as the product of two perpendicular basal diameter measurements.

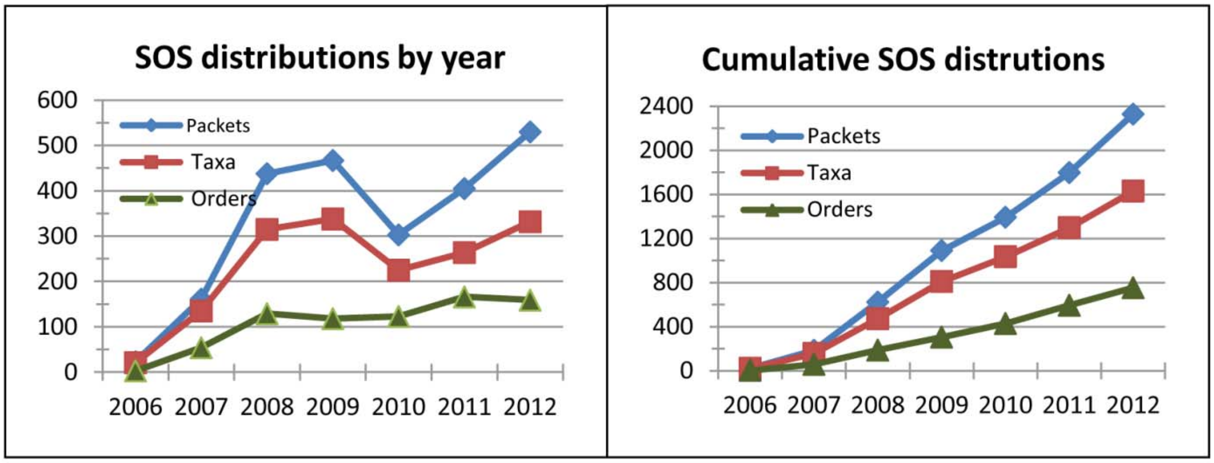


**Figure 3.** Seeds of Success yearly and cumulative distribution from the National Plant Germplasm System over the last seven years.

**Table 3.** Institutional sources of Seeds of Success seed orders distributed from the National Plant Germplasm System over the last 7 years.

| *Year* | *Foreign* | *State* | *ARS* | *US commerce* | *Other Federal* | *US Individual* | *US non-profit* | *Other* |
|---|---|---|---|---|---|---|---|---|
| 2006 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 |
| 2007 | 7 | 17 | 2 | 8 | 3 | 13 | 1 | 3 |
| 2008 | 25 | 38 | 5 | 18 | 3 | 12 | 3 | 25 |
| 2009 | 22 | 35 | 5 | 15 | 4 | 10 | 4 | 23 |
| 2010 | 29 | 40 | 7 | 11 | 7 | 10 | 5 | 14 |
| 2011 | 40 | 46 | 14 | 16 | 4 | 14 | 7 | 25 |
| 2012 | 20 | 40 | 6 | 10 | 8 | 14 | 5 | 56 |
| Totals | 143 | 216 | 40 | 78 | 32 | 73 | 25 | 145 |

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**Management Applications and Seed Production Guidelines**

Maps visualizing the interaction of genetic variability and climate for restoration species 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 manger experience without changing their basic form or links between genetic variation and climate.

We recommend utilization of multiple populations of a given species within each seed zone to promote biodiversity needed for sustainable restoration and genetic conservation.

Collections representing each seed zone should be released, grown, and used for ongoing restoration projects.

**Products**

- Seed zones for key Great Basin restoration species ensure plant materials used for restoration are adapted, suitable, and diverse.
- Collection and conservation of native plant germplasm though cooperation between the National Plant Germplasm System (NPGS), the Western Regional Plant Introduction Station, Pullman, WA, and the Seeds of Success (SOS) program under BLM. This ensures availability of native plant genetic resources that otherwise may be lost as a result of disturbances such as fire, invasive weeds, and climate change.

**Project Title** Ecological Genetics of Big Sagebrush (*Artemisia tridentata*): Genetic Structure and Climate-based Seed Zone Mapping

**Project Agreement No.** 10-IA-11221632-266

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**Project Description**

*Artemisia tridentata* (big sagebrush) 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 diets, invasive weed exclusion (e.g., cheat grass, *Bromus tectorum*), snow catchment, and nutrient cycling. Big sagebrush is divided into three major subspecies: *tridentata*, *vaseyana*, *wyomingensis* 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 their 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.

Objectives

1) Establish common gardens from seed sources collected 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. 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 2010. First-year measurements were conducted in October and November 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 (< 2%) for the first year. 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. 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 *vaseyana* (data not shown). By late in 2012, mortality was low at two of the common gardens: Orchard at 11.3% and Majors Flat at 3.6%. However, at Ephraim, mortality had reached 43%.

There are strong patterns in which subspecies and populations have survived at Ephraim. Preliminary analyses suggest seed source mortality rates are correlated with precipitation and temperature interactions. Seed sources with warmer, longer and drier summers suffered higher mortality at Ephraim.

**Table 1.** Location information for three sagebrush common garden sites.

| Site name | Latitude | Longitude | Elevation (m) |
|---|---|---|---|
| Orchard, Ada Co., ID | 43.328 | -116.003 | 976 |
| Ephraim, Sanpete Co., UT | 39.369 | -111.580 | 1,686 |
| Majors Flat, Sanpete Co., UT | 39.337 | -111.521 | 2,088 |

*Molecular Genetics*

In September 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 have been compiled and annotated with over 21,000 sequences identified with putative function. These data include 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 phylogenetic studies. In September 2010 further RNA sequencing was completed on two populations of *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 *tridentata* and *vaseyana* samples, it was found that some interesting SNP patterns emerged. Out of approximately 1,000 SNPs between *tridentata* and *vaseyana*, *wyomingensis* was heterozygous for over one-third. Most of the remaining SNPs (approximately 60%) match *vaseyana* compared to *tridentata* (approximately 40%) (Bajgain et al. 2011).

The transcriptome data has been used to develop an array of DNA sequences associated with secondary metabolite pathways. These sequences (48 in total) were obtained from 329 individuals from 48 sites, approximately seven individuals per site (Figure 1). Phylogenetic relationships based on approximately 12,000 base pairs of DNA show diploid *tridentata* and *vaseyana* are distinct subspecies. Tetraploids, including *wyomingensis* are polyphyletic (i.e., multiple origins) and have a tendency to be an admixture of *tridentata* and *vaseyana* (Figure 2, Richardson et al. 2012).

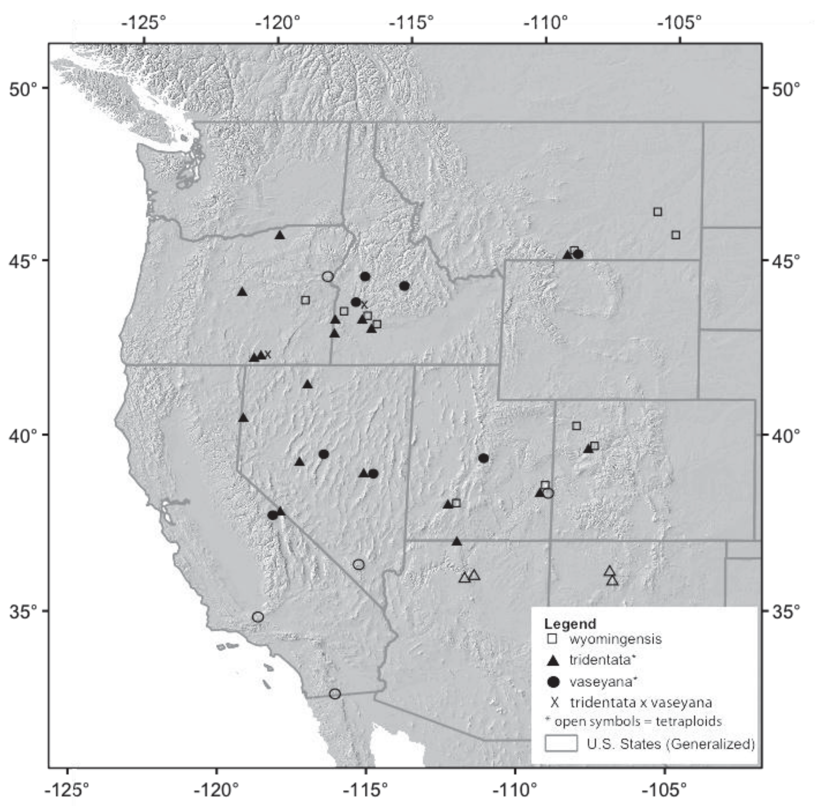


**Figure 1.** The location of 48 seed collection sites for *Artemisia tridentata* used in the molecular genetic study. The symbols identify subsp. *wyomingensis*, *tridentata* and *vaseyana*.

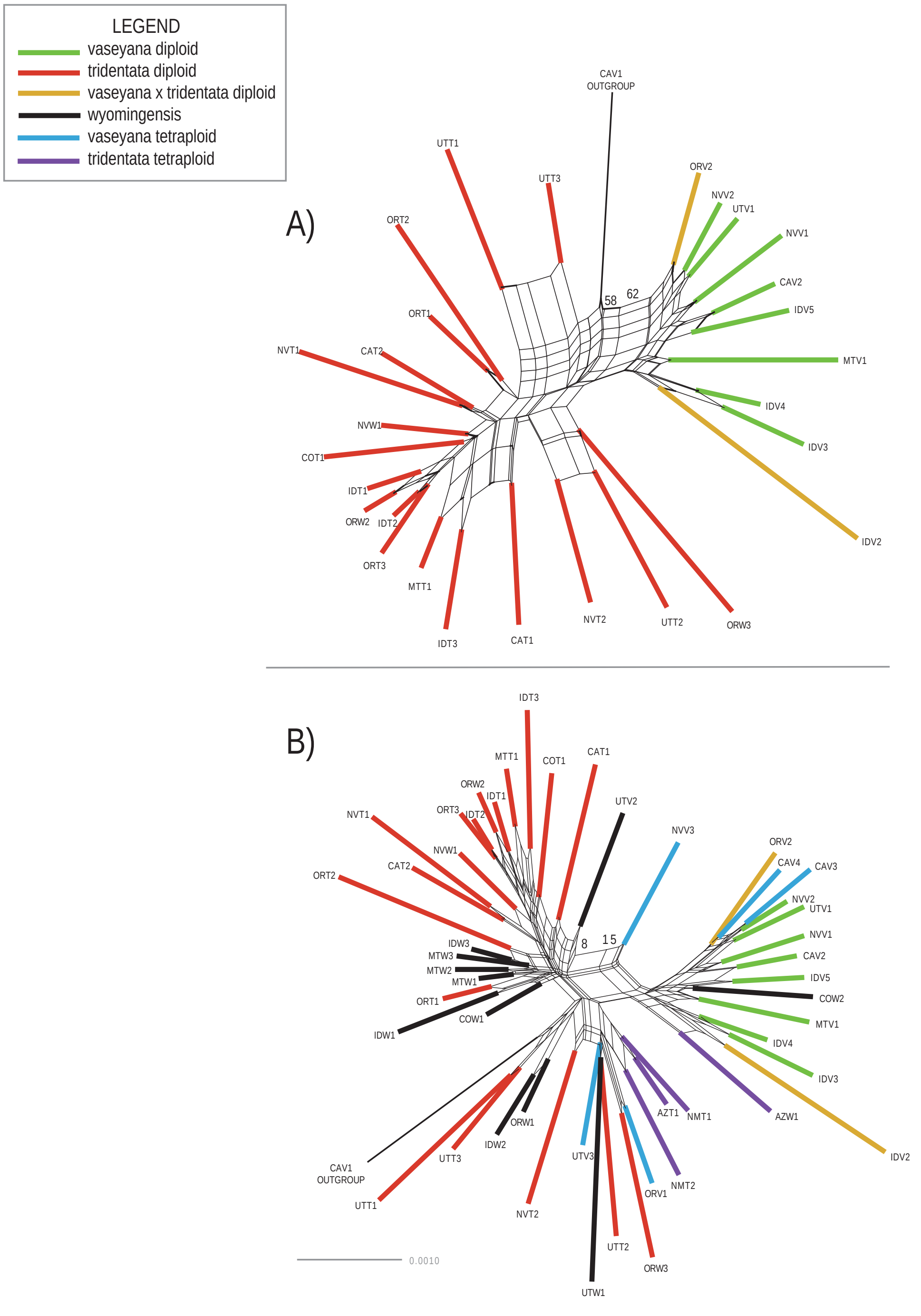


**Figure 2.** Unrooted phylogenetic networks using neighbor-net algorithm. The networks were constructed from uncorrected *p*-distances based on 24 contigs of consensus sequences of each collection site. A) Illustrates relationships between 28 diploid collections. B) Includes diploid collections and 20 tetraploid collections. Taxonomic differences are represented by colored edges and the scale bar indicates expected nucleotide changes per site. The outgroup species is *Artemisia arbuscula* (low sagebrush).

Future plans

*Common Gardens*

Genetic responses in common gardens, including growth, mortality and seed yield, will be used to evaluate climatic adaptation. These responses will be used to develop genetic-climate models to construct seed zones for current and future conditions.

*Molecular Genetics*

Future questions to be addressed with molecular genetics include: 1) can tetraploid lineages be identified on the landscape; 2) what are the phylogenetic relationships between big sagebrush and other sagebrush species; 3) has interspecific hybridization been an important evolutionary process in some tetraploid lineages?

*Electronic Nose*

Determining big sagebrush subspecies from harvested seed is extremely challenging for seed warehouses and management agencies, however proper identification is critical for successful restoration. We are evaluating the effectiveness and efficiency of using an electronic nose as a diagnostic tool for subspecies identification, especially for separation of diploid *tridentata* and tetraploids (e.g., *wyomingensis*). An electronic nose (e-nose) distinguishes differences in volatile organic compounds (VOCs, smells). An important factor in this evaluation is to consider environmental influences on VOCs, which could complicate diagnostic tests.

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**Management Applications and Seed Production Guidelines**

The molecular genetic research changes the taxonomic paradigm of *A. tridentata* subspecies. Subspecies *wyomingensis* is not a monophyletic group. Therefore, the manner in which seeds of *wyomingensis* are collected and used in the landscape should be done judiciously until we better understand the geographic/ecological distributions and any adaptive differences between tetraploid lineages.

**Products**

- Evaluation of quantitative traits for adaptive responses to climate and development of seed zones for big sagebrush subspecies (ongoing)
- Development of e-nose technology for *A. tridentata* subspecies diagnostics (ongoing). This could allow seed warehouse personnel to efficiently detect subspecies differences in harvested seed.
- Leveraged funding: National Fire Plan 2009-2012 ($65,000 per year), National Fire Plan 2013-2016 ($72,000 per year)
- Field tour given during the Society for Ecological Restoration Great Basin Chapter meeting, 2013 June 18-19, Ephraim, UT.

**Project Title** Selecting Sagebrush Seed Sources for Restoration in a Variable Climate: Ecophysiological Variation among Genotypes[1]

**Project Agreement No.** 11-IA-11221653-098

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[1]*This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government may be held liable for any damages resulting from the authorized or unauthorized use of this information.*

**Project Description**

Big sagebrush (*Artemisia tridentata*) communities dominate a large fraction of the United States and provide critical habitat for a number of wildlife species of concern. Loss of big sagebrush, due to fire followed by poor restoration success, continues to reduce the ecological potential of these ecosystem types, particularly in the Great Basin. Choice of appropriate seed sources for restoration efforts is currently unguided due to gaps in knowledge concerning genetic variation and local adaptation as they relate to a changing landscape. We are assessing the ecophysiological responses of big sagebrush to climate variation, comparing plants that germinated from ~20 geographically distinct populations of each of the three subspecies of big sagebrush, in addition to populations that differ in chromosome number (these provenances are also distinct genotypes revealed in molecular phylogenetics by B. Richardson). Major factors that influence restoration efforts are sagebrush responses to temperature and water stress in addition to whether tetraploidy, as demonstrated in other taxa, confers greater stress resistance. These remain important, but unanswered, questions.

Seedlings were previously (in 2010) planted into common gardens in Orchard, ID (normally supports Wyoming big sagebrush (*A. t. wyomingensis*) and basin big sagebrush; *A. t. tridentata*), Ephraim, UT (*A. t. tridentata*), and Majors Flats, UT (mountain big sagebrush; *A. t. vaseyana*), by U.S. Forest Service (USFS) collaborators Drs. B. Richardson and N. Shaw, (USFS Rocky Mountain Research Station, Provo, UT and Boise, ID ) as part of a Great Basin Native Plant Selection and Increase Project sponsored study.

Seed sources spanned all states in the conterminous western United States. Germination, establishment, growth and ecophysiological responses are being linked to climate of seed origin, genomics, and foliar palatability. New information is being produced to help guide the selection of appropriate seed sources by Bureau of Land Management (BLM) and USFS field offices when they are planning seed acquisitions for emergency post-fire rehabilitation projects in consideration of climate variability and wildlife needs.

Selection of seed sources in the absence of seed zone information typically prioritizes use of seeds from the closest geographic settings to the restoration site, based on the assumption of local adaptation (i.e., that local seed sources have a superior genetic and thus phenotypic match to their local growing environment than distant genotypes).

Objectives

1. Complete the assessment of basic ecophysiological limitations prevailing over the course of a year for established plants in the common garden(s).
2. Determine how ecophysiological performance and key physiological limitation vary within subspecies (among seed-source populations) and between subspecies to evaluate the assumption that local populations perform better than distant ones.
3. Assess how ecophysiological differences relate to whole-plant growth and survival (i.e. establishment success) and whether they can indicate if particular adaptive strategies are more or less successful.
4. Compare ecophysiological-climate adaptation in established plants with young establishing seedlings, and relate differences in ecophysiology to establishment success under different management treatment conditions.

Progress

A year-long campaign of measurements of survival and growth (complementing Dr. Richardon's efforts), shoot morphology, photosynthesis, water relations, and freezing avoidance and resistance was completed at the Orchard (ID) common garden. Secondly, photosynthesis and water status were measured on nine genotypes common to all three gardens (creating a reciprocal design with additional tetraploid populations to test for ploidy effects). Third, instrumentation for elemental and isotopic analyses was obtained, set up, tested, and applied to the project. Carbon isotopes were measured as a proxy for water-use efficiency, in all plants in all gardens, and measured %C and %N in all plants from the Orchard garden, totaling >2500 sample analyses. Extensive testing and method development was done for use of water isotopes to determine depth of soil water sources (as described as an objective in our 2011 report).

Lastly, starting in August 2012, nearly 2,700 seedlings were reared in containers, using native soils and an outdoor setting, for two related efforts. A new experiment was established to evaluate seed germination and initial seedling performance for three local genotypes under ambient and experimentally warmed conditions in the Birds of Prey National Conservation Area (BOP NCA). A total of 750 seedlings were successfully outplanted (bareroot) into these plots. Secondly, another 1,760 seedlings from 12 genotypes will be outplanted in 2013 into an experiment having large, replicated plots that have been grazed, mowed, seeded, treated with herbicide, or a combination of these factors.

Methods

Between 5 and 10 individual plants of nearly 20 populations per each of the three subspecies were planted into the Orchard, Ephraim, and Majors Flats common gardens in spring of 2010.

At the initiation of measurements, plants were all >18 months in age and ranged in height from 0.25 to >1 meter in height; all measurements began in August 2011 and concluded in June, 2012. We measured plant water status at pre-dawn by excising shoot tips and determining the negative tension of xylem water with a pressure chamber (model 1000, PMS Inc., Corvallis, OR). Soil water content is periodically determined using TDR probes (Hydrosense, Campbell Scientific, Australia). Photosynthesis and transpiration are measured in the field with a model 6400 portable photosynthesis instrument (LiCOR Inc, Lincoln, NE), and stomatal conductance, water-use efficiency (WUE, photosynthesis/transpiration), and other derivative parameters were calculated. Gas exchange rates were determined on a leaf mass basis, a projected leaf-area basis, and a silhouette leaf area basis. Leaf area and mass were determined using digital photography and by weighing, following 48 h of drying at 60ºC. Chlorophyll fluorescence of dark-adapted leaves was measured using a fluorometer (Mini-PAM, Walz, Germany), specifically to determine the ratio of variable to maximum fluorescence ($F_v/F_m$) as an indicator of maximum intrinsic light-use efficiency.

We measured leaf $^{13}C/^{12}C$ isotope ratios, a time-integrated measure of intrinsic WUE (water-use efficiency, = photosynthesis/conductance) on shoot tips collected in May 2012. WUE measured with isotopes provides a compliment to WUE measured instantaneously via gas exchange (described above), with the latter measure also reflecting aerodynamic and leaf microclimate effects. Isotopic analyses were done on a Costech flash combustion EA and Picarro cavity ring down spectrometer at the USGS Snake River Field Station. $^{13}C/^{12}C$ of samples relative to a standard (Pee Dee Belemnite) is reported using delta notation, with more negative values indicating a sample more depleted in $^{13}C$. We compared WUE measures with plant growth and survival and with each provenance's climate of origin (spline model, Rehfeldt 2006). All carbon analyses here were led by B. Lazarus at the USGS.

In August 2012, we sowed seeds of twelve genotypes into cone-tainers filled with native mineral soil and placed them in a shady outdoor garden in Boise (Table 1). The selected populations provide comparisons of subspecies, local adaptation, genotypes that differ in climate of origin, and ploidy. We observed reasonably high germination of 3-year old seed and in November we outplanted these to five areas burned in 2012 in the Birds of Prey National Conservation Area (the Swan, Coyote, Kave, South Point, and Pen fires). In each burn area, we constructed a 2.4-m x 2.4-m passive warming treatment using an open-sided chamber design, which increases nighttime plant and soil surface temperatures by several degrees Celsius. Plots were fenced and instrumented to measure air temperature in addition to the temperature and water content of the soil at several depths.

Preliminary Results

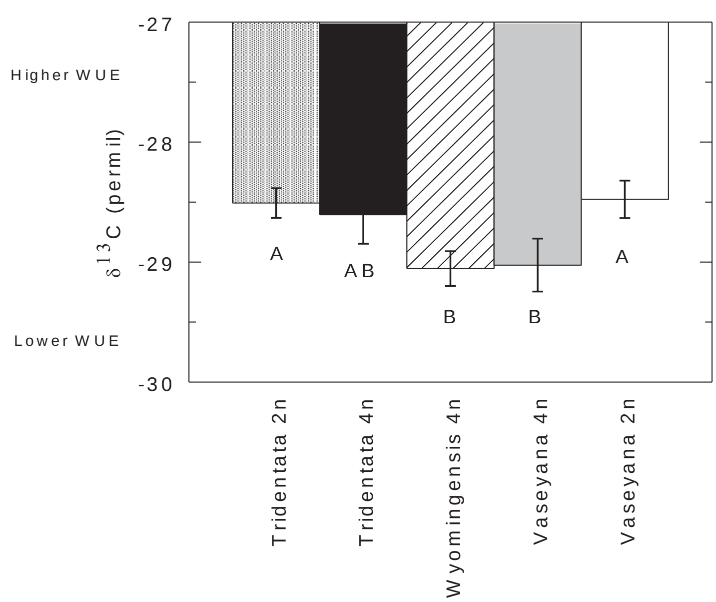
*Water-use Efficiency Indicated by Carbon Isotopes at Orchard, ID*

Only small differences in WUE were evident among subspecies and ploidy levels: WUE was lowest in tetraploid *A .t. vaseyana* and *wyomingensis*, and greatest in diploid *A. t. tridentata* and *vaseyana*, Figure 1). There was much greater variation in WUE among provenances (Figure 2) than among subspecies (Figure 1), i.e., greater variation among populations within a subspecies/ploidy level than between subspecies.

**Table 1.** Genotypes (provenances or populations) successfully outplanted and also seeded into five 2012 wildfires in the Birds of Prey National Conservation Area. At each wildfire site, planting and seeding was done into either control plots or plots that are experimentally warmed by passive warming chambers.

| Provenance | State | Block in Study | Subspecies | Climate of Origin | Ploidy |
|---|---|---|---|---|---|
| IDT-2 | ID | Warmed+Control | *tridentata* | Local region | 2N |
| BOP-W | ID | Warmed+Control | *wyomingensis* | Local site | 2N |
| IDV-2 | ID | Warmed+Control | *vaseyana* | Local region | 2N |
| NMT-2 | NM | Control | *tridentata* | Warm/Dry | 4N |
| UTT-1 | UT | Control | *tridentata* | Cool/Wet | 2N |
| IDW-2 | ID | Control | *wyomingensis* | Local | 2N |
| ORT-2 | OR | Control | *tridentata* | Warm/Dry | 2N |
| MTW-3 | MT | Control | *wyomingensis* | Cool/Wet | 2N |
| ORV-1 | OR | Control | *vaseyana* | Cool/Wet | 4N |
| IDW-3 | ID | Control | *wyomingensis* | Warm/Dry | 2N |
| IDV-3 | ID | Control | *vaseyana* | Cool/Wet | 2N |
| CAT-2 | CA | Control | *tridentata* | Warm/Dry | 2N |

**Figure 1**. Mean (± SE) water use efficiency (WUE – determined with carbon isotopes) of big sagebrush subspecies grown in a common garden. Letters denote T-test separation following 1-way ANOVA at alpha = 0.05. Data produced with. Data produced with B. Lazarus.



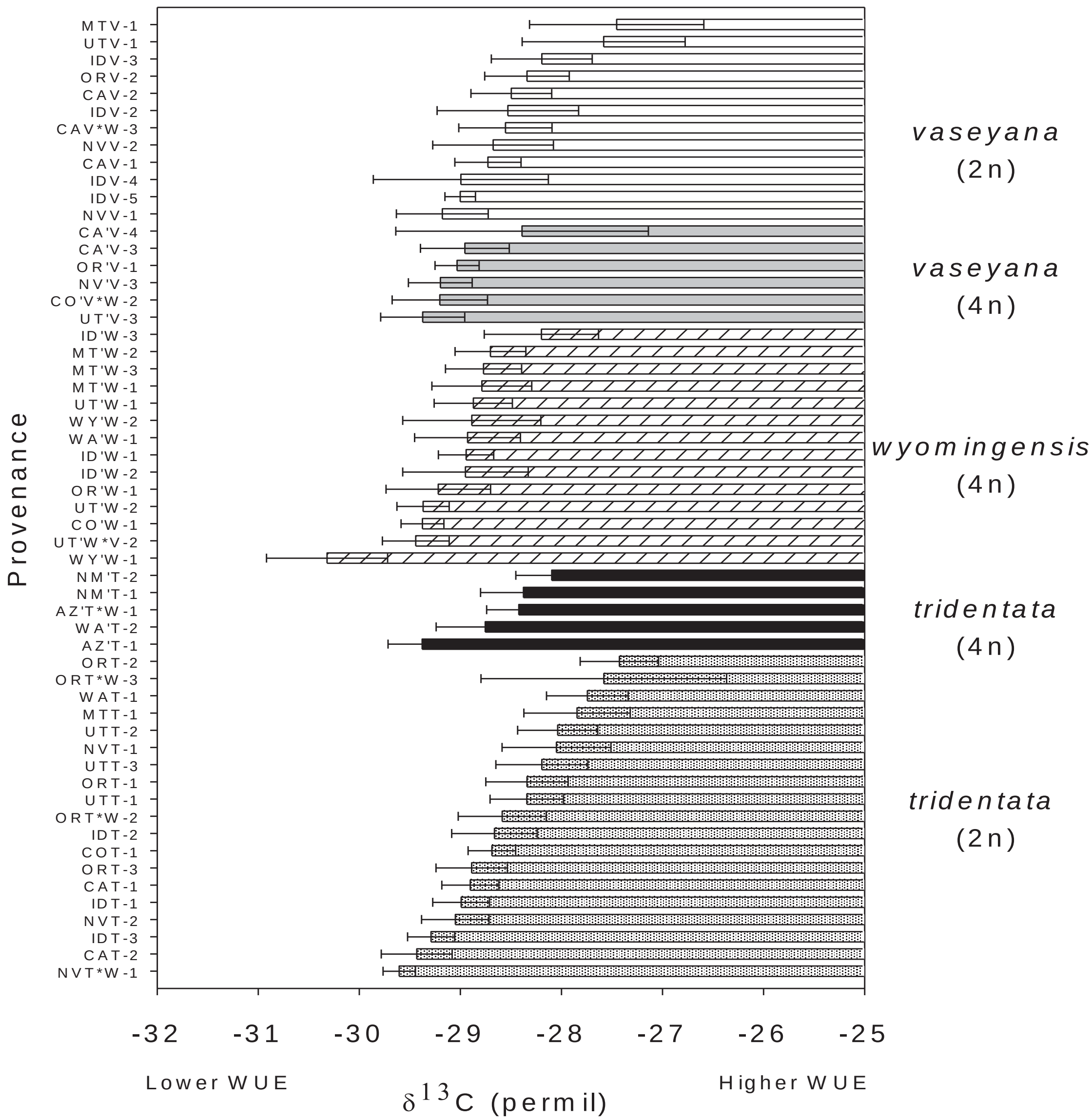



**Figure 2.** Mean (± SE) WUE of big sagebrush provenances organized by subspecies and ploidy levels. Means ± SE are of all plants per provenance in the Orchard garden.

Tetraploid provenances that originated in warmer climates showed higher WUE (Figure 3). No relationship between climate of origin, moisture, or temperature was observed for diploid provenances.

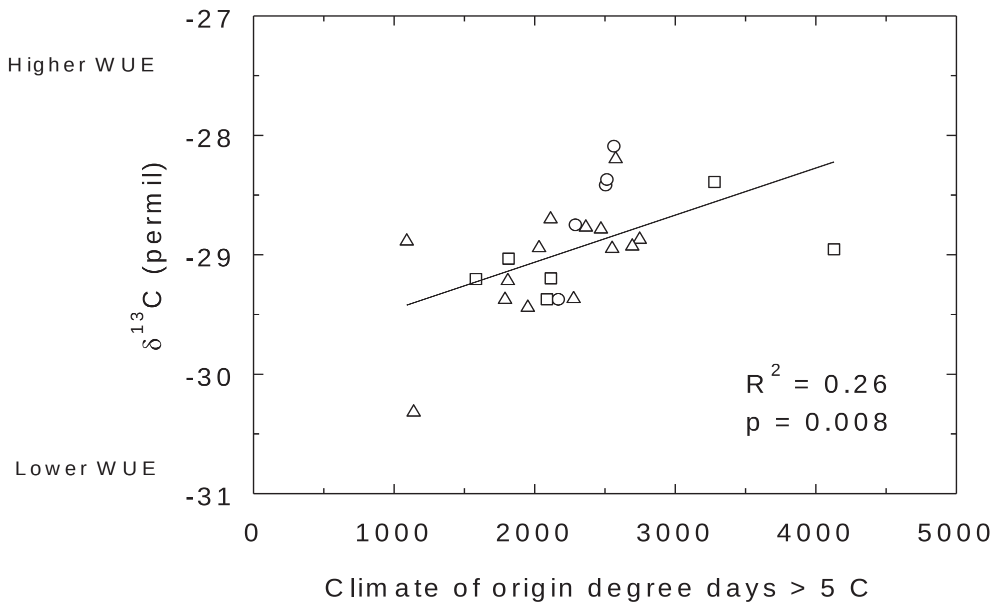



**Figure 3.** Relationship of WUE determined from carbon isotopes to the temperature of the geographic origin of seeds, for tetraploid (4n) provenances. Temperature is represented as the number of annual degree days > 5$^0$C (a measure of growing season warmth). (Each datum is the mean for a provenance (population). Squares are *A. t. vaseyana*, triangles are *A. t. wyomingensis,* and circles are *A. t. tridentata*.

Tetraploid provenances with higher WUE were also taller (Figure 4). No such relationship existed for diploids. Provenances with higher WUE had a broad mortality range (low-high), while those with lower WUE had lower mortality (Figure 5). Although plants from provenances that grew taller also had greater WUE, WUE was not positively related to survival, and the subspecies considered most drought adapted did not have the greatest WUE. Greater physiological variability within compared to among subspecies points to the importance of seed origins for restoration, particularly with 4N subspecies like Wyoming big sagebrush. Local adaptation in WUE is more prevalent in 4N compared to 2N populations, at least in the Orchard, ID common garden. Richardson et al. (2013) suggest that 4N genotypes may have originated from 2N mountain and basin big sagebrush. Wyoming big sagebrush in particular appears polyphyletic and tending to be derived from local basin or mountain sagebrush. These data thus point to a hypothesis that local adaptation has increased during the diversification of big sagebrush.

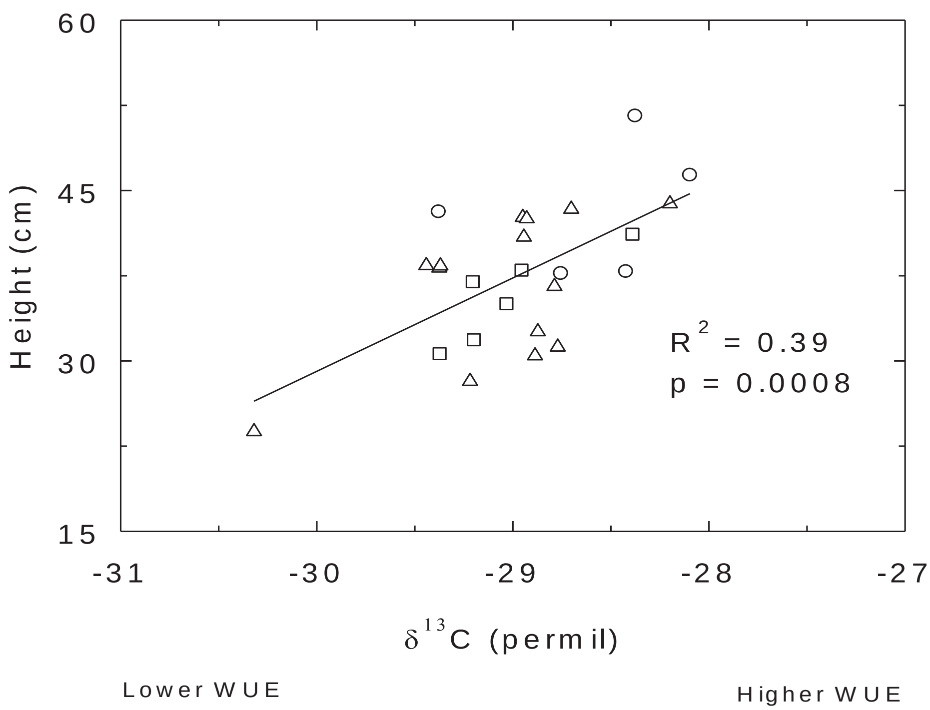



**Figure 4.** Relationship of shrub height to WUE determined from carbon isotopes, for tetraploid (4n) provenances (note that diploid provenances showed no significant relationship for these variables). Each datum is the mean for a provenance. Squares are *A. t. vaseyana*, triangles are *A. t. wyomingensis,* and circles are *A. t. tridentata*.

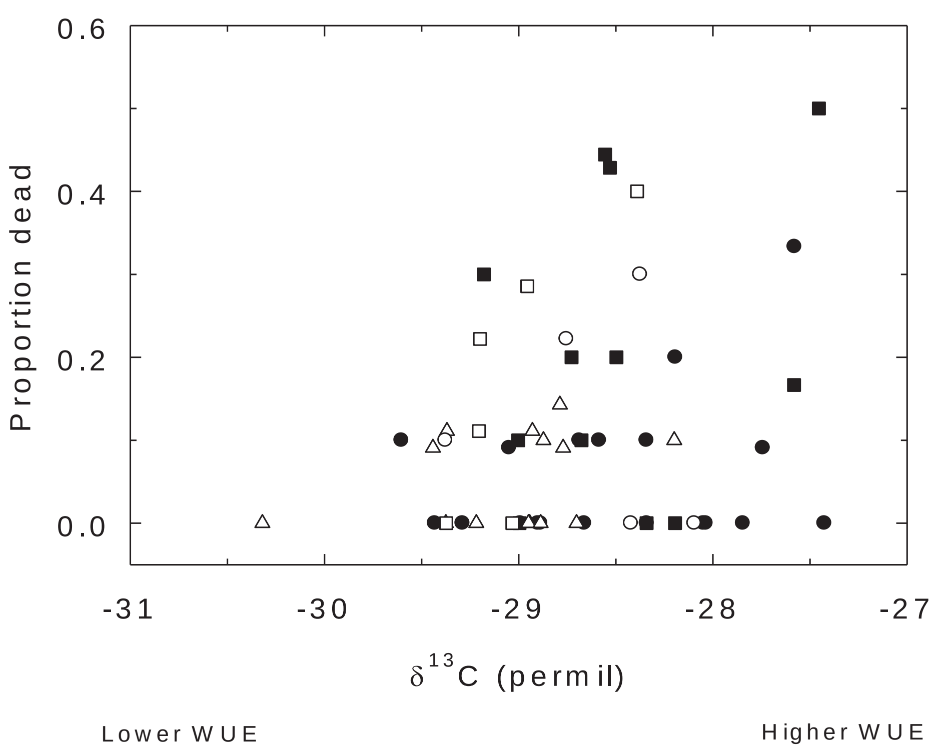



**Figure 5.** Relationship of survival to WUE determined from carbon isotopes for all subspecies and provenances (each represented by a datum showing the respective mean). Squares are *A. t. vaseyana*, triangles are *A. t. wyomingensis,* and circles are *A. t. tridentata*. Open symbols are tetraploid (4n) and closed symbols are diploid (2n).

*Test for Local Adaptation in Reciprocal Measurements at All Three Gardens*
In June 2012, we performed a test of local ecophysiological adaptation by asking if the populations (genotypes) of big sagebrush that were most local to each garden exhibited greater ecophysiological performance and less stress response than populations from the other gardens. Specifically, Wyoming and basin big sagebrush are the subspecies that naturally occur in the Orchard, ID, garden, and we asked if the most local seed source of each (IDW1 and IDT1, respectively) had greater performance and less stress than the seed sources of these subspecies that were most local to the Ephraim and Majors Flats, UT, gardens (which are relatively close together; UTW2, UTT1). The Ephraim garden would support basin big sagebrush if the site were in an undisturbed and natural condition, and so we asked if UTT1 had greater performance and less stress response than IDT1 in that garden. Mountain big sagebrush is the natural big sagebrush type for Major Flats, and there we asked if that seed source (UTV1) had greater performance and less stress response than that of the Idaho seed source (IDV2).

Photosynthesis was not greater in local genotypes, in any comparisons made (Figure 6). At the Orchard garden, photosynthetic carbon gain was not greater for local genotypes in either Wyoming (local = 8.27 ± 0.9, Utah = 8.23± 0.93 $\mu mol\ m^{-2}\ s^{-1}$) or basin big sagebrush (local = 7.1 ± 0.84, Utah = 8.23 ± 1.23 $\mu mol\ m^{-2}\ s^{-1}$). In the Ephraim garden, local basin big sagebrush had 5.9 ± 2.2 $\mu mol\ m^{-2}\ s^{-1}$ compared to 7.4 ± 1.6 $\mu mol\ m^{-2}\ s^{-1}$ from the distant Idaho genotype. At Majors Flat the local and distant Idaho seed sources did not differ (13.4 ± 2.6 verses 12.9 ± 1.6 $\mu mol\ m^{-2}\ s^{-1}$), respectively.

We did not observe local genotypes to have greater water status or differences in stomatal conductance or transpiration compared to distant genotypes. However, at the Orchard garden, local genotypes of Wyoming and basin big sagebrush had 19-25% greater WUE and, associated with this, maintained a steeper gradient of [$CO_2$] between the air and inside leaves (by 40 ppm, with ambient [$CO_2$] near 400 ppm; $p < 0.05$ for ANOVA). In the Ephraim and Major Flat gardens, there were no differences among local and distant genotypes for any of these parameters.

The differences in WUE among local and distant genotypes at Orchard, indicated by direct measurement of gas exchange, were not consistent with a lack of differences in WUE as measured by carbon isotopes (Figures 2 and 6). The isotopic composition of carbon in plants reflects carbon assimilated over long time scales, up to the life of the plant, whereas the gas exchange approach is a snapshot of physiology at the time of measurement. In this case, we measured gas exchange at the onset of summer drought in midsummer, but carbon is gained by sagebrush over much of the year. Thus, key differences in water-use efficiency among genotypes may occur mainly during summer.

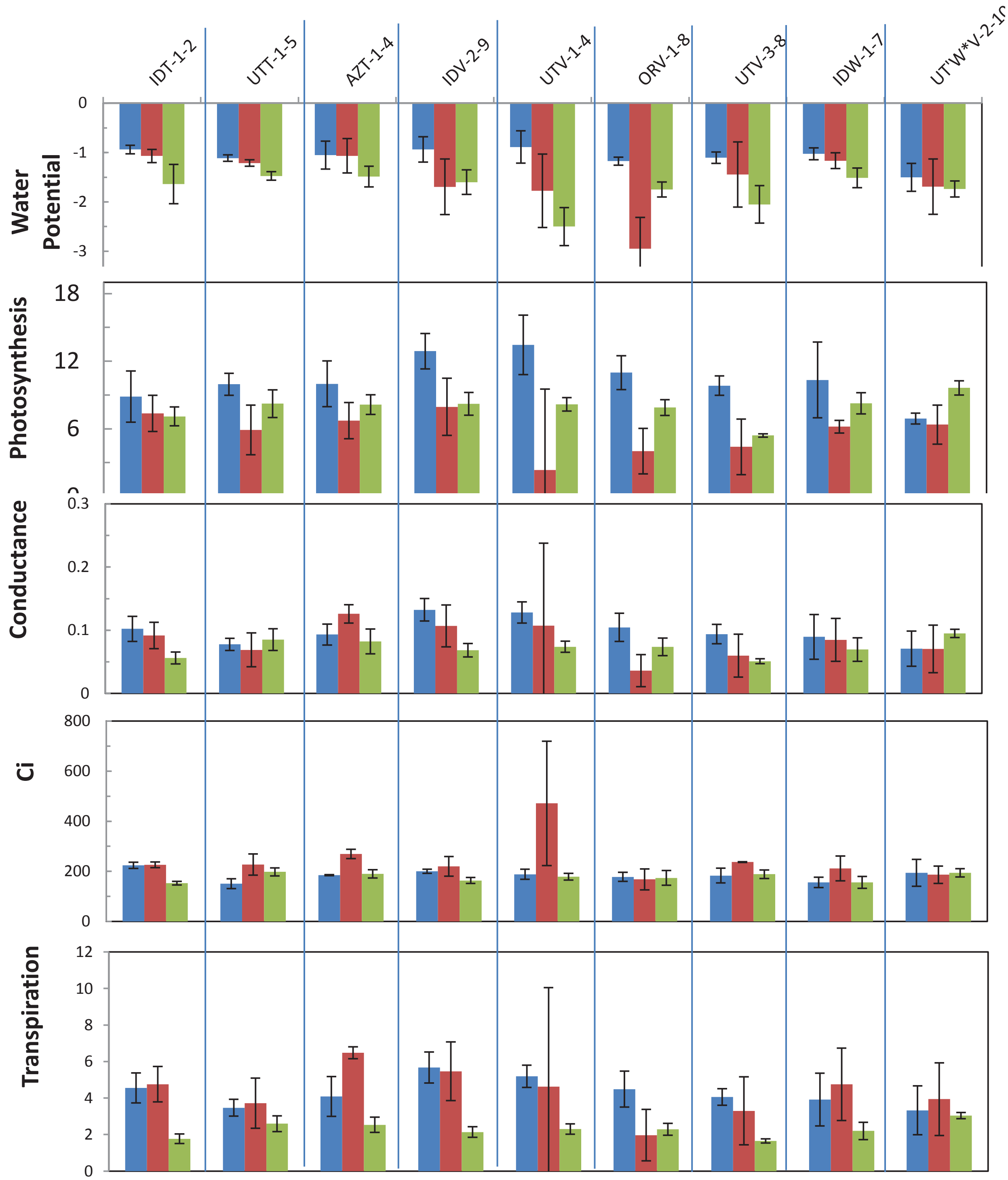



**Figure 6.** Ecophysiological properties of big sagebrush genotypes measured at the Major Flats (blue, left bars in each panel), Orchard (green, right bars in each panel), and Ephraim (red bars) gardens in June 2012. Values are means of three to five plants per population (genotype) and garden, errors are SE. Units are as described in Table 2.

*Test for Ploidy Effects across All Three Gardens*

We compared water status, specific leaf area, and photosynthetic performance in three tetraploid and three diploid genotypes in each of the three gardens in June 2012 (three to five replicate plants per population). We hypothesized that the tetraploid plants would exhibit properties that confer greater stress resistance, such as greater WUE (photosynthesis/transpiration) and $C_i$ less stomatal conductance, and less specific leaf area. $C_i$ is $[CO_2]$ inside leaves and indicates stomatal constraints relative to carbon demand, thus affecting WUE. Specific leaf area represents a direct tradeoff in photosynthesis (growth) and stress resistance, with lower values generally indicative of stress acclimation.

There were no differences between ploidy levels in water potential, photosynthesis, conductance, $C_i$, transpiration, and specific leaf area, which are not consistent with the prediction of greater stress resistance in tetraploids (Table 1). There was 15% greater WUE (photosynthesis/transpiration) in tetraploids, providing slight support for the prediction.

**Table 2.** Ecophysiological parameters in tetraploid (4n) and diploid (2n) big sagebrush. Values are means of the average values for each genotype in each garden (n = 3 gardens) in June 2012. Units are MPa for water potential (measured at pre-dawn), µmol $m^{-2}$ $s^{-1}$ for photosynthesis, mol $m^{-2}$ $s^{-1}$ for conductance (stomatal), ppm for $C_i$ ($[CO_2]$ inside leaves), mol $m^{-2}$ $s^{-1}$ for transpiration, and $cm^2/g$ for specific leaf area. Statistical significance of differences between the ploidy levels according to T-tests are shown on the bottom rows.

| | **Water Potential** | **Photosynthesis** | **Conductance** | **Ci** | **Transpiration** | **WUE** | **Specific Leaf Area** |
|---|---|---|---|---|---|---|---|
| ***4n*** | | | | | | | |
| AZT1 | -1.27 | 9.07 | 0.088 | 187 | 3.31 | 2.74 | 4.04 |
| ORV1 | -1.96 | 7.63 | 0.072 | 173 | 2.92 | 2.62 | 4.83 |
| UTV3 | -1.53 | 6.55 | 0.068 | 203 | 3.00 | 2.18 | 3.64 |
| **mean** | **-1.59** | **7.75** | **0.08** | **188** | **3.08** | **2.52** | **4.17** |
| **SE** | **0.20** | **0.73** | **0.01** | **9** | **0.12** | **0.17** | **0.35** |
| ***2n*** | | | | | | | |
| UTT1 | -1.27 | 8.03 | 0.077 | 192 | 3.26 | 2.46 | 4.01 |
| IDV2 | -1.41 | 9.69 | 0.103 | 194 | 4.42 | 2.19 | 3.81 |
| UTV1 | -1.72 | 7.99 | 0.103 | 279 | 4.04 | 1.98 | 4.87 |
| **mean** | **-1.47** | **8.57** | **0.09** | **222** | **3.91** | **2.19** | **4.23** |
| **SE** | **0.13** | **0.56** | **0.01** | **29** | **0.34** | **0.14** | **0.33** |
| **t** | -0.55 | -0.86 | -1.27 | 1.58 | -1.8 | 4.60 | 0.2 |
| **P** | 0.32 | 0.24 | 0.17 | 0.12 | 0.1 | 0.02 | 0.47 |

*New Sagebrush Seedling Experiment*

In November, 4-month old cone-tainer stock were outplanted into plots containing our sagebrush genotypes and they demonstrated relatively high initial survival as of December 2012. Prior to outplanting in November and following several nighttime frosts and high sunlight exposure, we measured chlorophyll fluorescence on all populations. The ratio of variable to maximum fluorescence emitted from leaves, $F_v/F_m$, indicates light-use efficiency and thereby health and stress level of leaves (maximum value = 0.8). Lower values of $F_v/F_m$ indicate plant stress. Preliminary data from our rearing experiment suggest local adaptation to climate in sagebrush seedlings is more evident than in adults (Figure 7).

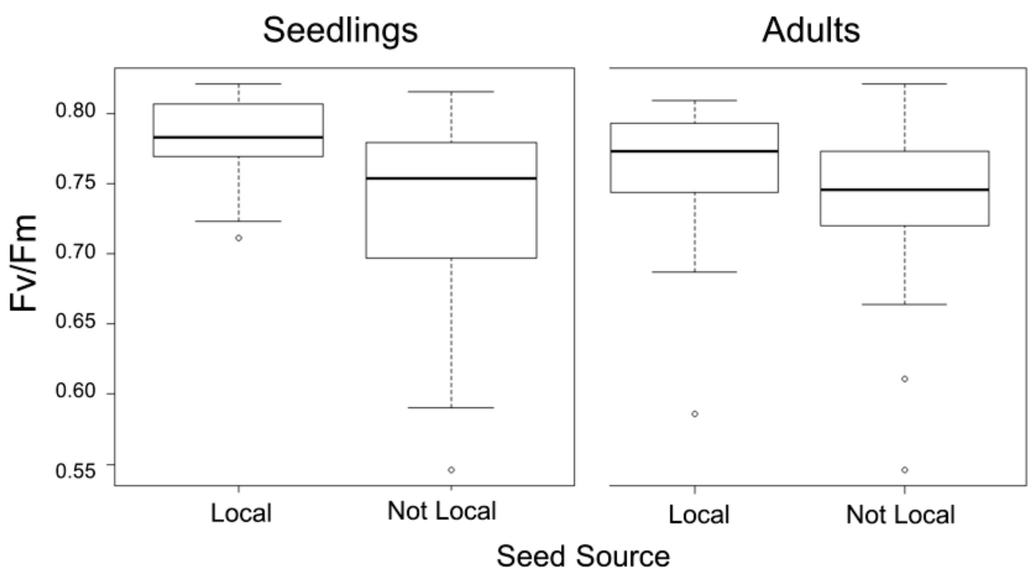



**Figure 7.** Photochemical light-use efficiency determined by chlorophyll fluorescence following a darkening treatment. Seedlings on 2012 October 25 demonstrated a significant difference in $F_v/F_m$ as a result of seed origin, $F_{1,48}$=8.59, $p < 0.01$. Adult sagebrush demonstrated no significant differences on 2011 November 11, $F_{1,68}$=1.28, $p = 0.26$. Data produced with M. Brabec.

<u>Future Plans</u>

We will test the hypothesis that access to deeper and wetter soils improves water status and the photosynthesis and growth of the top-performing populations using a stable isotope approach. We will match ratios of the stable isotopes of water (D:H and 18O:16O) in the xylem of all plants to the same ratios of different water sources (from shallow and deep soils). The isotopic composition of water in stem xylem is the same as the water source, so a mixing model can be used to determine water source. Accomplishment of these analyses will require some refinement of our new Picarro laser spectrometer approach for measuring water isotopes, particularly in standardizing the measurements. We hypothesize that top performers will not express a water-efficient strategy, but instead will have an isotopic signature that suggests an advantage of access to abundant deep soil water derived from winter and spring rain.

We will measure germination and new seedling responses to the climate treatments that have been established in the BOP NCA. We are planning to outplant our remaining seedlings into a related USGS/Joint Fire Sciences project in the BOP NCA that has created very large treatments of mowing, seeding, grazing, and herbicide application.

## Publications

We have just completed the majority of analyses planned on the established common-garden plants, and several manuscripts are in preparation for submission in 2013.

## Presentations

Germino, M. J. 2012. Field presentation at the Utah Chapter for Society for Range Management and Society for Ecological Restoration Field Tour and Summer Meeting, 2012 June 19, Epphraim, UT

Germino, M. J.; Vanderveen, J.; Svenson, L.; Richardson, B. 2012. Differences in ecophysiology and climate responses among subspecies and provenances of big sagebrush: implications for seed selection. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT.

## Management Applications and Seed Production Guidelines

Our short-term dataset is still in the preliminary stage, but the analyses may serve a key role in helping project long-term likelihood of growth and establishment of plants from different seed sources. Sagebrush restoration is increasingly of interest for conservation of sagebrush-dependent wildlife, and our results will soon compliment other evidence to begin establishing bases for seed-transfer guidelines. Our research is indicating that inferences on sagebrush genetic adaptation should be drawn from multiple gardens and be from both young establishing seedlings as well as established, mature plants.

## Products

- Two substantial efforts to leverage the project were made by the U.S. Geological Survey Forest and Rangeland Ecosystem Science Center because the research meets a priority need for solving landscape-level problems in the Great Basin.
  1) Additional technician salary funds were provided in the form of an equivalent match, which is key because there are many plants in the common garden (ca. 450) and the measurements and subsequent data management and analyses are time consuming.
  2) Grant funds from the USGS Climate Science Center were applied for and obtained, enabling construction of the climate experiment at the BOP NCA.

**Project Title** Evolution of Native Plants in Cheatgrass Invaded Systems

**Project Agreement No.** 10-CR-11221632-104

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**Project Description**

Objectives

While the invasion of cheatgrass (*Bromus tectorum*) has resulted in the loss of native plant diversity across the Great Basin, there are areas where remnant native plants persist in even highly invaded environments. This research was designed to ask if these remnant plants represent opportunities for restoration. If they are persisting because of particular traits that are adaptive in cheatgrass-invaded environments, they may serve as valuable sources of restoration material.

We examined populations of five common native perennial grass species (Sandberg bluegrass, [*Poa secunda*], big squirreltail [*Elymus multisetus*], Indian ricegrass [*Achnatherum hymenoides*], needle and thread [*Hesperostipa comata*], and Thurber's needlegrass [*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 cheatgrass competition? 2) Which species exert the strongest competitive effect on cheatgrass? 3) Does native plant phenology differ between invaded and uninvaded populations? and 4) Are tolerant and/or competitive plants present in higher frequencies in invaded compared to uninvaded 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 cheatgrass while the other was grown alone, and we measured tolerance (ability to maintain size) and competitive ability (the ability to reduce size of cheatgrass) for each plant (Figure 1).


**Figure 1.** Competition experiment between native grasses and cheatgrass. These two plants are pieces of the same individual, collected from the wild and divided into two pieces. One half (left) was grown alone, while the other half (right) was grown with competition from cheatgrass. Using this design, we could determine when native species most affected the biomass of cheatgrass, and which native species were the most tolerant of competition.

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 cheatgrass competition than uninvaded populations. Sandberg bluegrass and one population of big squirreltail had the strongest suppressive effect on cheatgrass, and these two species were the only ones that flowered when grown with cheatgrass. The ability to tolerate competition (maintain a large size) was not always related to the ability to suppress cheatgrass, indicating that different traits may be involved in tolerance and competitive ability in this system.

Conclusions

Our study indicates that response to cheatgrass 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 cheatgrass invasion within the Great Basin. We found differences in the way species and populations of the same species performed with an invasive competitor, indicating that carefully choosing restoration plants with desired effects could improve restoration success in the Great Basin. Including a mix of species, some which are good at tolerating cheatgrass competition and others that are good at suppressing it, may be the most effective way to restore 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 these populations may be evolving in response to cheatgrass. Studies have shown similar results with other natives responding to exotic invasive competitors (Callaway et al. 2005, Mealor and Hild 2007, Lau 2008, Leger 2008, Cipollini and Hurley 2008, Ferrero-Serrano et al. 2010). In addition to considering adaptation to climatic factors in seed source selection, field performance in highly invaded areas should be a criterion for deciding which populations will be used for restoration.

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**Products**

- Research highlighted in: Ogburn, Stephanie. 2012. Weed Wackers. High Country News. September 2012: 16-20.

**Project Title** Globemallow and Big Sagebrush Performance under Varying Conditions

**Project Agreement No.** 09-JV-11221632-067

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**Project Description**

*Big Sagebrush Seedling Cold Storage*

Objectives

Limited information is available on nursery cultural and production practices for big sagebrush (*Artemisia tridentata*). In response to a request from growers of big sagebrush in the Intermountain West, a study was designed to investigate seedling overwinter cold storage, which is an important component of seedling production that can impact seedling quality. We hypothesized that seedling quality after transplanting would not be impacted by storage method, but that mold issues were more likely to occur in cooler storage.

Methods

One hundred seedlings were randomly placed in either refrigerated cooler (2 to 4°C) or freezer storage (0 to -2°C). Seedlings were placed in storage for 2 months beginning March 2011. On May 2011, seedlings were transplanted into 3.8 L pots containing 2:1 sand: vermiculite and watered every 5 days. After 2 months of growth in a greenhouse at the University of Idaho Pitkin Forest Nursery, Moscow, Idaho, the study was terminated. Morphological parameters measured and calculated included: height growth, root-collar diameter (RCD) growth, shoot volume growth (Burdett 1979), and root and shoot dry weights.

Results and Future Directions

Results of an analysis of variance (ANOVA) showed that storage treatment had no effect on any of the morphological parameters measured; however seedling mortality was higher for freezer-stored seedlings. Based on our results, overwinter storage in a cooler can be recommended for big sagebrush seedlings. Freezer storage may inhibit the growth of storage molds, but further study is needed to determine the appropriate hardening regimes and lifting dates for this storage method.

*Variation in Wyoming big sagebrush*

There is limited information on within-subspecies variation of big sagebrush, which is a keystone species in Great Basin ecosystems. To address this gap in the literature, two studies were conducted that evaluated phenotypic variation in Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*).

One study evaluated morphological and physiological differences between seedlings grown from seed collected from one mother plant at each of five locations within the range of Wyoming big sagebrush. Five 1-year old seedlings were transplanted into 9.63 L pots containing 2:1 sand: vermiculite. Height growth, RCD growth, root and shoot volume growth, specific leaf area, and seedling dry weights were measured 4 months after transplanting. Biweekly gas exchange measurements were also made. Data analysis is forthcoming.

A second study evaluated the morphological response of transplanted Wyoming big sagebrush seedlings to water treatments. Seedlings were grown from seed collected from two mother plants at each of five locations within the range of Wyoming big sagebrush. One-year old seedlings were randomly placed in either a fully saturated treatment or a "dry" treatment that received 20% that amount of water, and were transplanted into 5.05 L pots that were 76.2 cm tall and contained 2:1 sand: vermiculite. Seedlings in both treatments were watered biweekly. Volumetric water content of the soil was monitored throughout the 4-month study. At the end of the study, height growth, RCD growth, predawn water potentials, root volume growth, and shoot dry weights were measured. To further assess root structure, root dry weights were obtained after roots were partitioned into three sections (0-25 cm, 25-50 cm, and greater than 50 cm). Data analysis is forthcoming.

*Globemallow: Seed Dormancy and Seedling Physiology*

Introduction

Munro's globemallow (*Sphaeralcea munroana* [Douglas] Spach; Malvaceae), an herbaceous perennial endemic to the Great Basin, is an important candidate for use in restoration. This species tolerates drought, extreme temperatures, and establishes on a variety of soil types. It is an effective soil stabilizer, serves as an important host for native pollinators, and is a food source for numerous animals (Beale and Smith 1970; Pendery and Rumbaugh 1986; Rumbaugh et al. 1993; Pavek et al. 2011). The species' popularity among growers and land managers has recently increased but there is still a lack of information regarding seed dormancy and early seedling physiology, making the effective use of the species difficult.

Objectives

1. To understand dormancy mechanisms in seeds of Munro's globemallow.
2. To evaluate the feasibility and efficiency of various dormancy breaking techniques.
3. To evaluate the morphological and physiological characteristics of Munro's globemallow seedlings in response to a range of temperature and moisture conditions during early establishment.

Seed Dormancy and Germination Trials

Four studies designed to investigate the dormancy mechanisms of Munro's globemallow seed and evaluate the suitability of non-traditional scarification techniques for operational use were conducted. Specifically, for the first two experiments, seeds were collected in August 2010 near Payette, Idaho (N 43° 52' 49.6", W 116° 47' 01.8"), and kept at 21 ± 1°C to avoid the possibility of stratification during refrigerated storage. Experiments three and four used seeds obtained from native stands throughout the Wasatch mountains of northern Utah (Great Basin Seeds LLC, Ephraim, UT) and stored at 1.5 ± 0.5°C. All treatments had five, 50-seed replicates except those in experiment one, which had ten 15-seed replicates.

Experiment 1: To ensure that seeds were indeed physically dormant and evaluate the effects of two scarification treatments on increasing seed permeability, we compared seed water uptake after exposure to three treatments: 1) control, 2) mechanical scarification with a sharp blade, and 3) boiling water scarification achieved by a 10-second submergence in 100°C water (Kildisheva et al. 2011). Seeds in each replicate were weighed to the nearest 0.1 mg and re-weighted at 1 hour intervals for 10 hours and once at the end of the 24-hour observation period (Gama-Arachchige et al. 2010). Seed mass increase, expressed as a mean percentage, was calculated. Subsamples of control, mechanically scarified, and boiling water scarified seeds were scanned with a scanning electron microscope. To understand the morphological changes in the seed coat (i.e., whether the boiling water treatment effectively opened the water gap located in the chalazal region of the seed), the chalazal region and the dislodged chalazal cap were observed and photomicrographed.

Experiment 2: We compared germination of fresh (recently collected) seeds after exposure to: 1) control, 2) mechanical scarification, 3) stratification, or 4) combined scarification + stratification treatments. Mechanical scarification procedures were consistent with those mentioned above. Seeds were stratified at 4.5 ± 0.02° C for 6 weeks on moistened germination paper inside sealed Petri dishes (Kildisheva et al. 2011).

Experiment 3: In order to evaluate the effects of scarification, water, and gibberellic acid on germination we subjected seeds to eight treatments: 1) control; 2) mechanical scarification; soak in 100 ppm $GA_3$ solution for 3) 24-h or 4) 48-h; scarification plus 5) 24 h or 6) 48 h soak in DI water; and scarification plus 7) 24 h or 8) 48-h soak in 100 ppm $GA_3$ solution (Kildisheva et al. 2011).

Experiment 4: To investigate the effects of "non-traditional" scarification which can be employed for large-scale seed treatment, we subjected fresh seeds to a 1) control; 2) boiling water (10 sec submergence in 100°C); 3) tumbling; 4) burning; 5) dry-heat; or 6) burning + dry heat scarification treatments. Seeds were tumble-scarified in a rotary rock tumbler with dry aluminum oxide grit for 72 h (Kildisheva 2011; Kildisheva et al., submitted). Following tumbling, seeds were separated from grit using a series of sieves (Dreesen 2004). For burning scarification, seeds were placed onto a metal mesh screen in a single layer, submerged uniformly in 95% ethyl alcohol ($C_2H_5OH$) for 1 min, placed on a fire-resistant surface, ignited with a hand-held butane torch, and allowed to burn for 10 sec before being extinguished with deionized (DI) water (Sugii 2003; Kildisheva et al., submitted). For dry-heat scarification seeds were subjected to 80°C for 60 min (Baskin and Baskin 1997). Seeds in the burning + dry-heat scarification treatment were burned first.

General Findings

Results indicate that Munro's globemallow seeds are physically dormant due to the impermeability of the seed coat and the presence of a cap structure covering the water gap, which must be dislodged so imbibition can take place. A significant increase in germination was documented across all experiments following scarification. We observed no evidence for additional dormancy types, with both stratification and $GA_3$ failing to improve germination compared to scarification alone. Irrespective of treatment, maximum imbibition was reached after 7 h, but mass gain was highest for mechanically scarified seeds. Although mechanical scarification and scarification + DI water achieved the highest germination across all studies, submergence of seed in boiling water resulted in 49% germination and can be a feasible method for operational seed treatment.

Influence of Various Temperature and Moisture Regimes on Early Establishment and Growth of Munro's Globemallow

Munro's globemallow seeds were collected from five locations throughout Oregon and Idaho, bulked, mechanically scarified to break dormancy, and sown into 66 ml containers (Model RLC4, Stuewe and Sons, Inc., Tangent, OR, U.S.A.) (Kildisheva et al. 2011; Kildisheva and Davis, in preparation). Following germination, a one-time application of 18-24-16 (N-P-K) fertilizer (Water Soluble Rose Plant Food, Scotts Co., Marysville, OH, U.S.A.) was administered to all containers at a rate of 3.8 mg N per plant. Treatments included four moisture (3-, 6-, 9- and 12-day intervals between recharging each container to field capacity) and two diurnal temperature (17/3°C or 23/9°C) treatments. Each temperature x moisture treatment combination was randomly assigned to 20 seedlings that remained under these growing conditions for 25 days. Mortality, physiological (photosynthesis, stomatal conductance, and transpiration), as well as morphological (number of true leaves, leaf area, above- and below-ground biomass, and root-to-shoot ratios) assessments were made at the end of the 25-day period.

Under the tested scenarios, low temperatures (17/3°C) impeded plant growth, largely due to a reduction in the belowground growth. Root growth was influenced by moisture availability and temperature, but under cool conditions the temperature influence surpassed the influence of moisture. Plants grown under the warmest, driest conditions (23/9°C and 12-day irrigation interval) reduced shoot but increased root production. None of the tested gas exchange parameters were significantly affected by the imposed temperature and moisture conditions. Our findings suggest that even during early establishment, seedlings of Munro's globemallow are drought tolerant. It seems reasonable to assume that because cool night temperatures inhibit growth to a greater extent than the reduction in moisture, a later sowing date (analogous to 23/9°C diurnal conditions) may enhance the establishment of Munro's globemallow (Kildisheva 2011; Kildisheva and Davis, in preparation).

Future Research Recommendations

- Trials with boiling water and other forms of scarification are necessary to further improve the germination and seed handling practices of Munro's globemallow seeds.
- Because seeds that were previously stored germinated better, it is essential to understand which factors (environmental conditions during seed set, seed moisture content, storage temperature and duration, or additional cleaning procedures) caused this germination improvement.
- Although boiling scarification was effective at breaking dormancy and is an appealing option for operational use, it is still unclear whether seeds could be treated prior to planting and stored for a period of time, without a loss of viability. It is also unclear how pre-treated seeds will respond following planting, especially if growing conditions are not favorable for establishment at sowing time.

- Field observations which evaluate plant responses to environmental conditions during the entire life cycle are necessary.

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Kildisheva, O. A.; Davis, A. S. [Submitted]. Temperature and moisture influence on early growth of *Sphaeralcea munroana* seedlings. Ecological Restoration.

Overton, E. C.; Pinto, J. R.; Davis, A. S. [Submitted]. Insights into big sagebrush seedling storage practices. Native Plants Journal.

**Presentations**

Overton, E. C.; Davis, A. S. 2011. Enhancing native plant seedling handling practices using forest nursery methods. Society of American Foresters National Convention, 2011 November 2-6, Honolulu, HI.

**Management Applications and Seed Production Guidelines**

Information on big sagebrush seedling overwinter storage can be used by Growers to aid in the production of high quality seedlings, which may limit mortality at outplanting.

Evaluating trait variation in Wyoming big sagebrush can aid in understanding of differences in growth patterns that may occur between populations on the landscape.

Munro's globemallow seeds exhibit physical dormancy, which is best relieved by mechanical (93%) or boiling water (49%) scarification. Additional cleaning and dry cold storage may benefit seed germination.

Munro's globemallow shows considerable potential for restoration use on arid sites, but is negatively affected by low temperatures( ≤ 17/3°C), which could make it a poor competitor with cool season grasses during the establishment phase.

As a result of growth reduction due to cool temperatures, a later sowing date may improve establishment in nurseries, seed production areas, and restoration sites.

**Products**

- Presentations were given at seedling grower meetings to share the information on refining cultural practices for the growth and storage of big sagebrush seedlings. This information has also been submitted for publication in Native Plants Journal.

**Project Title** Banking Wyoming Big Sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) Seed

**Project Agreement No.** 12-IA-11221632-149

**Principal Investigators and Contact Information**

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**Project Description**

National Seed Laboratory Overview

The National Seed Laboratory (NSL), Dry Branch, GA, is developing seed cleaning, testing and storage protocols for species selected by 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.

Banking Wyoming Big Sagebrush Seed

Big sagebrush (*Artemisia tridentata*) seed supplies are variable and tentative in any year because they are collected from wild stands influenced by interannual variability in environmental conditions. In addition, viability of big sagebrush seed declines rapidly in warehouse storage. Because of increasing demand for large quantities of site-adapted Wyoming big sagebrush seed for uses including post-fire rehabilitation and sage-grouse habitat improvement is increasing, improved techniques for maintaining the viability of seed harvested in good production years is needed to provide more economical and genetically appropriate seed supplies.

To examine this problem, we procured five commercially produced seed lots of Wyoming big sagebrush from the Great Basin. Portions of each lot were cleaned to low (15-27%) or high (66-

80%) purity and stored under various combinations of temperature (20, 2, -8 or -20$^{o}$C) and equilibrium relative humidity (ERH; 30, 40, 50 or 70%) for 5 y in 6-mil polybags (Karrfalt and Vankus 2009; Karrfalt and Shaw, in press). See Figure 5 for correlation of ERH with seed moisture content. Purity, ERH and storage temperature were all important factors to successful seed storage as determined by germination tests (AOSA 2011) conducted following 3, 6, 15, 29, 41 and 60 months of storage (Figs. 1-2; Karrfalt and Shaw, in press). Results show that germination was maintained for at least 60 months when high purity seed was dried to 30% ERH, sealed in moisture proof containers and kept frozen at temperatures $^{<}$ 8$^{o}$C. Low purity seeds were mostly nonviable after about 24 months of storage at any ERH and temperature combination (data not shown). Because they can deteriorate rapidly, Wyoming big sagebrush seeds should be dried, cleaned, and placed in storage soon after harvest. Figure 3 provides a conversion from the more commonly used percent seed moisture to ERH; ERH is a useful measure because it precludes having to dry and weigh the seed.

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**Publications**

Karrfalt, R. P.; Shaw, N. [In press]. Banking Wyoming big sagebrush seeds. Native Plants Journal.

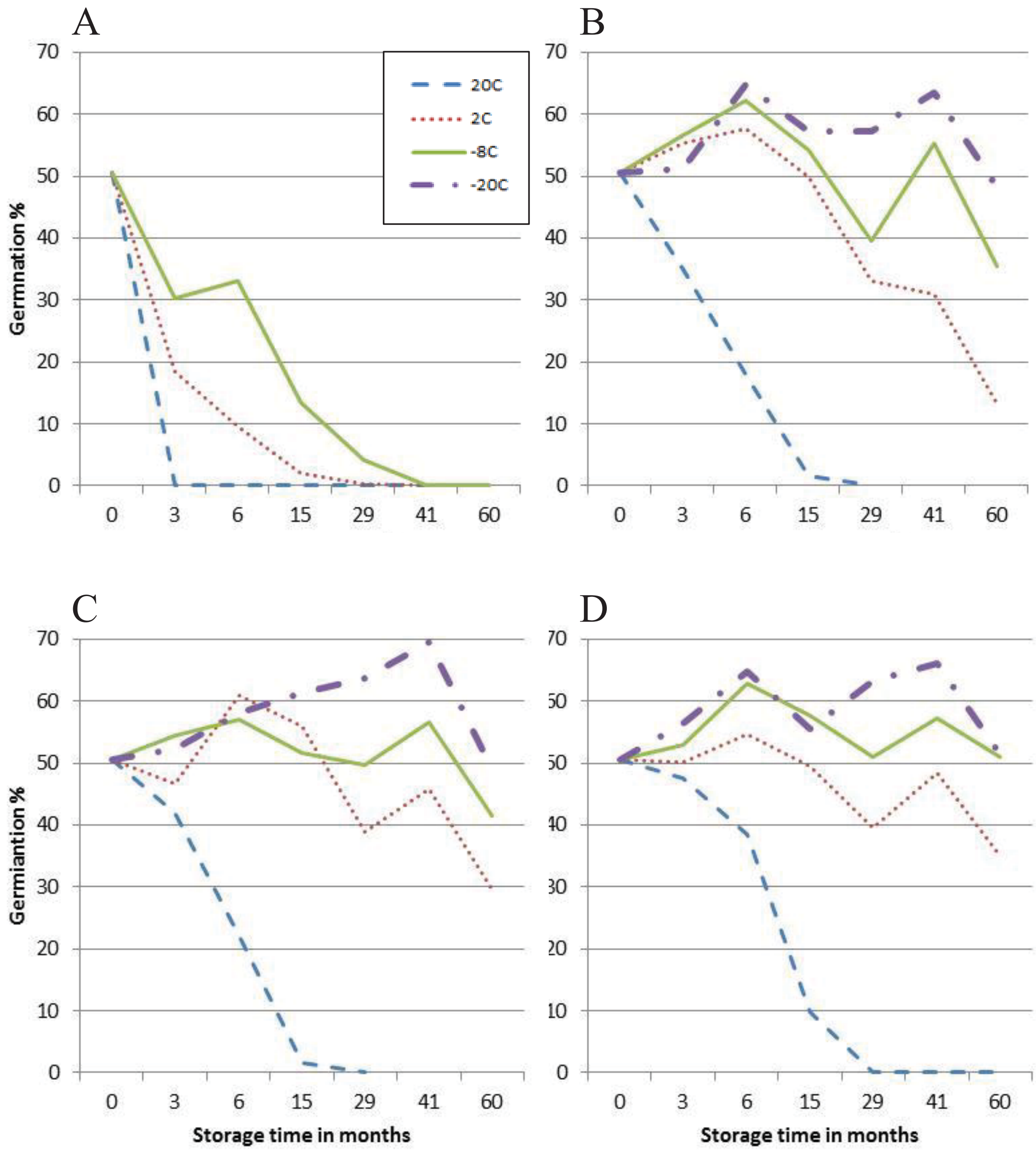


**Figure 1.** The effect of storage temperature on the germination of Wyoming big sagebrush seeds sealed in 6-mil poly bags at A. 70% ERH (equilibrium relative humidity), B. 50% ERH, C. 40% ERH, and D. 30% ERH.

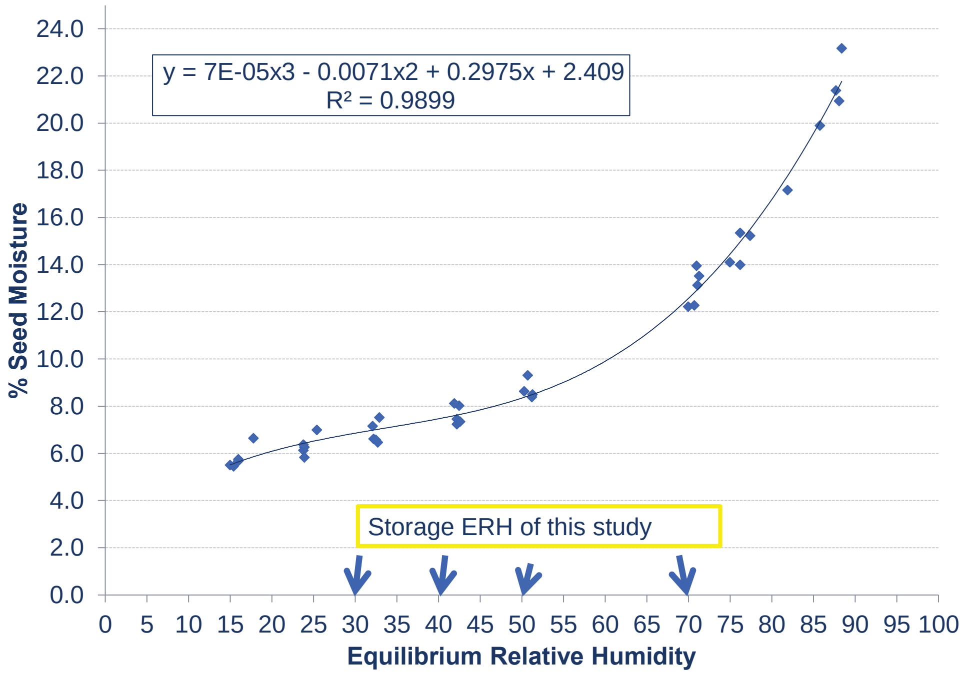


**Figure 3.** The relationship of seed moisture for *Artemisia tridentata* ssp. *wyomingensis* to equilibrium relative humidity (ERH).

**Presentations**

Karrfalt, R. P. 2012. Wyoming big sagebrush: 5-year seed storage results. Great Basin Native Plant Selection and Increase Project Annual Meeting. 2012 February 21-22, Salt Lake City, Salt Lake City, Utah.

Karrfalt, R. P. 2012. Banking *Artemisia tridentata* spp. w*yomingensis* seeds. 65$^{th}$ Annual Meeting of the Society of Range Management, 2012 January 29-February 3, Spokane, WA.

**Management Applications and Seed Production Guidelines**

By following the recommendations from this seed storage study, seeds of *Artemisia tridentata* spp. w*yomingensis* seeds can be successfully stored for at least 5 years. Use of this procedure reduces bulk and permits storage of multiple seed sources in good production years, increasing the availability of seed from across the area of concern to meet unpredictable seed source needs. Seed acquisition can be conducted in a more orderly, cost effective manner.

**Products**

- <u>Wyoming big sagebrush seed storage protocol:</u> Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis*) seeds can be stored without loss of viability for at least 5 years when seeds are cleaned to a purity of > 66%, dried to 30% ERH, sealed in 6-mil poly bags to maintain the low moisture content, and stored at -8 to -20$^{o}$C (or lower).

**Project Title** Modeling Seedling Root Growth of Great Basin Species

**Project Agreement No.** 09-JV-11221632-056

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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.

Objectives

1. Develop thermal accumulation models for seedling root penetration for forbs, grasses, and cheatgrass (*Bromus tectorum*).
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.

*Growth Chamber Study*

We measured 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 was organized in a randomized block design of four blocks and two soils in a walk-in growth chamber. Black plexiglass holders were constructed to hold 70 clear plastic root tubes (five replicates x 14 collections), each 2.5-cm in diameter by 20-cm long. Each block contained 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 kept the tubes slanted at a 45° angle, which minimized root exposure to light. For each of six constant temperatures runs (5, 10, 15, 20, 25, and 30° C), three seeds of a collection were sown 0.5 cm below the soil surface against the lower side of each planting tube. Prior to sowing, Utah milkvetch seeds were scarified in sulfuric acid for 15 minutes followed by stratification at 1.5° C for 2 weeks with squirreltail seeds. Time to germination was recorded in petri dishes filled with 25 seeds of each collection and placed on racks below the root experiment in the incubation chamber. Tubes were checked 6 days per week and the depth of the deepest root was recorded. Soil temperatures were measured with six thermocouples per block placed into the ends of root tubes and attached to a CR10X micrologger (Campbell Scientific, Inc., Logan, UT). Temperatures were read each minute, and average hourly temperatures were recorded. At the end of each temperature run, one tube of each collection per block was harvested and dry weight of the root biomass was recorded. The entire experiment was also conducted at three diurnal temperatures based on cold, cool, and warm soil temperatures recorded in the field. We will compare actual root depths with those predicted from thermal accumulation models.

**Table 1.** Plant materials tested in root study.

| | Scientific name | Common name | Release | 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[1] | 2007 |
| | *Astragalus utahensis* | Utah milkvetch | | USFS Shrub lab[1] | 2002 |
| | *Linum perenne* | Blue flax | 'Appar' | UDWR[2] | 2003 |
| | *Lupinus arbustus* | Longspur lupine | | Wells, NV; UDWR[2] | 2004 |
| **Perennial grasses** | *Agropyron cristatum x A. desertorum* | Crested wheatgrass | 'Hycrest' | UDWR[2] | 2003 |
| | *Agropyron desertorum* | Crested wheatgrass | 'Nordan' | Granite Seed | 2003 |
| | *Elymus elymoides* | Squirreltail | Sanpete | UDWR[2] | 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 |

[1]USFS Shrub Lab: U.S. Forest Service Provo Shrub Sciences Lab, Provo, UT
[2]UDWR: Utah Division of Wildlife Resources, Great Basin Research Center, Ephraim, UT

*Field Experiment*

The same experiment as described above was conducted at two locations in Utah for 2 years 1) on the Brigham Young University (BYU) 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 field experiment the first year, 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 were read every minute and hourly averages recorded with 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.

<u>Project Status</u>

*Growth Chamber Experiment*

We conducted all six of the constant temperature runs and all three of the 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 (Figures 1 and 2). In sand, squirreltail and Nordan predicted degree days were greater than actual. In soil, Secar, squirreltail, and longspur lupine predicted degree days were significantly greater than their actual degree days. 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 in predicted squirreltail, which required more degree days than actual (Figure 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 (Cheat05), cheatgrass 2007 (Cheat07), annual agoseris, and flax (Figure 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 (Figure 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 (Figure 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 Cheat05 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. 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 Cheat05 did require fewer degree days than bluebunch wheatgrass. For inter-species comparisons in soil, flax required the most degree days of any species. Cheat05 and (Cheat08) 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 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 bluebunch wheatgrass requires 250-350 (Figure 2). SageSTEP data from four Great Basin pinyon-juniper locations for 2 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 sufficient 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 2 years. We are currently analyzing these data.

Characterization of Establishment Environment
We derived several seasonal variables to characterize the soil temperature and plant available water in seedbeds, including wet thermal time and percentage of time at seven temperature ranges, frost and frost-free days, and wet period duration. Thus far, we addressed a concern that germination timing response at extreme warm (> 30°C) and cool (< 5°C) temperature ranges have high variability and may require further investigation if a large sum of thermal time occurs at those temperatures. Our preliminary results indicate that a minority of time is spent at the temperature ranges of concern. As a result, germination prediction models based on the summation of thermal time should be valid (Rawlins et al. 2012b).

Future Work and Research Perspective
We have conducted all of our experimental work for this grant and continue to analyze data and prepare publications. The current research is part of an ongoing research program to better understand how seedling establishment relates to environmental conditions and plant growth characteristics (Table 2). Additional future work will continue to characterize the establishment environment using measurements from 170 soil moisture stations and predict establishment success for specific sites, weather scenarios, and plant materials using the germination and seedling root growth models we have developed.

## Management Applications and Seed Production Guidelines

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 to enable selection for more consistent and vigorously establishing native plants.

**Table 2.** Schedule and status of research phases to predict seed germination and seedling establishment in the Great Basin.

| **Research phase** | **Past and current work** | **Major findings** | **Published or planned publications** |
|---|---|---|---|
| Characterize seedbed environment | Soil moisture and temperature measurements from 30 sagebrush/bunchgrass, pinyon-juniper, crested wheatgrass, and cheatgrass sites and 170 stations in the Great Basin | Soil moisture and temperatures fluctuate much more at 1-3 cm in the germination zone than 13-30 cm deep in the seedling establishment zone. Wet degree days accumulate fastest in spring, only slightly in winter, and erratically in fall as a function of timing and amount of precipitation. The number of days when the soil is wet and within certain temperature ranges has been determined for two sites and is being determined for the other sites. | Published:<br>Chambers et al. 2007; Roundy et al. 2007; Rawlins et al. (2012b).<br><br>In preparation or submitted:<br>Young, et al. Effects of shredding Utah juniper on soil moisture and temperature (submitted).<br><br>Cline et al. The germination environment of Great Basin seedbeds<br><br>Cline et al. Soil moisture availability and temperature of the seedling root zone in the Great Basin<br><br>Roundy et al.(2007) Piñon-juniper reduction effects on soil temperature and water availability of the resource growth pool. (Submitted) |
| Develop models of germination and seedling growth | Roundy's lab developed germination models for 14 collections while Hardegree's lab developed models for numerous desirable species collections and weed collections.<br><br>Roundy's lab developed root growth models for 14 collections. | Timing of germination can be predicted in relation to accumulated time and temperature above a threshold temperature for non-dormant seed lots. The models work best at moderate temperatures.<br><br>Seminal root growth or time for roots to reach a soil depth can be predicted similarly, but will vary with other variables besides soil moisture and temperature, such as soil texture and nutrient availability. | Published: Roundy et al. 2007, Rawlins (2012a).<br><br>Hardegree et al. (2013)<br><br>In preparation:<br>Young et al. Thermal accumulation modeling of seedling root depth. |
| Compare modeled and actual responses in lab and field | Roundy's lab has compared predicted and actual timing of germination under simulated field seedbed temperatures in the lab and in field seedbeds for | Thermal accumulation tends to overestimate time required to germinate seed subpopulations, but is accurate enough for field predictions. Wet thermal accumulation models using | Published: Rawlins et al (2012a,b)<br><br>In preparation:<br>Young et al. Field prediction of seedling root depth using a wet-thermal |

| Research phase | Past and current work | Major findings | Published or planned publications |
|---|---|---|---|
| | 2 sites and 2 years. | continuous thermal accumulation and a wet threshold of -1.5 MPa water potential best predicted germination in the field. Accuracy was 80% or greater for most collections in late winter to spring.<br><br>Data from field and laboratory comparisons of predicted and actual seedling root depth is being analyzed. | accumulation model. |
| Extend predictions to a range of plant materials, environments, and land treatments | Roundy et al. (2007) Cheatgrass germination prediction analysis for 9 sites in Great Basin.<br><br>Cline is currently preparing a germination prediction analysis of 32 plant materials for 30 sites and across a range of years and treatments, such as prescribed fire and mechanical brush or tree control.<br><br>Roundy, Young, and Cline will eventually extend the germination and root growth model predictions to 30 sites across the Great Basin to predict probability of seedling mortality. | In an analysis of cheatgrass germination potential for 9 sites and 4 years (36 site-years) Roundy et al. (2007) found that cheatgrass had high germination potential in spring, low potential in winter and high potential in fall when rains occurred before temperatures decreased to near freezing. | Published:<br>Roundy et al. (2007)<br><br>In analysis and preparation:<br><br>Cline et al. Potential germination of weed and revegetation species in the Great Basin I: Effects of seasonal weather, site characteristics, and treatments.<br><br>Cline et al. Potential germination of weed and revegetation species in the Great Basin II: Seedlot comparison.<br><br>Roundy or TBA et al. Predicting seedling mortality from thermal accumulation models of germination and root growth. |

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Cline, N. L.; Roundy, B. A. 2012. Germination prediction from soil moisture and temperature in the Great Basin. Society of Range Management 65th Annual Meeting, 2012 January 29- February 3, Spokane, WA.

Roundy, B.; K. Young, K.; N. Cline, N.; Hardegree, S.; Rawlins, J. 2012. Environmental effects on seedling establishment. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, Utah.

**Publications**

Rawlins, J. K.; Roundy, B. A.; Davis, S. M.; Egget, D. 2012a. Predicting germination in semi-arid seedbeds. I. Thermal germination models. Environmental and Experimental Botany. 76: 60-67. http://dx.doi.org/10.1016/j.envexpbot.2011.10.003

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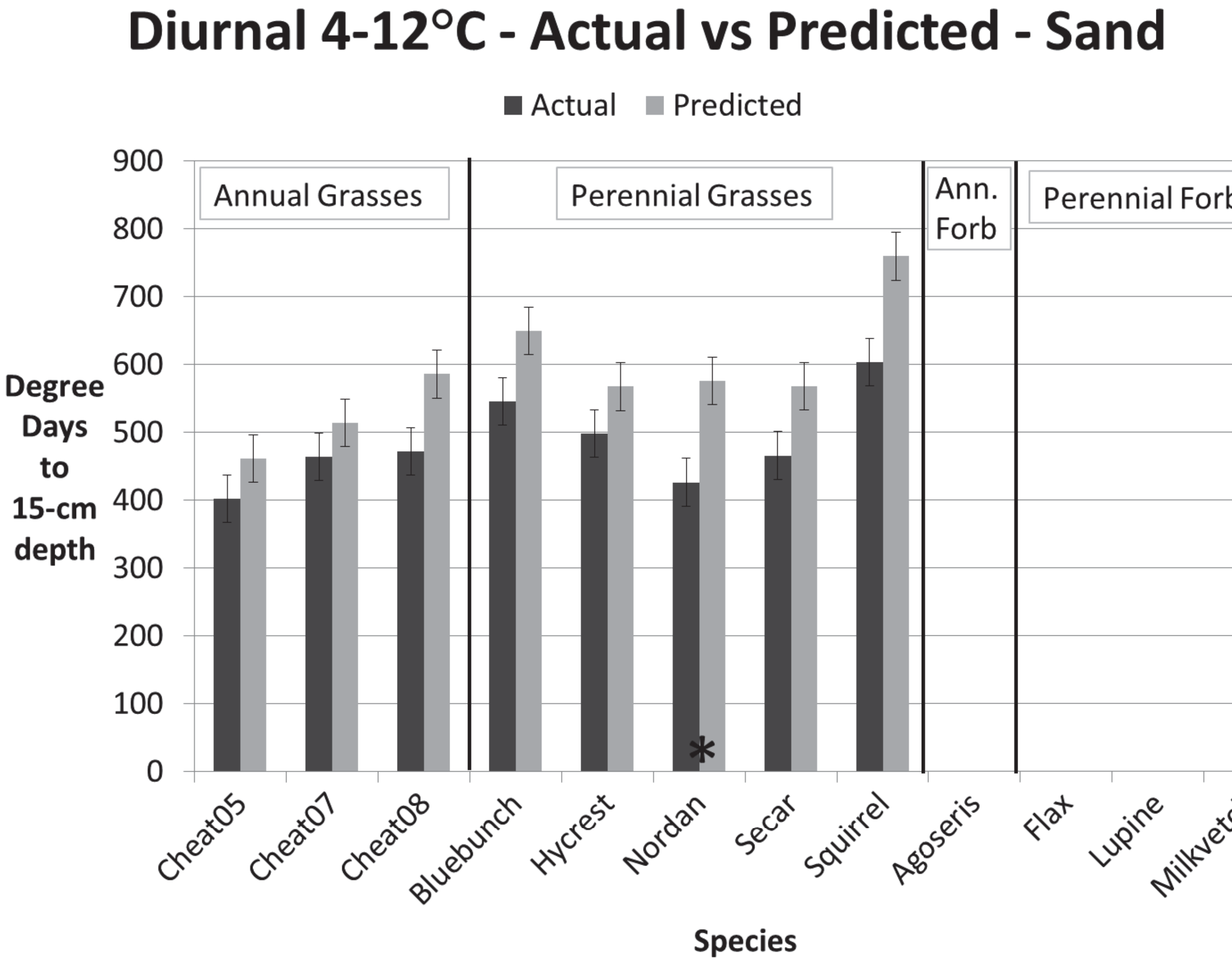


**Figure 1.** Actual verses predicted degree days to 15-cm root depth in sand for the growth chamber diurnal root tr
(*) indicates significant difference at 95% confidence level.

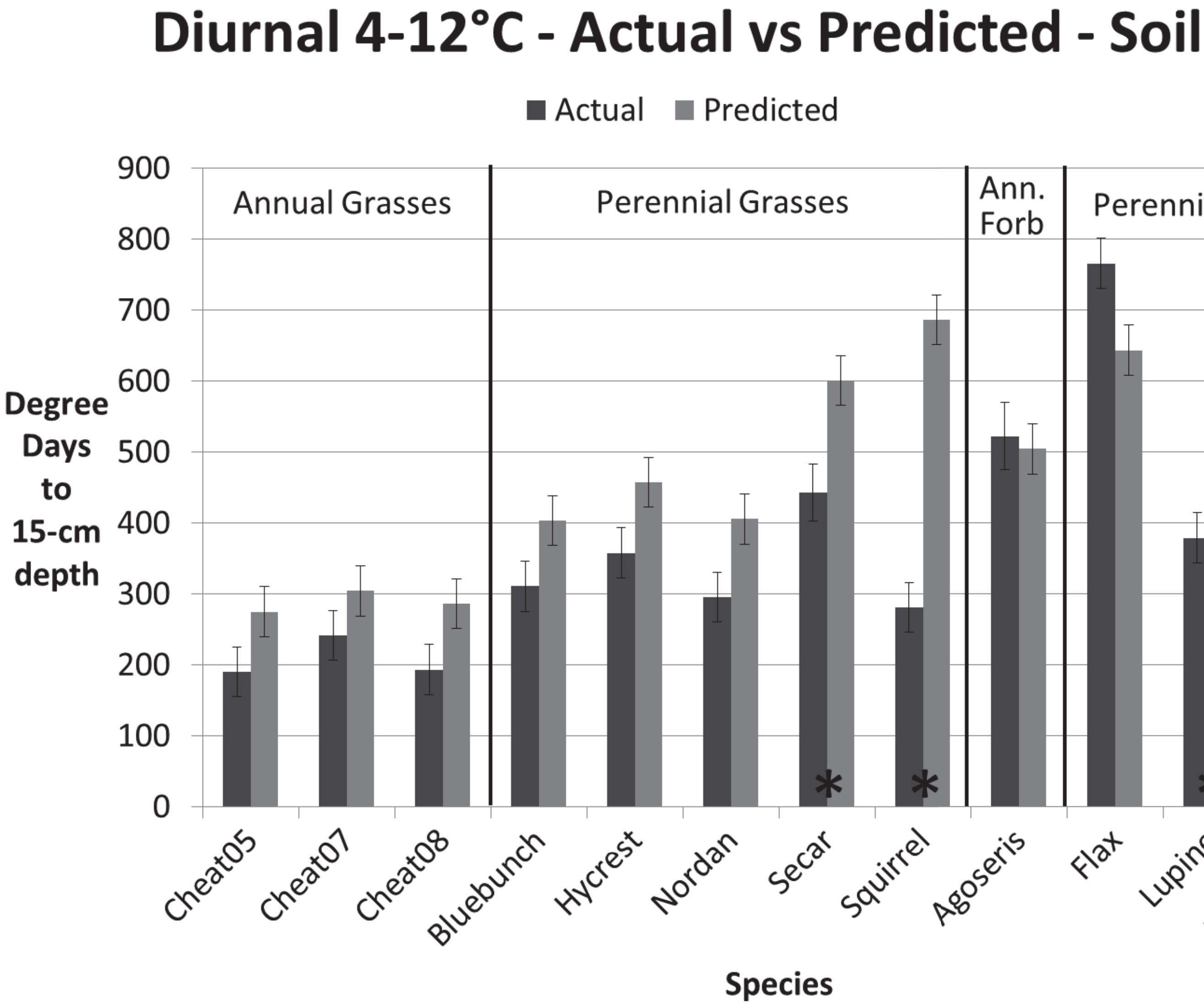


**Figure 2.** Actual verses predicted degree days to 15-cm root depth in soil for the growth chamber diurnal root tri
(*) indicates significant difference at 95% confidence level.

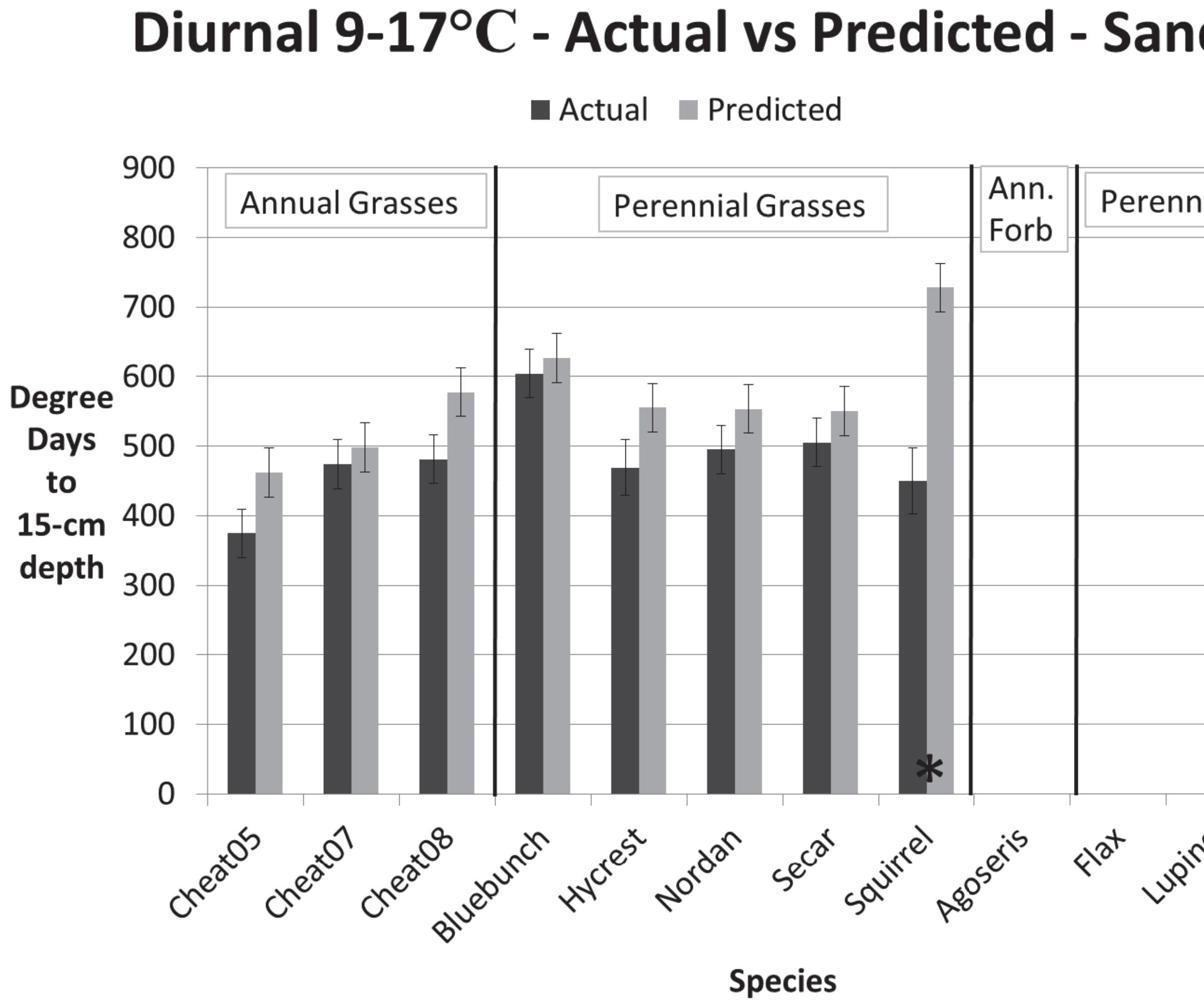


**Figure 3.** Actual verses predicted degree days to 15-cm root depth in sand for the growth chamber diurnal root t
(*) indicates significant difference at 95% confidence level.

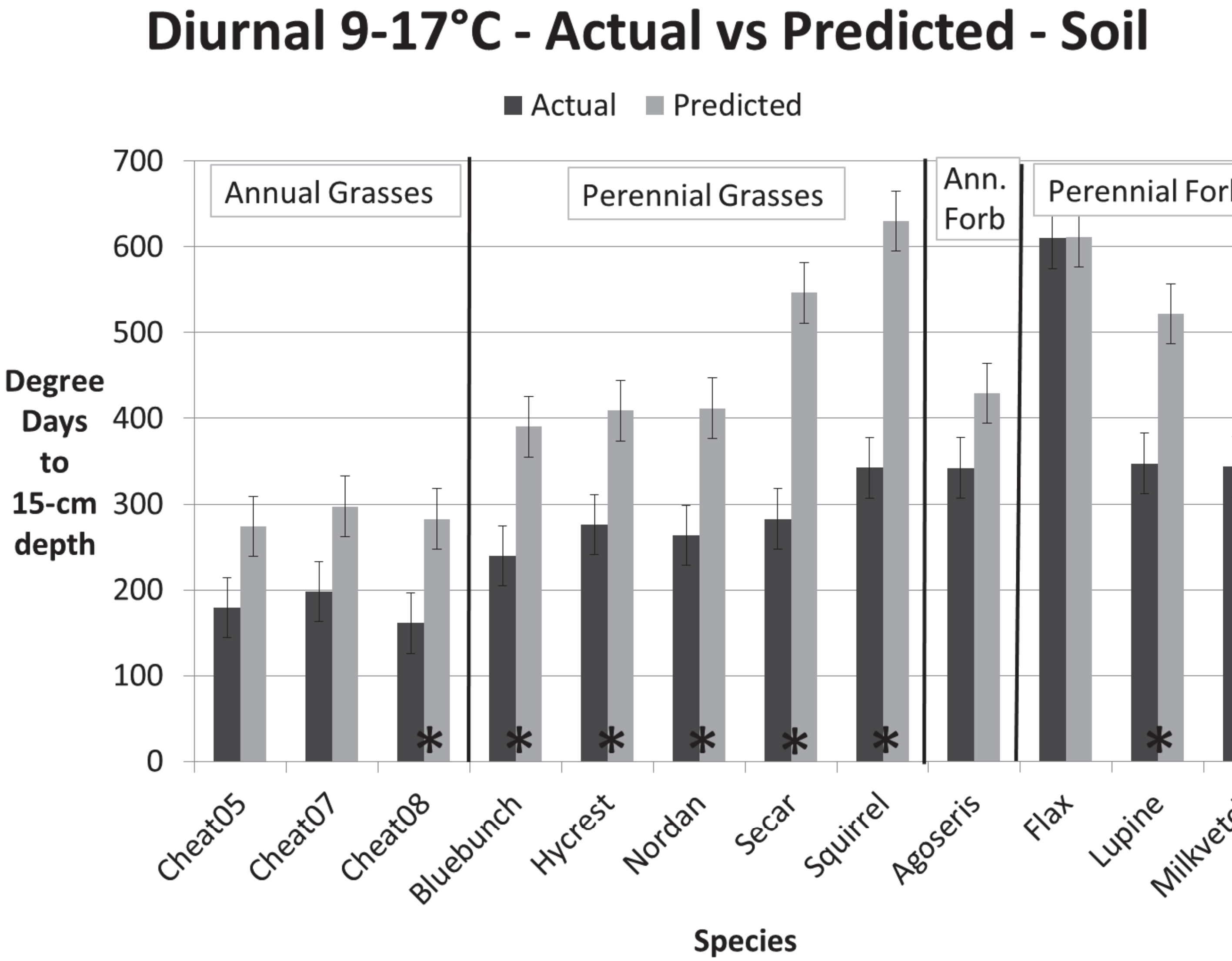


**Figure 4.** Actual verses predicted degree days to 15-cm root depth in soil for the growth chamber diurnal root tri
(*) indicates significant difference at 95% confidence level.

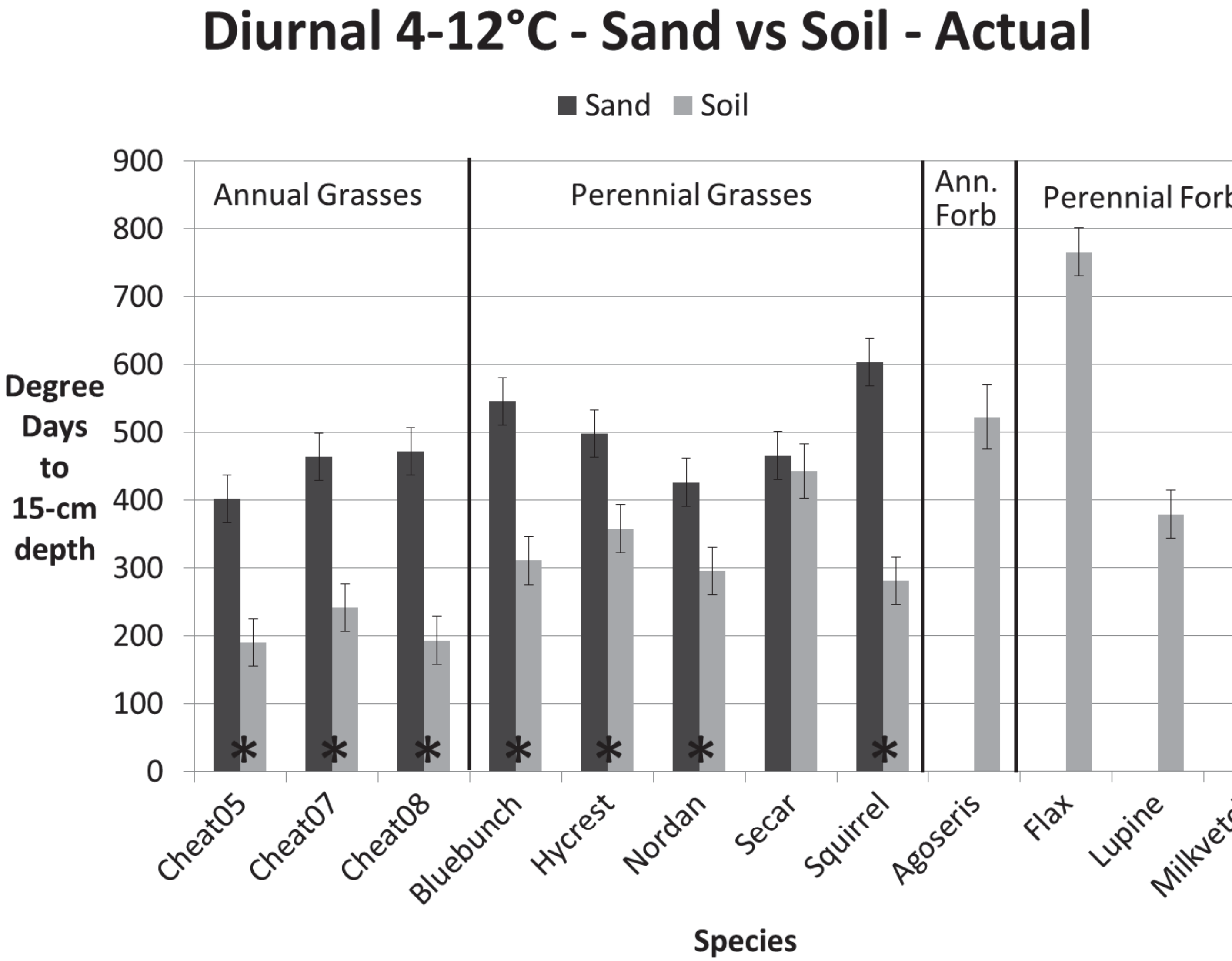


**Figure 5.** Actual sand verses soil degree days to 15-cm root depth for the growth chamber diurnal root trial 4-12
indicates significant difference at 95% confidence level.

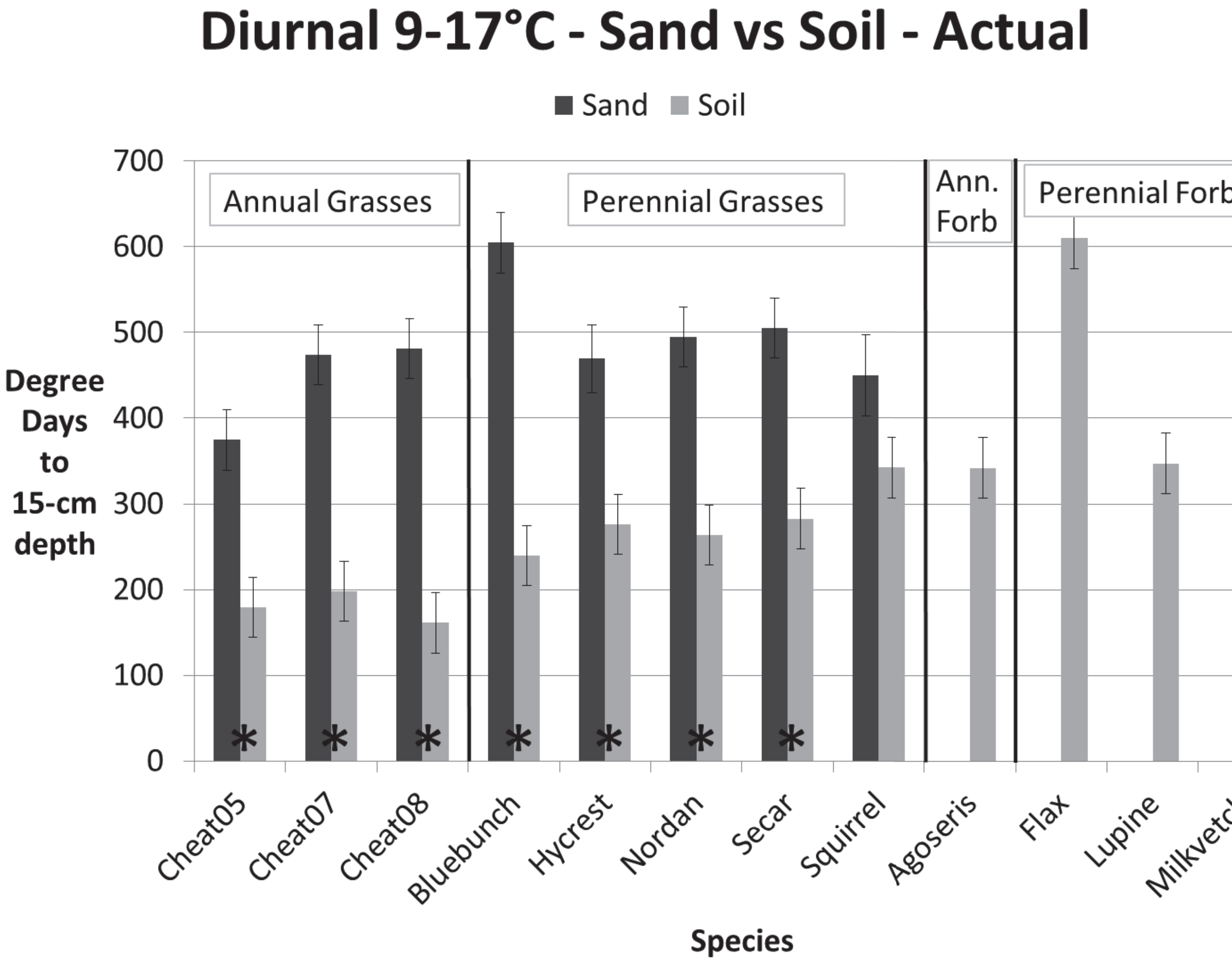


**Figure 6.** Actual sand verses soil degree days to 15-cm root depth for the growth chamber diurnal root trial 9-17
indicates significant difference at 95% confidence level.

**Project Title** Pre-inoculation of Wyoming Big Sagebrush Seedlings with Native Arbuscular Mycorrhizae: Effects on Mycorrhizal Colonization and Community Composition after Transplanting

**Project No.** 10-JV-11221632-062

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**Project Description**

Introduction

Reestablishment of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis)* has proven difficult due to high seedling mortality. Major factors responsible for seedling mortality are summer drought and low growth rates (Stahl et al. 1998; Lambrecht et al. 2007). Slow growth decreases the plant's ability to compete for resources and may prevent the seedlings from developing an adequate root system to maintain hydration during the dry summer.

One factor that could improve the growth rates and stress tolerance of sagebrush seedlings is the establishment of symbiotic associations with arbuscular mycorrhizal fungi (AMF) (Stahl et al. 1998). Mycorrhizae are well known to improve nutrient uptake, particularly phosphorus, and in so doing markedly increase plant growth (Smith and Smith 2011). In addition, colonization by AMF can increase tolerance to water deficits (Augé 2001).

Inoculation of seedlings with arbuscular mycorrhizal fungi (AMF) is a common practice aimed at improving seedling establishment (Allen 1989; St. John 1997; Requena et al. 2001) The success of this practice largely depends on the ability of the inoculum to multiply and colonize the growing root system after transplanting and on the particular species colonizing the roots (Weinbaum et al. 1996; Jones and Smith 2004; Caravaca et al. 2005). In this study, Wyoming big sagebrush seedlings were inoculated with native AMF and transplanted to native soil. Following transplanting, we evaluated the extent of colonization, possible changes in AMF composition, and the effects of mycorrhizal colonization on seedling survival.

Specific Objectives

1) Determine the effect of pre-inoculation with native mycorrhizae on colonization of roots that developed after transplanting.
2) Compare the mycorrhizal community of non-inoculated and inoculated seedlings.
3) Analyze the effect of changes in colonization and community composition on seedling survival.

Methods

Native AMF were multiplied from soil collected at Kuna Butte, Idaho (N 43° 26' 43.5", W 116° 26' 51.4") using Sudan grass pot cultures. The pot cultures contained a mixture of nine phylotypes including three known species, *Rhizophagus intraradices*, *Glomus microaggregatum,* and *Funneliformis mosseae*.

Seedlings were first grown in a greenhouse in 50 ml cone-tainers containing roots and soil from the pot cultures (pre-inoculated seedlings) or sterilized pot cultures (non-inoculated seedlings). In early spring, 3-month old seedlings were transplanted to soil collected from Kuna Butte. This is a sandy soil with an available phosphorus content of 8.1 µg $g^{-1}$ of soil. The seedlings were grown in 24 L tree-pots under natural climatic conditions at the Idaho Botanical Gardens (N 43° 35' 52.1", W 116° 9' 42.3"). Fifty pots were assigned for each treatment. Mycorrhizal colonization was assessed prior to transplanting and 2.5 and 5 months after transplanting. The effect of inoculation on colonization and seedling survival was also investigated in seedlings transplanted during the fall. For this purpose, we conducted an experiment similar to the one just described, but with transplanting in early October. Colonization of seedlings was assessed at the time of transplanting and 7 months afterwards.

Colonization was determined by the intersection method after staining with Chlorazol black E (McGonigle et al. 1990). Growth and survival of sagebrush seedlings was monitored biweekly. At the time of colonization assessment, DNA was isolated from roots and soil samples. The isolated DNA was amplified via nested PCR. General fungal primers LR1 and FLR2 were used for initial amplification. The second PCR amplification was conducted using the Glomeromycota specific primers FLR3 and FLR4 that amplify regions of the large subunit ribosomal RNA gene (LSU rDNA) (Gollotte et al. 2004). The resulting amplicons were cloned and then sent to a commercial facility for sequencing. The LSU rDNA sequences were aligned using a database of reference sequences and subsequently grouped into operational taxonomic units (OTUs) with sequence similarities ≥ 95% using the Mothur program (Schloss et al. 2009. These OTUs were used to characterize possible differences in AMF community composition among treatments. For this purpose, we used the libshuff method, which determines whether communities have the same structure based on the Cramer-von Mises test (Schloss et al. 2004).

Results

For both the spring and fall experiments, pre-inoculated seedlings showed at the time of transplanting a total colonization above 55% (Figure 1A, C). In contrast, colonization was negligible in the non-inoculated seedlings. The arbuscular colonization was much lower than total colonization, but pre-inoculated seedlings had significantly higher arbuscular colonization than non-inoculated ones (Figure 1B, D). After transplanting in both May and October, the non-inoculated seedlings became colonized by mycorrhizae present in the soil. However, several months after transplanting, the percent colonization in the non-inoculated seedlings remained significantly lower than in the pre-inoculated ones. For seedlings transplanted in May, total colonization five months after transplanting was 20% for non-inoculated and 48% for pre-inoculated seedlings (Figure 1A). Similarly, non-inoculated and pre-inoculated seedlings transplanted in October 2011 had in May 2012 a total colonization of 23 and 43%, respectively (Figure 1C). Differences were also apparent for arbuscular colonization, which through the experiment was higher in pre-inoculated than non-inoculated seedlings (Figure 1B, D). Taken

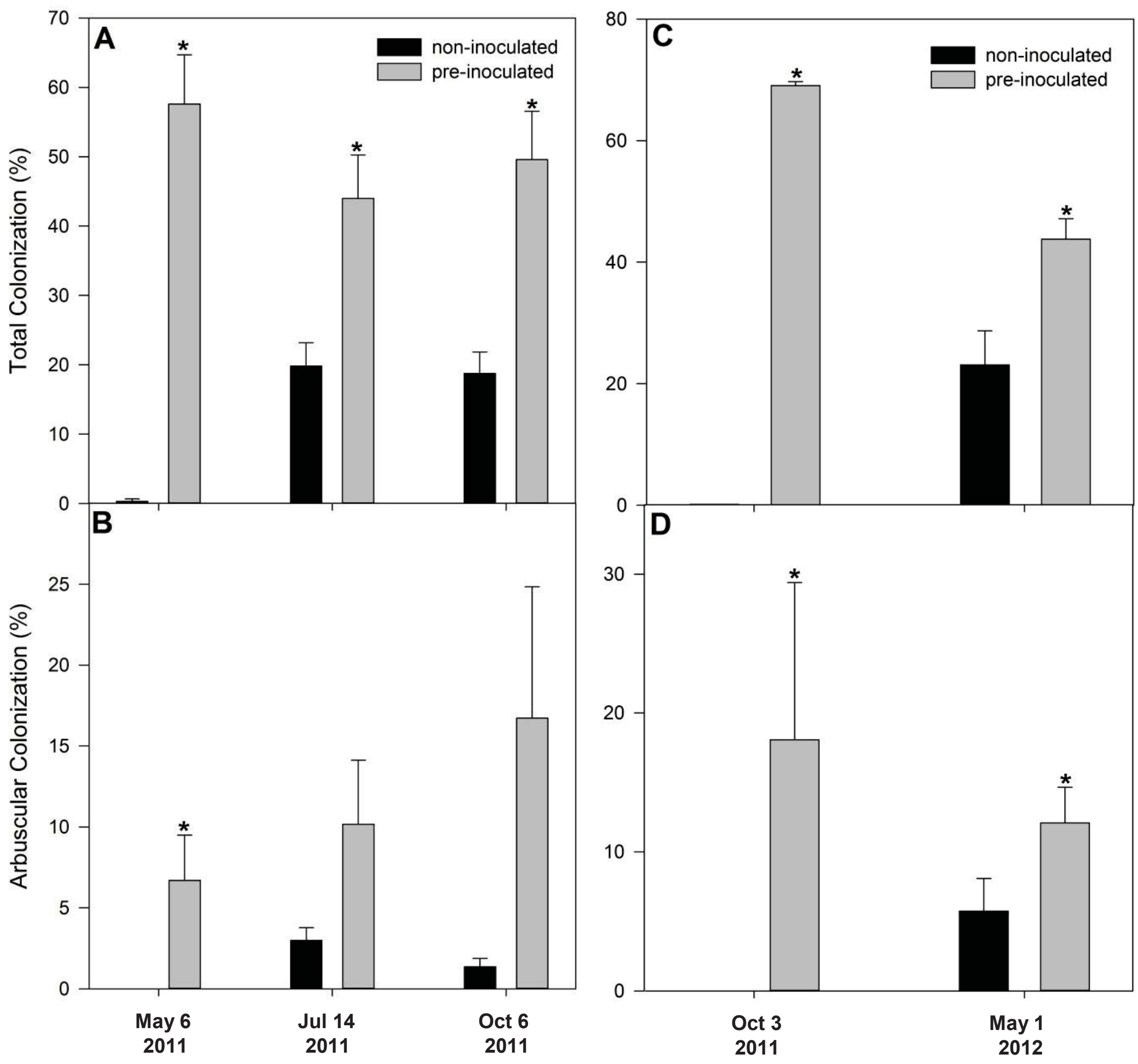


**Figure 1.** Total (**A,C**), and arbuscular colonization (**B, D**) in non-inoculated and pre-inoculated seedlings of Wyoming big sagebrush transplanted on May 6, 2011 (**A,B**) or October 3, 2011 (**C, D**). For samples collected in July and October of 2011 and in May of 2012, measurements were made in roots that developed after transplanting. Mean (± SE) of five to eight seedlings. For a particular date, values marked by an asterisk (*) are significantly different from the non-inoculated treatment ($p < 0.05$).

together, these results indicate that the AMF inoculum contributed to the colonization of the roots that developed after transplanting, resulting in higher levels of colonization than those naturally occurring in the soil.

In addition to differences in colonization, the AMF composition of the roots varied depending on the inoculation treatment and transplanting time. Based on the molecular analyses, we identified a total of 24 OTUs (Figure 2). This suggests substantial AMF diversity, particularly considering that the OTUs were identified in a single host species growing in soil from one site (Sanchez-Castro et al. 2012; vande Voorde et al. 2010). Nine of the 24 OTUs were only present in pre-inoculated seedlings. Furthermore, three OTUs were only detected in pre-inoculated seedlings transplanted in spring (May), while five others only in pre-inoculated seedlings transplanted in the fall (October) (Figure 2). These differences in the presence/absence of OTUs combined with differences in OTU frequency among treatments indicate dissimilarities in AMF community composition. In particular, the AMF community composition of pre-inoculated seedlings was different from that of non-inoculated ones, but only for seedlings transplanted during the spring (Table 1). In addition, for both inoculated and non-inoculated seedlings, the AMF community of samples collected in early fall (spring transplanting) was different from that of samples collected in the spring (fall transplanting) (Table 1). These results suggest seasonal changes in the structure of the AMF community.

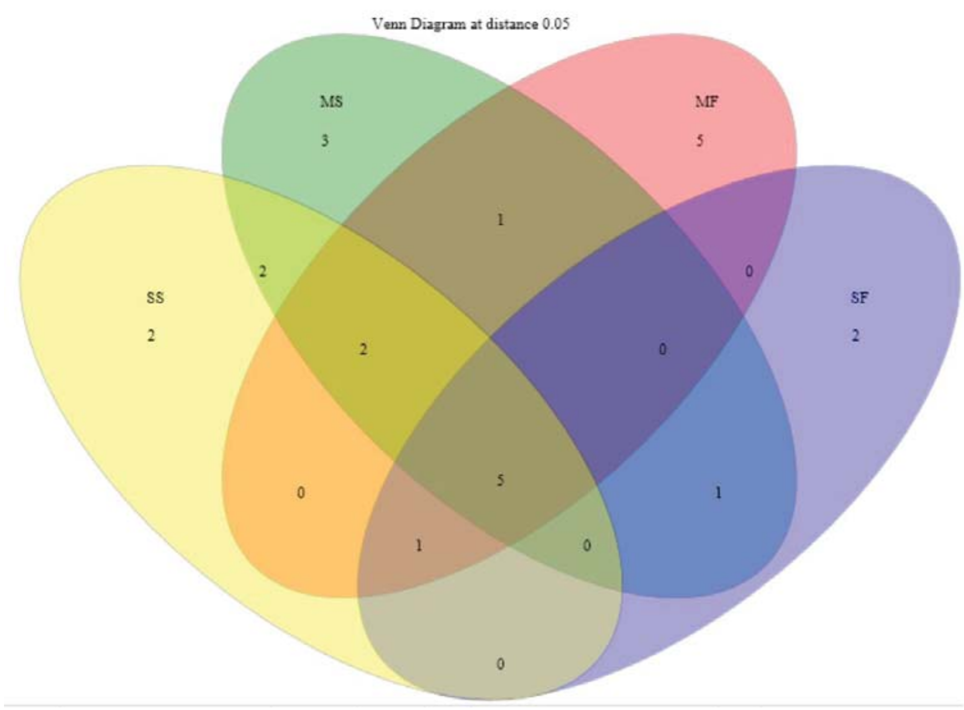


**Figure 2.** Depiction of 24 shared and non-shared OTUs between treatments (SS = non-inoculated and spring transplanted, SF = non-inoculated and fall transplanted, MS = pre-inoculated and spring transplanted, MF = pre-inoculated and fall transplanted. Samples for DNA extraction were collected 5 and 7 months after the spring and fall transplanting, respectively. Sequences were assigned to different OTUs when their pairwise distance was greater than 5%.

**Table 1.** Comparison of arbuscular mycorrhizae community composition among treatments.

| Comparison | Significance[1] |
|---|---|
| non-inoculated/spring transplanted *vs.* pre-inoculated/spring transplanted | 0.0007* |
| non-inoculated/fall transplanted *vs.* pre-inoculated/fall transplanted | 0.0254 |
| non-inoculated/spring transplanted *vs.* non-inoculated/ fall transplanted | <0.0001* |
| pre-inoculated/ spring transplanted *vs.* pre-inoculated/fall transplanted | <0.0001* |
| non-inoculated spring transplanted *vs.* pre-inoculated fall transplanted | <0.0001* |
| non-inoculated fall transplanted *vs.* pre-inoculated spring transplanted | 0.0007* |

[1]Significant differences were weighted based on the number of multiple comparisons. Only values marked by an asterisk (*) are significantly different from each other.

For the seedlings transplanted during the spring, the observed differences in colonization and community composition between non-inoculated and pre-inoculated seedlings were correlated with differences in seedlings establishment. Five months after transplanting, seedling survival was 24% higher in pre-inoculated than non-inoculated seedlings ($p < 0.01$). In contrast, no seedling mortality was observed for seedlings transplanted during fall. Both non-inoculated and pre-inoculated seedlings had 100% survival by June 8, 2012. After this time, the experiment was ended because plant growth and survival became limited by the size of the pots.

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Acknowledgments

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**Presentations**

Davidson, B.; Serpe, M. D. 2012. Improvement in colonization and seedling survival of Wyoming big sagebrush following inoculation with native arbuscular mycorrhizal fungi. Mycological Society of America Annual Meeting, 2012 July 15-18, New Haven, Connecticut.

Davidson, B.; Serpe, M. D. 2012. Mycorrhizal colonization and survival of Wyoming big sagebrush following inoculation and transplanting. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 12-22, Salt Lake City, UT.

Davidson, B,; Serpe, M. D. 2012. Improvement in colonization and seedling survival of Wyoming big sagebrush following inoculation with native arbuscular mycorrhizal fungi. Northwest Scientific Association Annual Meeting, 2012 March 28-31, Boise, ID.

Holten, R.; Roberts, E.; Serpe, M. D. 2012. Survival of native arbuscular mycorrhizal inoculum following transplanting of Wyoming big sagebrush. National Conference of Undergraduate Research. Annual Meeting, 2012 March 29-31, Ogden, UT.

**Management Applications and Seed Production Guidelines**

The results indicate that pre-inoculation with native arbuscular mycorrhizae can increase colonization after transplanting and also seedling survival, particularly for seedlings transplanted during the spring. Thus, in sandy soils similar to the ones used in this study, reestablishment of Wyoming big sagebrush appears to be partly limited by low mycorrhizal density. In these soils, practices aimed at increasing AMF density such as planting of pre-inoculated seedlings or of species that can act as mycorrhizal-net builders are likely to increase the success of restoration efforts.

**Project Title** Smoke-induced Germination of Great Basin Native Forbs

**Project Agreement No.** 11-CR-11221632-005

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**Project Description**

The first step, to conduct a wide literature review of as many Great Basin species that respond to smoke as possible, has been completed. The second step is to test as many species as possible to determine smoke response. This portion of the project is now underway. The third step will be to further investigate responsive species to determine whether smoke response varies by population by testing seeds from as many populations of the species in question as possible. Finally, we aim to develop seeding protocols for several of the most responsive species. This will be done by testing different methods of smoke application to the seeds followed by seeding of the seeds into field settings.

**Presentations**

Pendell, E.; Cox, R. 2012. Effect of smoke on native seed germination. Texas Tech University Undergraduate Research Conference, Texas Tech University, 2012 April 22-25, Lubbock, TX.

**Management Applications and Seed Production Guidelines**

Land managers, seed producers or others will use the results to better plan restoration seedings to include a higher diversity of native forbs and to plan restoration treatments to take advantage of smoke-responsive species.

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

**Project Agreement No.** 11-IA-11221632-007

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**Project Description**

Greenhouse Seedling Emergence Studies

We were interested in identifying techniques that can be used to optimize seed germination and seedling emergence in four legume species native to the Great Basin of the western U.S., including basalt milkvetch (*Astragalus filipes*), Blue Mountain or western prairie clover (*Dalea ornata*), Searls' prairie clover (*Dalea searlsiae*), and purple prairie clover (*Dalea purpurea*); research on the first two species was supported by the Great Basin Native Plant Selection and Increase Project. Seedlots of these species were tested with the tetrazolium test by the Utah State Seed Laboratory to determine seed viability. Although total viable seed in the non-treated seedlots was greater than 85%, hard seed ranged from 79-88%. Seedlots were left untreated or scarified. The acid-scarified seeds were treated by soaking the seeds in concentrated sulfuric acid for 5 minutes, rinsing in tap water, and air-drying the seed. Other experimental treatments included soil type: sand, 33% clay, 67% clay, and clay, and water droplet size. A total of 50 seeds were planted in greenhouse soil benches for each treatment, and four replications were used in a randomized complete block design in a greenhouse with two complete runs of the experiment conducted. Seedling counts were made and emerged seedlings were removed on 8-9 dates starting at Day 3 and going to Day 21. Speed of emergence was calculated based on the number of seedlings counted at each day summed across the experimental period (Maguire 1962).

Results of the greenhouse experiment are shown in Table 1. The main effects of water droplet size, species, and seed treatment were significant ($p \leq 0.05$). The two-way interactions of soil type by species (ST X SP) and species by seed treatment (SP X T) were also significant ($p \leq 0.01$). The three-way interaction of soil type by species by seed treatment (ST X SP X T) was also significant. Speed of emergence was greatest in western prairie clover, followed by Searls' prairie clover, purple prairie clover, and basalt milkvetch. All species emerged faster when the seed was scarified; however, this effect was least for basalt milkvetch, which generally had a low rate of emergence. For western prairie clover and Searls' prairie clover, speed of emergence was greater in the sand compared to the soils with clay. For basalt milkvetch, emergence was slowest in the sand treatment compared to the soils with clay content, probably because of the drying effect on seed germination and emergence.

**Table 1.** Analysis of variance table for greenhouse seedling emergence study.

| | Speed of Emergence No. viable seed/day[1] | | |
|---|---|---|---|
| **Factor** | **df** | **F value** | **Sign[2]** |
| Droplet (D) | 1 | 9.94 | * |
| Soil type (ST) | 3 | 0.62 | NS |
| D X ST | 3 | 0.36 | NS |
| Species (SP) | 3 | 765.5 | ** |
| D X SP | 3 | 1.58 | NS |
| ST X SP | 9 | 9.06 | ** |
| D X ST X SP | 9 | 0.94 | NS |
| Seed Treatment (T) | 1 | 3,874.08 | ** |
| D X T | 1 | 1.69 | NS |
| ST X T | 3 | 0.65 | NS |
| D X ST X T | 3 | 0.86 | NS |
| SP X T | 3 | 324.95 | ** |
| D X SP X T | 3 | 2.22 | NS |
| ST X SP X T | 9 | 2.06 | * |
| D X ST X SP X T | 9 | 1.19 | NS |

[1]Based on tetrazolium assessment of viable seed in each seed lot.

[2]NS = not significant, * = $p < 0.05$, ** = $p < 0.01$

Release of Majestic Germplasm and Spectrum Germplasm Western Prairie Clover

Western prairie clover (*Dalea ornata*) is a perennial leguminous forb that occurs naturally in Idaho, Washington, Oregon, California, and Nevada. Two natural-track selected germplasms of western prairie clover were released in 2011 for use in revegetation of semiarid rangelands in the western USA (Bhattarai et al. 2011; Johnson et al. 2011). Majestic Germplasm western prairie clover originates from seed collected from indigenous plants in Sherman County, Oregon, whereas Spectrum Germplasm western prairie clover originates from seed collected from indigenous plants in Malheur County, Oregon. Common-garden and DNA-marker data for 22 collections of western prairie clover were used to develop these releases on a genetic basis. Majestic Germplasm was selected to represent a genetically differentiated group of western prairie clover from the western Columbia Plateau and western Blue Mountains Ecoregions. Spectrum Germplasm was selected to represent the genetically differentiated group from the central and eastern Columbia Plateau, central and eastern Blue Mountains, Northern Basin and Range, and Snake River Plain Ecoregions. Besides the substantial and significant genetic differentiation detected between these two germplasm sources, these germplasms also reflect differences in flowering date, which was a significant delineator of the two groups as well as significantly correlated with environmental variables at the collection sites. Western prairie clover is a new species in the commercial seed trade, and these are the first releases of this species.

Field Seeding Studies

Based on the results of the greenhouse experiments, field seeding studies were established at Clarno, Powell Butte, and Ontario, OR. The former two sites were established cooperatively with Matt Horning, USFS Deschutes National Forest, and the latter with Clinton Shock and Erik Feibert, Oregon State University Malheur Experiment Station. Field plots were planted in fall 2011, spring 2012, and fall 2012. Studies included scarified and non-treated seed of Majestic and Spectrum germplasm western prairie clover and NBR-1 germplasm basalt milkvetch. Additional treatments at Ontario included a fungicide application on the seed. Establishment data will be collected for 2 years post-planting, but sites will be kept to allow for long-term observation. Preliminary observations from Clarno and Powell Butte suggest that spring plantings of the western prairie clover seed were the most successful, and fall plantings of NBR-1 scarified seed was the most productive. Plots in Ontario were unsuccessful due to logistical issues.

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**Presentations**

Johnson, D. A.; Bushman, B. S. 2012. Challenges of developing North American legumes for use on Great Basin rangelands. Eastern Nevada Landscape Coalition Conference; 2012 January 18-19; Ely, NV.

Johnson, D. A.; Bushman, B. S.; Jones, T. A.; Connors, K. J. 2012. Effect of seed scarification and seeding depth on greenhouse seedling emergence in western prairie clover, Searls' prairie clover, and basalt milkvetch. Society for Range Management Annual Meeting; 2012 January 29-2 February: Spokane, WA.

Johnson, D. A.; Bushman, B. S.; Jones, T. A.; Connors, K. J. 2012. Effect of seed scarification and seeding depth on greenhouse seedling emergence in western prairie clover, Searls' prairie clover and basalt milkvetch. Great Basin Native Plant Selection and Increase Project Annual Meeting; 2012 February 21-22; Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

**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

**Project Title** Great Basin Native Forb Development and Cultural Practices

**Project Agreement No.** 09-JV-11221632-193, 11-JV-11221632-009, 12-JV-11221632-050

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**Project Description**

Native Lupine Cultivation

In 2007, we planted cultural practice trials of four common native lupines: silvery lupine (*Lupinus argenteus*), longspur lupine (*L. arbustus*), hairy bigleaf lupine (*L. prunophilus*), and silky lupine (*L. sericeus*). Two species, longspur lupine and hairy bigleaf lupine, exhibited signs of iron deficiency chlorosis, shortly followed by necrosis. All longspur lupine seedlings died shortly after germination and did not regrow the following year. The hairy bigleaf lupine plantings in one of our three treatment groups regrew the following year. The species, however, has shown signs of iron deficiency chlorosis each year and did not flower and set seed until 2011, 4 years after planting.

Due to the total loss of the longspur lupine plots and the 66% loss of the hairy bigleaf lupine plots, as well as the stunted and delayed growth of surviving hairy bigleaf lupine plots, we have designed and begun implementing a study of iron deficiency chlorosis. Our objective is to identify a practical and effective method of treating iron deficiency chlorosis for these species. This study focuses on the four lupine species and four treatments of EDDHA chelated iron: control or no application, seed application, foliar application, and a combined seed and foliar application (Table 1). We measured germination, establishment, age at first flowering, seed yield, overall greenness (with a chlorophyll meter), and nutrient content of seedlings (by random destructive sampling). We also began a greenhouse study using the same species and treatments to determine plant biomass in response to the EDDHA chelated iron fertilizer applications.

**Table 1.** Codes for study treatments of EDDHA chelated iron (Fe) applications to lupine species.

| Code | Treatment |
|---|---|
| Control | Control, no treatment |
| Native | Wild population untreated |
| Seed | Fe application to seed |
| Foliar | Chlorophyll measurements of seedlings prior to Fe foliar application |
| Both | Chlorophyll measurements of seedlings prior to Fe foliar application but which received Fe application to seeds |
| Foliar2 | Chlorophyll measurements after two Fe foliar applications (one immediately after seedling chlorophyll measurements and one 2 weeks later) to treatment “Foliar” |
| Both2 | Chlorophyll measurements after two Fe foliar applications (one immediately after seedling chlorophyll measurements and one 2 weeks later) to treatment "Both" |

In spring of 2012, we calculated germination by sampling seedling density in 0.25 m (0.82 ft) of every meter in every seeded row. Silvery lupine failed to germinate and was excluded from the rest of the study. In general, the other three species and treatments germinated well (Figure 1). Plots at our Snow Field Station farm exhibited greater germination than the plots in our Fountain Green farm. We did not conduct statistical analyses on the germination data; the data will serve as a baseline when we calculate establishment in spring of 2013.

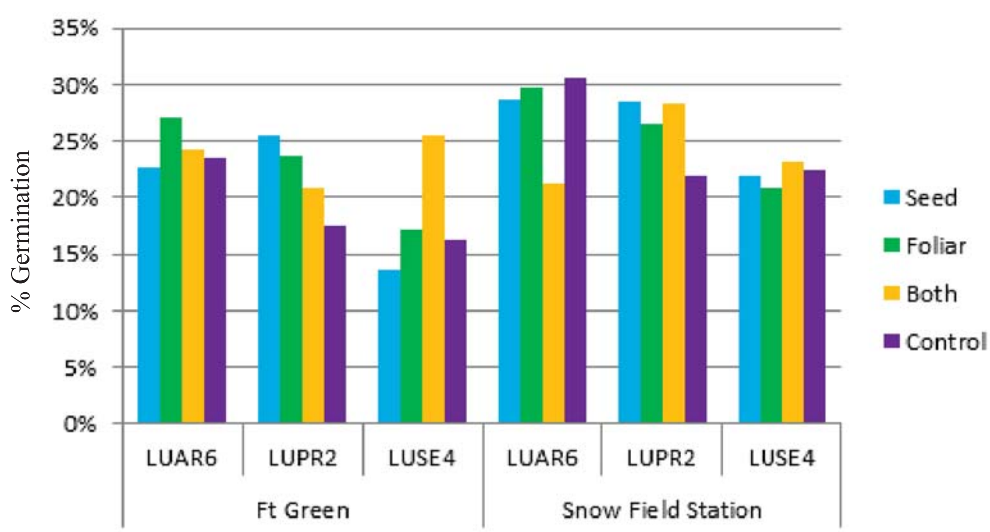



**Figure 1.** Percent germination of three lupine species and four EDDHA chelated iron treatments at Fountain Green and Snow Field Station, Utah. Iron treatments are: Seed—seed application, Foliar—foliar application, Both—seed and foliar application, and Control—no application. LUAR6 = silvery lupine, LUPR2 = hairy bigleaf lupine, LUSE4 = silky lupine. See Table 2 for species code scientific names.

**Table 2.** Lupine species plant code descriptions (USDA-NRCS 2000).

| Plant Code | Scientific Name | Common Name |
|---|---|---|
| LUAR6 | *Lupinus arbustus* | Longspur lupine |
| LUAR3 | *Lupinus argenteus* | Silvery lupine |
| LUPR2 | *Lupinus prunophilus* | Hairy bigleaf lupine |
| LUSE4 | *Lupinus sericeus* | Silky lupine |

When plants had between three and four leaves, we used a chlorophyll content meter (Opti-Sciences CCM-300, Hudson, NH) to measure chlorophyll fluorescence and content of 50 plants from each treatment in each block. The CCM-300 measures chlorophyll fluorescence at 700 nm and 735 nm and uses this ratio to accurately measure chlorophyll content ($mg/m^{-2}$; Gitelson et al. 1999). After the initial readings were taken the foliar application of EDDHA chelated iron was applied to the foliar and the combined treatment groups. Two weeks later the application of EDDHA chelated iron was repeated. We then measured chlorophyll fluorescence and content of all treatment groups that received the foliar application (Table 3).

**Table 3.** Treatments and timing of EDDHA chelated iron (Fe) applications to lupine species. "X" represents Fe application; "M" represents measurements of chlorophyll fluorescence and content.

| Treatment | Fe application to seed | Chlorophyll measurement on seedlings (3-4 leaves) | Fe application to foliar | Fe application to foliar after 2-wk growth | Chlorophyll measurement on 2-wk growth |
|---|---|---|---|---|---|
| Native | | M | | | |
| Control | | M | | | |
| Seed | X | M | | | |
| Foliar | | M | X | X | M |
| Both | X | M | X | X | M |

We took readings of natural, untreated populations ('Native') of the lupines to be used as a baseline comparison of our experimental garden plots. We ran an analysis of variance with the R statistical computing program (R Core Team 2012) of both the chlorophyll fluorescence ratio and chlorophyll content comparing the treatments within each species. We ran the analysis with all farms and blocks collectively only analyzing the treatment differences within each species.

*Longspur lupine*
The chlorophyll fluorescence ratio (CFR) results for longspur lupine indicate that the Native population has the greatest CFR and is statistically similar to Both2 (Figure 2). The next highest CFR mean values are Both2 and Foliar2, which were statistically similar. Foliar2, Both, and Seed treatments are all statistically similar. There was a significant difference between Both and Both2 ($p = 0.02135$). There was also a significant difference between the Foliar and Foliar2 treatments ($p < 0.0001$). The Control was statistically similar to Foliar treatment.

The chlorophyll content results for longspur lupine are very similar to the CFR results (Figure 3). The native population had the highest mean chlorophyll content and is statistically similar to Both2. Both2 has statistically similar chlorophyll content as Foliar2. Seed, Both, and Foliar2 are all statistically similar. Control and Foliar had the lowest mean chlorophyll content and are statistically similar. Both is significantly lower than Both2 ($p = 0.013$). Foliar2 is significantly greater than Foliar ($p < 0.00001$).

*Hairy bigleaf lupine*
The CFR results for hairy bigleaf lupine (Figure 4) indicate that the Native population has the highest mean and is statistically similar to Both2, Foliar2, and Seed treatments. Foliar2, Both, and Seed treatments are all statistically similar. Foliar has the lowest mean and is statistically similar to Control. Both2 was significantly higher than Both ($p = 0.02215$). Foliar2 was significantly greater than Foliar ($p < 0.00001$).

The chlorophyll content for hairy bigleaf lupine (Figure 5) indicates that the Native population has the highest mean and is statistically similar to Both2, Foliar2, and Seed. The mean values for Foliar, Foliar2, and Seed) are statistically similar. Control and Foliar have the lowest mean values and are statistically similar. Both2 is significantly greater than Both ($p = 0.02186$). Foliar2 is significantly greater than Foliar ($p < 0.00001$).

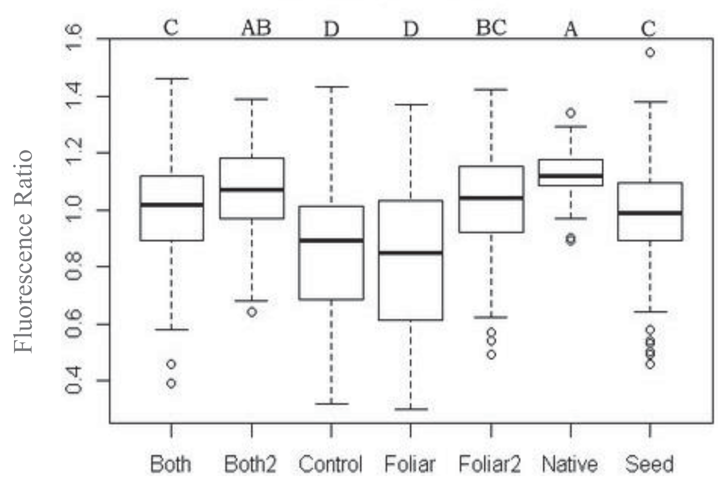
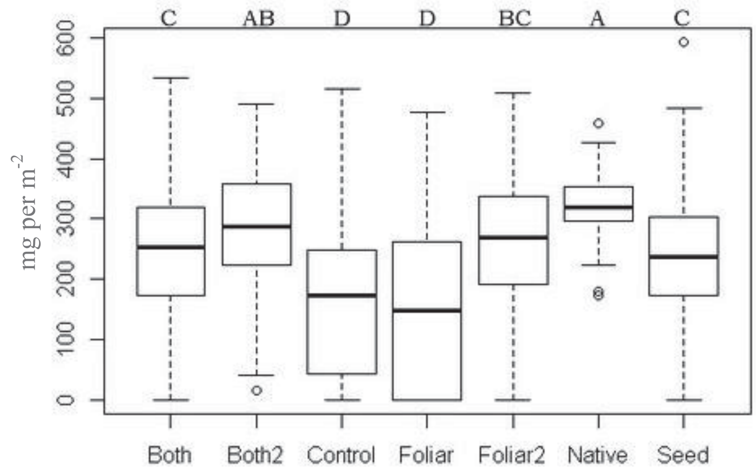



**Figure 2.** Box-and-whisker plot of chlorophyll fluorescence ratio, by treatment, for longspur lupine. Letters above bars statistically compare treatments; the same letters represent treatments that do not differ ($p > 0.05$).

**Figure 3.** Box-and-whisker plot of chlorophyll concentration (mg/m$^{-2}$), by treatment, for longspur lupine. Letters above bars statistically compare treatments; the same letters represent treatments that do not differ ($p > 0.05$).



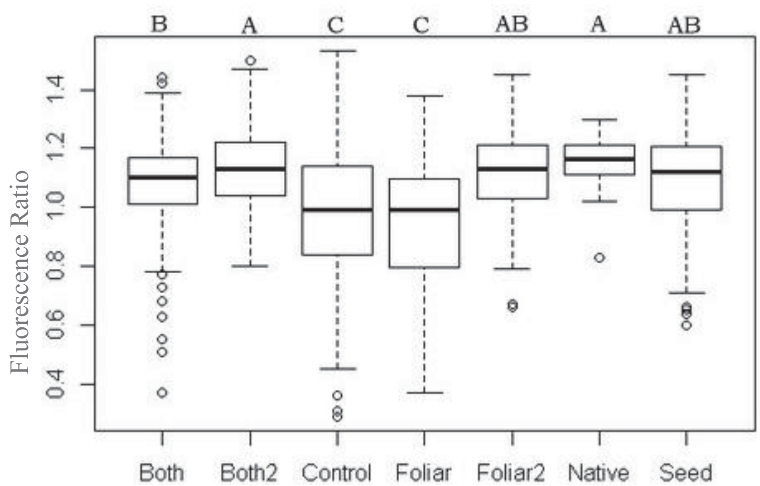
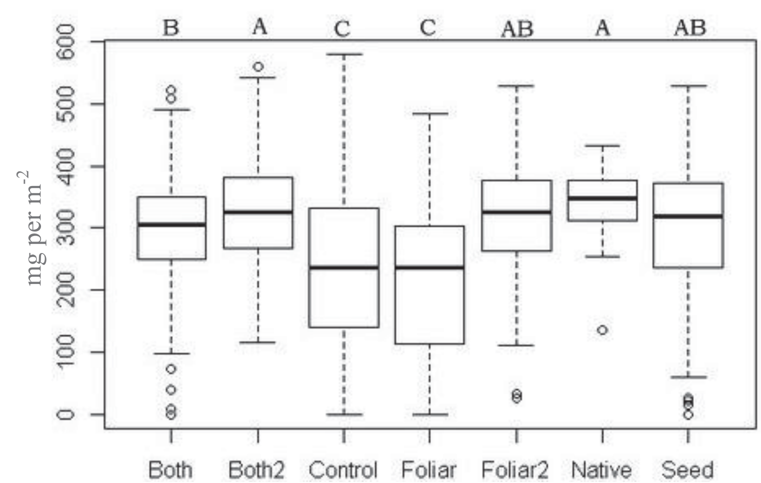




**Figure 4.** Box-and-whisker plot of chlorophyll fluorescence ratio, by treatment, for hairy bigleaf lupine. Letters above bars statistically compare treatments; the same letters represent treatments that do not differ ($p > 0.05$).

**Figure 5.** Box-and-whisker plot of chlorophyll concentration (mg/m$^{-2}$), by treatment, for hairy bigleaf lupine. Letters above bars statistically compare treatments; the same letters represent treatments that do not differ ($p > 0.05$).



*Silky lupine*
The CFR results for silky lupine (Figure 6) indicate that Both2 has the highest mean value and is statistically similar to the Native population. The Native population and Foliar2 treatments have mean values that are statistically similar. Both and Native have mean values that are statistically similar. Both and Seed treatments have mean values that are statistically similar. Seed and Control have mean values that are statistically similar. Foliar and Control have the lowest mean values and are statistically similar. Both2 is significantly greater than Both, as is Foliar2 compared to Foliar ($p < 0.00001$).

The chlorophyll content concentration analysis results for silky lupine (Figure 7) indicates that Both2 has the greatest mean value and is statistically similar to the Native population. Foliar2 and Native were statistically similar. Both and Seed treatments are statistically similar. Seed and Control are statistically similar. Foliar has the lowest mean value and is statistically similar to Control. Both2 is significantly greater than Both ($p < 0.00001$), as is Foliar2 compared to Foliar ($p < 0.00001$).

*Iron Content*
We conducted random destructive sampling of 20 plants from all species and treatment groups prior to the foliar EDDHA chelated iron application. These were sent to Brigham Young University Environmental Analytical Lab, Provo, UT, to be analyzed for iron content. We also took plant samples after the foliar Fe applications; however silky lupine was the only species that had adequate new foliage in the Control to sample. Leaves harvested from natural populations of each species were also sent to the lab to be analyzed; results will serve as a baseline for species' iron content in non-agricultural soil.

In spring of 2013 we will collect more leaf material from our plots and native populations to be sent in for iron content analysis to investigate the long term effects on the iron treatments applied to seed or seedlings. We will also be looking for the correlation between iron content and chlorophyll fluorescence ratio by taking multiple chlorophyll content meter readings from individual plants and sampling these same plants for iron content.

We are currently in the process of analyzing the biomass data from our greenhouse trials. We predict that the plants grown from Fe-treated seeds will have greater root mass than plants with Fe-treated foliar or which were not treated.

<u>Transplant Study</u>
Arrowleaf balsamroot (*Balsamorhiza saggitata*), Hooker's balsamroot (*B. hookeri*), tapertip hawksbeard (*Crepis acuminata*), and gray hawksbeard (*C. intermedia*) pose problems in cultivation due to the length of time it takes for them to establish before they flower and produce seed, typically 3 to 5 years. Seed growers are not willing to devote agricultural fields to crops that are not producing income. In order to determine whether we might shorten the time between field planting and seed production, we investigated the feasibility of establishing seed fields from transplant stock. We began by seeding beds with 15-cm (5.9-in) row spacing to create a dense bed of seedlings that can be transplanted before they are large mature plants. Three beds were planted in 2009, eight in 2010, twenty-six in 2011, and 25 in 2012. In the spring of 2013, the first beds planted will be ready for transplanting. We will categorize the root stock by crown diameter

and root length and use plant size as treatments in our experimental design. These factors will be important to consider because the time it will take for them to flower after transplanting remains unknown.

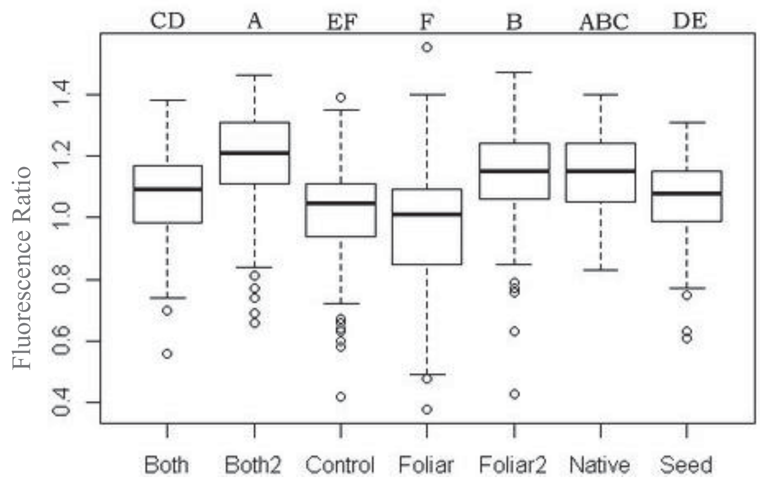



**Figure 6.** Box-and-whisker plot of chlorophyll fluorescence ratio, by treatment, for silky lupine. Letters above bars statistically compare treatments; the same letters represent treatments that do not differ ($p > 0.05$).

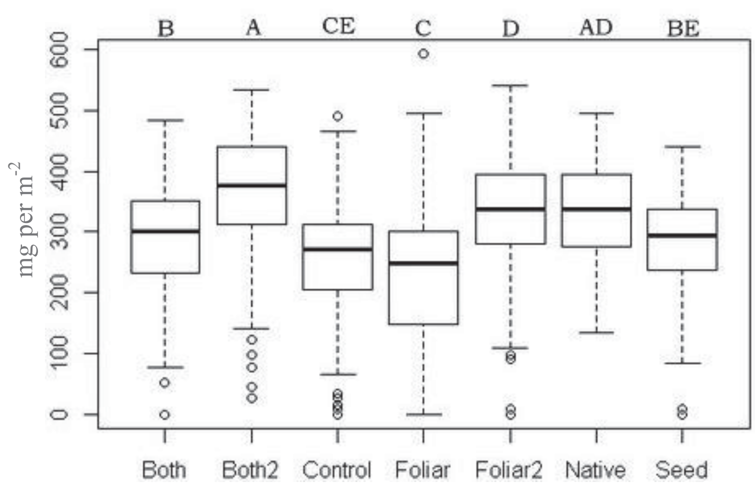



**Figure 7.** Box-and-whisker plot of chlorophyll concentration ($mg/m^{-2}$), by treatment, for silky lupine. Letters above bars statistically compare treatments; the same letters represent treatments that do not differ ($p > 0.05$).

<u>Common Garden</u>
Cushion buckwheat (*Eriogonum ovalifolium*)
In 2010 and 2011, we harvested seed from each accession in the common garden. However, the resulting harvests had low seed yields and low seed viability. Due to these factors, we purchased pollination cages and set up a study to attempt to increase both seed yield and viability of the

accessions in the common garden. Unfortunately, the common garden had over-winter die-off due to a combination of drought conditions and age. The surviving plants did flower and set seed, however, we found evidence of seed predation. The resulting harvest showed no increase in seed production or seed viability.

The new cushion buckwheat common garden will be planted in the spring of 2013. The new common garden consists of the 11 highest yielding accessions from the 2010 and 2012 common garden harvests (Table 4). We planted both wildland-harvested seed and seed harvested from the common garden for a total of 22 accessions. The new common garden will be focusing on high yield seed production and will investigate if seed yield is a trait that will be carried on in subsequent generations. The common garden will be planted on two farms and each consists of five randomized complete blocks. We expect the first seed harvest to be in the summer of 2014.

**Table 4.** Cushion buckwheat common garden highest seed yield accessions 2010-2012.

| Lot # | Site | Ecoregion |
|---|---|---|
| EROV-U11-2002 | Sand Pass | 13k Lahontan Sagebrush Slopes |
| EROV-U13-2002 | Toano | 13q Carbonate Woodland Zone |
| EROV-U20-2005 | Crittenden Res. | 13r Central Nevada High Valleys |
| EROV-U23-2005 | Crittenden Res. | 80a Dissected High Lava Plateau |
| EROV-U27-2005 | Newcastle | 13c Sagebrush Basins and Slopes |
| EROV-U28-2005 | Jungo Road | 13z Upper Lahontan Basin |
| EROV-U29-2005 | Cobre | 80a Dissected High Lava Plateau |
| EROV-U30-2004 | Hwy 26 mm 280-281 | 12g Eastern Snake River Basalt Plains |
| EROV-U7-2002 | Pequop Foothills | 13p Carbonate Sagebrush Valleys |
| EROV-U8-2002 | North Battle Mountain | 13m Upper Humboldt Plains |
| EROV-U9-2002 | Adobe Hill | 13m Upper Humboldt Plains |

Seed Increase and Foundation Fields

We continued to maintain stock seed accessions planted in 2009, 2010, and 2011 which consists of 65 accessions of 11 species between the UDWR farms in Fountain Green, Utah and Ephraim, Utah (Table 5). In addition to these we planted 15 accessions of four species at the Fountain Green, Utah farm, 29 accessions of 18 species at the Ephraim, Utah farm, and 18 accessions of five species at the Nephi, Utah farm. These are the stock seed increase fields for our pooled source releases that will be distributed to growers as sufficient seed is produced and native plant material releases made. We have also planted seed of 19 accessions and 12 species in the greenhouse that will be transplanted to the farms in the spring for species' evaluations.

**Table 5.** Farm plantings at three Utah farms, Utah Division of Wildlife Resources, Great Basin Research Center.

## Fountain Green Farm

| Species / Source | Lot Number | Year Planted | Purpose of Plantings |
|---|---|---|---|
| *Balsamorhiza hookeri* - Hooker's balsamroot | | | |
| Palisade | BAHO-U2-2009 | 2009 | Root Transplant |
| Emigrant | BAHO-U3-2008 | 2010 | Root Transplant |
| Card Canyon | BAHO-U77-2006 | 2010 | Root Transplant |
| Palisade | BAHO-U2-2009 | 2011 | Seed Increase |
| Water Canyon | BAHO-U2-2009 | 2011 | Seed Increase |
| Relay Station | BAHO-U76-2005 | 2011 | Seed Increase |
| N. Battle Mountain | PSSL-115 | 2011 | Seed Increase |
| Big Butte | PSSL-97 | 2011 | Seed Increase |
| *Balsamorhiza sagittata* - arrowleaf balsamroot | | | |
| Palisade | BASA3-U77-2009 | 2009 | Root Transplant |
| Sand Pass | BASA3-U30-2009/PSSL-110 | 2011 | Seed Increase |
| Devil's Playground | BASA3-U33-2009 | 2011 | Seed Increase |
| Twelve Mile | BASA3-U35-2002 | 2011 | Seed Increase |
| Elko | BASA3-U73-2005 | 2011 | Seed Increase |
| Palisade | BASA3-U77-2008 | 2011 | Seed Increase |
| Sand Pass | BASA3-U30-2005 | 2012 | Seed Increase |
| Devil's Playground | BASA3-U33-2005 | 2012 | Seed Increase |
| Twelve Mile | BASA3-U35-2005 | 2012 | Seed Increase |
| *Crepis acuminata* - tapertip hawksbeard | | | |
| Relay Station | CRAC2-U36-2009 | 2009 | Root Transplant |
| Soldier Canyon | CRAC2-U38-2006 | 2010 | Root Transplant |
| N of Elko ELCI Site | CRAC2-U44-2006 | 2010 | Root Transplant |
| N. Battle Mountain | CRAC2-U5-2002 | 2010 | Root Transplant |
| Comins Lake | CRAC2-B3-2001 | 2011 | Seed Increase |
| MM 356 I-80 | CRAC2-U3-2002 | 2011 | Seed Increase |
| Relay Station | CRAC2-U36-2009 | 2011 | Seed Increase |
| I-80 MM 273 | CRAC2-U37-2004 | 2011 | Seed Increase |
| N of Elko ELCI Site | CRAC2-U44-2006 | 2011 | Seed Increase |
| N. Battle Mountain | CRAC2-U5-2002 | 2011 | Seed Increase |
| I-80 MM 268 | CRAC2-U53-2005 | 2011 | Seed Increase |
| Hodgsen Pond | CRAC2-U54-2002 | 2011 | Seed Increase |
| Paradise Rancho | CRAC2-U59-2007 | 2011 | Seed Increase |
| Adobe Hill | CRAC2-U8-2002 | 2011 | Seed Increase |

| Species / Source | Lot Number | Year Planted | Purpose of Plantings |
|---|---|---|---|
| Devil's Canyon | PSSL-106 | 2011 | Seed Increase |
| Suzie Creek | PSSL-87 | 2011 | Seed Increase |
| I-80 MM 356 | CRAC2-U3-2002 | 2012 | Seed Increase |
| Relay Station | CRAC2-U36-2006 | 2012 | Seed Increase |
| I-80 MM 273 | CRAC2-U37-2004 | 2012 | Seed Increase |
| N. Battle Mountain | CRAC2-U5-2006 | 2012 | Seed Increase |
| I-80 MM 268 | CRAC2-U53-2005 | 2012 | Seed Increase |
| Paradise Hill | CRAC2-U59-2007 | 2012 | Seed Increase |
| *Crepis intermedia* - gray hawksbeard | | | |
| Mineral Mountain | CRIN4-U58-2005 | 2009 | Root Transplant |
| Elko ELCI Site | CRIN4-U45-2005 | 2010 | Root Transplant |
| Nephi Dry Farm | CRIN4-U56-2005 | 2010 | Root Transplant |
| Mineral Mountain | CRIN4-U58-2005 | 2010 | Root Transplant |
| Buster Mt. | CRIN4-B1-2003 | 2011 | Seed Increase |
| Elko ELCI site | CRIN4-U45-2005 | 2011 | Seed Increase |
| Nephi Dry Farm | CRIN4-U56-2011 | 2011 | Seed Increase |
| Mineral Mt. | CRIN4-U58-2005 | 2011 | Seed Increase |
| Mineral Mountain | CRIN4-P1-2005 | 2012 | Seed Increase |
| Nephi Dry Farm | CRIN4-U56-2011 | 2012 | Seed Increase |
| *Sphaeralcea grossulariifolia* - gooseberryleaf globemallow | | | |
| Sevier Lake | PSSL-122 | 2011 | Seed Increase |
| Major's Place | PSSL-130 | 2011 | Seed Increase |
| Cove Fort | PSSL-173 | 2011 | Seed Increase |
| Scooby | RMRS-1225 | 2011 | Seed Increase |
| Wadsworth Ranch | SPGR2-U65-2009 | 2011 | Seed Increase |
| Major's Place | PSSL-130 | 2012 | Seed Increase |
| Road to Lund | SPGR2-U15-2012 | 2012 | Seed Increase |
| Cherry Creek | SPGR2-U30-2004 | 2012 | Seed Increase |
| Pioche | SPGR2-U63-2008 | 2012 | Seed Increase |
| Antelope Springs | SPGR2-U64-2009 | 2012 | Seed Increase |
| Cove Fort | SPGR2-U71-2012 | 2012 | Seed Increase |

## Nephi Dry Farm

| Species / Source | Lot Number | Year Planted | Purpose of Plantings |
|---|---|---|---|
| *Balsamorhiza hookeri* - Hooker's balsamroot | | | |
| Eco Road | PSSL-105 | 2012 | Seed Increase |
| *Balsamorhiza sagittata* - arrowleaf balsamroot | | | |

| Species / Source | Lot Number | Year Planted | Purpose of Plantings |
|---|---|---|---|
| ARS Plots | BASA3-B23-2004 | 2012 | Seed Increase |
| Richmond | BASA3-B29-2004 | 2012 | Seed Increase |
| Ox Valley | BASA3-U36-2006 | 2012 | Seed Increase |
| Pocatello Valley | BASA3-U54-2004 | 2012 | Seed Increase |
| Pequop Pass | BASA3-U70-2005 | 2012 | Seed Increase |
| Soldier Canyon | BASA3-U72-2009 | 2012 | Seed Increase |
| *Crepis acuminata* - tapertip hawksbeard | | | |
| Coyote Hills | CRAC2-U10-2006 | 2012 | Seed Increase |
| *Crepis intermedia* - gray hawksbeard | | | |
| Pequop Pass | CRIN4-U2-2008 | 2012 | Seed Increase |
| *Iliamna rivularis* – streambank wild hollyhock | | | |
| Freemont | ILRI-U1-2012 | 2012 | Species Evaluation |
| *Sphaeralcea munroana* - Munro's globemallow | | | |
| Overstreet Adrian | SPMU1-BY10 | 2012 | Seed Increase |
| Road to Hoo Doo Ridge | SPMU2-BY09 | 2012 | Seed Increase |
| Owyhee Dam Road | SPMU2-BY10 | 2012 | Seed Increase |
| Crowley | SPMU4-BY10 | 2012 | Seed Increase |
| Harney Lake | SPMU5-BY10 | 2012 | Seed Increase |
| Burns Junction | SPMU6-BY10 | 2012 | Seed Increase |
| Twin Springs | SPMU8-BY10 | 2012 | Seed Increase |
| I-84W MP11 | - | 2012 | Seed Increase |
| Sandhollow 1 | - | 2012 | Seed Increase |
| Sandhollow 2 | - | 2012 | Seed Increase |
| I-84E MP8 | - | 2012 | Seed Increase |

## Snow Field Station

| Species / Source | Lot Number | Year Planted | Purpose of Plantings |
|---|---|---|---|
| *Aquilegia formosa* - western columbine | | | |
| Loop Road | AQFO-U3-2012 | 2012 | Species Evaluation |
| Wales | AQFO-U5-2012 | 2012 | Species Evaluation |
| *Aster sp.* - Aster | | | |
| Log Canyon | ASTER-U1-2012 | 2012 | Species Evaluation |
| *Balsamorhiza hookeri* - Hooker's balsamroot | | | |
| CTTNCK | BAHO-P4-2011 | 2011 | Seed Increase |
| Indian Creek Reservoir | | 2012 | Seed Increase |
| *Balsamorhiza sagittata* - arrowleaf balsamroot | | | |
| Coyote Hills | BASA3-U32-2007 | 2011 | Seed Increase |

| Species / Source | Lot Number | Year Planted | Purpose of Plantings |
|---|---|---|---|
| Buck Lake | BASA3-U45-2003 | 2011 | Seed Increase |
| Coffee Pot Crater | BASA3-U50-2003 | 2011 | Seed Increase |
| Stinking Water | BASA3-U65-2004 | 2011 | Seed Increase |
| Willow Creek | PSSL-104 | 2011 | Seed Increase |
| *Castilleja sp.* - Indian paintbrush | | | |
| Log Canyon | CAST11-U1-2012 | 2012 | Species Evaluation |
| *Crepis acuminata* - tapertip hawksbeard | | | |
| Diamond Peak | CRAC2-B5-2002 | 2011 | Seed Increase |
| Robinson Pass | CRAC2-B8-2003 | 2011 | Seed Increase |
| Limerick Canyon | CRAC2-U12-2002 | 2011 | Seed Increase |
| Lamoille Canyon | CRAC2-U22-2006 | 2011 | Seed Increase |
| Cherry Creek | CRAC2-U39-2004 | 2011 | Seed Increase |
| Toano | CRAC2-U6-2001 | 2011 | Seed Increase |
| Winnemucca Mt. | CRAC2-U7-2005 | 2011 | Seed Increase |
| Vernon Creek | PSSL-152 | 2011 | Seed Increase |
| Angel Lake | PSSL-85 | 2011 | Seed Increase |
| *Crepis occidentalis* - western hawksbeard | | | |
| Baldies | CROC-U1-2009 | 2011 | Species Evaluation |
| *Delphinium nuttallianum* - twolobe larkspur | | | |
| Bald Mt. Pass | DENU2-U1-2011 | 2011 | Species Evaluation |
| *Iliamna rivularis* - streambank wild hollyhock | | | |
| Freemont | ILRI-U1-2012 | 2012 | Species Evaluation |
| *Linum kingii* - King's flax | | | |
| Kirch WMA | LIKI2-U1-2012 | 2012 | Species Evaluation |
| *Muhlenbergia asperifolia* - scratchgrass | | | |
| Hinkley | MUAS-U1-2012 | 2012 | Species Evaluation |
| *Penstemon eatonii* - firecracker penstemon | | | |
| Monroe | PEEA-U1-2012 | 2012 | Seed Increase |
| Wales | PEEA-U2-2012 | 2012 | Seed Increase |
| Beaver | PEEA-U3-2012 | 2012 | Seed Increase |
| Chalk Canyon | PEEA-U4-2012 | 2012 | Seed Increase |
| Shoal Creek | PEEA-U5-2012 | 2012 | Seed Increase |
| *Penstemon procerus* - littleflower penstemon | | | |
| Baldy Mt. | PEPR2-U1-2011 | 2011 | Species Evaluation |
| Baldy Mt. | PEPR2-U1-2011 | 2012 | Seed Increase |
| *Penstemon rostriflorus* - Bridge penstemon | | | |
| Shoal Creek | PERO10-U1-2012 | 2012 | Seed Increase |
| Beaver | PERO10-U2-2012 | 2012 | Seed Increase |

| Species / Source | Lot Number | Year Planted | Purpose of Plantings |
|---|---|---|---|
| *Penstemon rydbergii* - Rydberg's penstemon | | | |
| PERY-U1-2011 | Snow Field | 2011 | Species Evaluation |
| PERY-U1-2011 | Snow Field | 2012 | Seed Increase |
| *Penstemon strictus* - Rocky Mountain penstemon | | | |
| Pleasant Valley | PEST2-U1-2011 | 2011 | Species Evaluation |
| Pleasant Valley | PEST2-U1-2011 | 2012 | Seed Increase |
| *Perideridia bolanderi* - Bolander's yampah | | | |
| Relay Station | PEBO2-U21-2007 | 2011 | Seed Increase |
| Stampede Ranch | PEBO2-U2-2006 | 2011 | Seed Increase |
| Suzie Creek | PEBO2-U3-2005 | 2011 | Seed Increase |
| Swales | PEBO2-U5-2002 | 2011 | Seed Increase |
| Pole Creek | PEBO2-U6-2006 | 2011 | Seed Increase |
| *Potentilla arguta* - tall cinquefoil | | | |
| Log Canyon | POAR7-U1-2012 | 2012 | Species Evaluation |
| *Rudbeckia occidentalis* - western coneflower | | | |
| Log Canyon | RUOC2-U1-2012 | 2012 | Species Evaluation |
| Loop Road | RUOC2-U2-2012 | 2012 | Species Evaluation |
| *Scrophularia lanceolata* - lanceleaf figwort | | | |
| Log Canyon | SCLA-U1-2012 | 2012 | Species Evaluation |
| *Sphaeralcea coccinea* - scarlet globemallow | | | |
| Pony Express Road | PSSL-101 | 2011 | Seed Increase |
| Mona | SPCO-U10-2011 | 2011 | Seed Increase |
| Eagle Mt. | SPCO-U55-2005 | 2011 | Seed Increase |
| Highway to Springville | SPCO-U11-2012 | 2012 | Seed Increase |
| *Sphaeralcea parvifolia* - smallflower globemallow | | | |
| Pioche | PSSL-37 | 2012 | Seed Increase |
| White River | SPAM2-P2-2008 | 2012 | Seed Increase |
| Mule Shoe Valley | SPPA2-P2-2005 | 2012 | Seed Increase |
| Beryl Junction | SPPA2-U60-2012 | 2012 | Seed Increase |
| Geyser Ranch | SPPA-U28-2005 | 2012 | Seed Increase |
| Pole Creek | SPPA-U57-2006 | 2012 | Seed Increase |

Wildland Seed Collection

In 2011, we compiled a database on historic population locations and collection sites, as well as, historic herbaria sites of our target species throughout the Great Basin. In 2012, this tool served us well in prioritizing sites to search for new populations for seed harvest. We located 76 new sites with populations of at least 50 plants (Figure 8). At each site we collected three herbarium specimens. One specimen will be kept in our office herbarium, one will be sent to the Stanley L. Welsh Herbarium at Brigham Young University, Provo, Utah, and the third will be available for loan by request of collaborators. We were unable to harvest seed from all 76 sites in 2012; hence, the unsampled sites will be included in prioritization of seed harvest trips in the coming seasons.

Although drought reduced the number of populations and species able to produce seed, we were able to harvest seed from 52 accessions of 29 species (Table 6). The majority of the species we observed flowered in the early summer but failed to produce seed due to dry conditions. The populations from which we did harvest seed had poor yields per plant. We moved the focus of our collecting from the lower basins and valleys where target species were not producing seed, to montane and riparian habitats where species were flowering and producing seed.. The exceptions we observed are firecracker penstemon and Bridge penstemonwhich flowered and produced seed throughout their range; and gooseberryleaf globemallow, smallflower globemallow, and James' galleta populations growing in the southern portion of the Great Basin that received the monsoonal moisture events during the late summer and flowered and set seed in mid-October. In the coming year we will be identifying and collecting from more sites of firecracker penstemon and Bridge penstemon due to their ability to flower and produce seed in drought years.

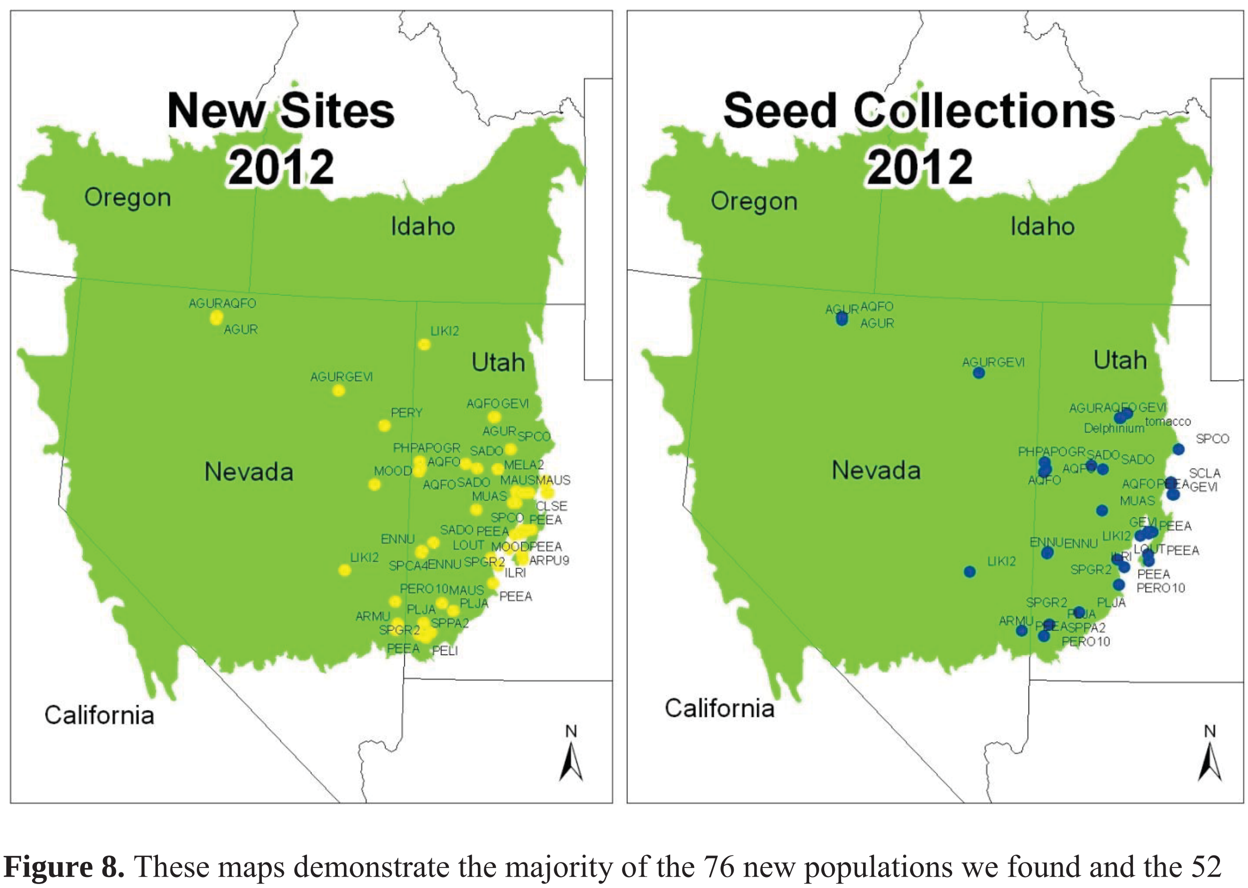



**Figure 8.** These maps demonstrate the majority of the 76 new populations we found and the 52 sites from which we harvested seed in western Utah (Table 6). We will continue to use historic herbaria records to prioritize our seed collecting.

**Table 6**. Species collected in 2012.

| USDA Plant Code | Scientific Name | Common Name | No. of Collections |
|---|---|---|---|
| AGUR | *Agastache urticifolia* | nettleleaf giant hyssop | 6 |
| AQCOO | *Aquilegia coerulea* var. *ochroleuca* | white Colorado columbine | 1 |
| AQFO | *Aquilegia formosa* | western columbine | 5 |
| ARMU | *Argemone munita* | flatbud pricklypoppy | 1 |
| ARPU9 | *Aristida purpurea* | purple threeawn | 1 |
| ASCO12 | *Astragalus convallarius* | lesser rushy milkvetch | 1 |
| ASTER | *Aster* sp. | aster | 1 |
| CAST11 | *Castilleja* sp. | Indian paintbrush | 1 |
| CHANA2 | *Chamerion angustifolium* | fireweed | 1 |
| DENU2 | *Delphinium nuttallianum* | upland larkspur | 1 |
| ENNU | *Enceliopsis nudicaulis* | nakedstem sunray | 2 |
| GEVI | *Geranium viscosissimum* | sticky purple geranium | 4 |
| ILRI | *Iliamna rivularis* | streambank wild hollyhock | 1 |
| IPCO5 | *Ipomopsis congesta* | ballhead ipomopsis | 1 |
| LIKI2 | *Linum kingii* | King's flax | 2 |
| LOUT | *Lotus utahensis* | Utah bird's-foot trefoil | 1 |
| MUAS | *Muhlenbergia asperifolia* | scratchgrass | 1 |
| PEEA | *Pensetomon eatonii* | firecracker penstemon | 5 |
| PERO10 | *Penstemon rostriflorus* | Bridge's penstemon | 2 |
| PHACE | *Phacelia* sp. | phacelia | 1 |
| PLJA | *Pleuraphis jamesii* | James' galleta | 2 |
| POAR7 | *Potentilla arguta* | tall cinquefoil | 1 |
| POGR | *Potentilla gracilis* | slender cinquefoil | 1 |
| RUOC2 | *Rudbeckia occidentalis* | western coneflower | 2 |
| SADO4 | *Salvia dorii* | purple sage | 2 |
| SCLA | *Scrophularia lanceolata* | lanceleaf figwort | 1 |
| SPCO | *Sphaeralcea coccinea* | scarlet globemallow | 1 |
| SPGR2 | *Sphaeralcea grossulariifolia* | gooseberryleaf globemallow | 2 |
| SPPA2 | *Sphaeralcea parvifolia* | smallflower globemallow | 1 |

## Germination Studies

### *Ballhead ipomopsis*

Little is known about the germination requirements of ballhead ipomopsis. Therefore, we examined the effect of a 10-wk cold-stratification of seeds on germination compared to a control group. From each accession 50 seeds were placed onto moistened blotter paper in 10 petri dishes. Five dishes were kept at 4°C (39.2ºF) for 10 weeks before being placed in an incubator (Precision Scientific Low Temperature Illuminated Incubator, Winchester, VA). The other five dishes were placed directly into an incubator. Germination was recorded every 7 days for 21 days; after which the % germination could be calculated (number of seedlings/total seeds planted).

In 2011 we were able to make several collections of ballhead ipomopsis from western Utah. Crystal Peak and Snake Pass accessions were collected in central western Utah located approximately 110 km (68 mi) west of Fillmore; Utah and Uvada accessions were collected in southwest Utah located approximately 80 km (50 mi) northwest of St. George, Utah on the Nevada border.

The Crystal Peak and Snake Pass accessions had increased germination in response to cold-stratification (Figure 9); however, in a statistical comparison,  only the Crystal Peak accession showed a significant difference ($p = 0.0278$, ANOVA). The Uvada accession had decreased germination in response to cold-stratification (Figure 9). The differences in response to the stratification period may be due to winter climate at the collections sites (Kitchen 2001). However, our data are inconclusive and we will need to evaluate germination responses from accessions collected throughout the species' range to determine germination regulatory functions of each ecotype (Meyer 1992) before such a conclusion can be made.

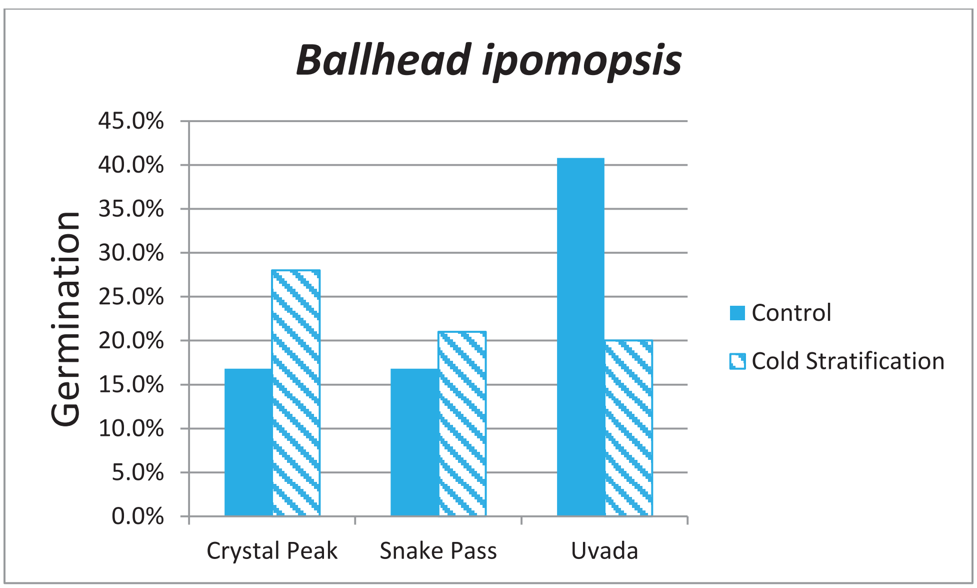



**Figure 9.** Effect of cold-stratification on germination of ballhead ipomopsis on three western Utah accessions. Cold-stratification improved germination in two of three accessions and decreased germination in the third accession.

*Golden princesplume*

Little is known about the stratification requirements for golden princesplume. Therefore, we examined the effect of a 10-wk cold-stratification of seeds on germination compared to a control group. From each accession, 50 seeds were placed onto moistened blotter paper in 10 petri dishes. Five dishes were kept at 4°C (39.2ºF) for 10 weeks before being placed in an incubator. The other five dishes were placed directly into an incubator. Germination (number of seedlings) was recorded every 7 days for 21 days.

In 2011 we collected three accessions of golden princesplume from western Utah and eastern Nevada. The collection sites were Bidwell Pass located approximately 18 km (11 mi) north of West Wendover, Nevada; Smelter Knolls located approximately 25 km (16 mi) northwest of Delta, Utah; and Silver Peak located approximately 35 km (22 mi) west of Cedar City, Utah.

Stratification significantly reduced germination compared to the control groups for all three accessions (Figure 10; $p < 0.000001$. The accession from Bidwell Pass had the highest % germination in the control group and the lowest % germination in the stratification group (Figure 10). This species is non-dormant, and stratification did not improve germination in our trials.

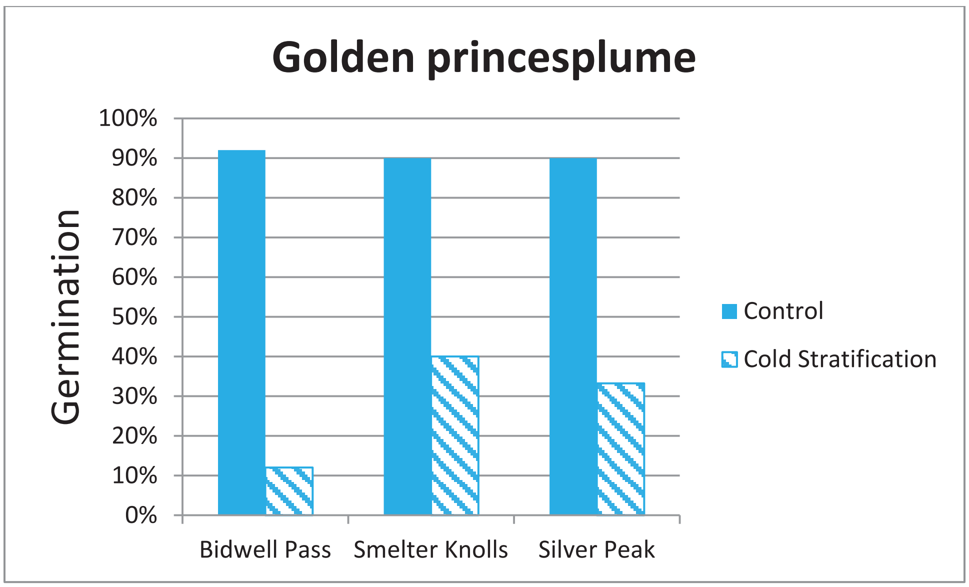



**Figure 10.** Golden princesplume seed from all accessions was non-dormant, and stratification decreased germination.

*Streambank wild hollyhock*
Streambank wild hollyhock (*Iliamna rivularis)* commonly grows in riparian and aspen/fir communities throughout the intermountain west (Welsh et al. 2003). Mountain hollyhock is an early seral stage? species that dominates sites following forest fires and may become abundant following clear cutting or mechanical treatments (Matthews 1993). We examined mechanisms controlling seed dormancy and germination in our trials by replicating the effects that fire, heat, and smoke may have on seed. We examined the effects of smoke, the hormone gibberellic acid, boiling water, and dry heat at two temperature ranges. We also investigated other ways to scarify the seeds including chemical scarification with sulfuric acid, the hydrophobic solvents xylene and brake cleaner, and mechanical scarification using an electric scarifier (Seedburo Electric Seed Scarifier, Des Plaines, IL).

In 2012, we harvested a large amount of seed from a site west of Richfield, Utah and used seed from this accession in our study. Following the various seed treatments, 25 seeds from each treatment were placed into 16 petri dishes: four petri dishes were cold-stratified for 0, 8, or 16 weeks at 6° C. The petri dishes were then placed in an incubator, and germination was recorded every 7 days for 21 days. Generally, there was greater germination in each subsequent period of stratification. As not all treatments produced an enhancement in germination, we do not list all of the results at this time. Listed below are the three treatment groups with the greatest germination responses.

Boiling Water Treatment
Seed was kept at a constant temperature in boiling water for five periods of time: 5, 10, 15, 30, and 60 seconds. Initial germination response in the group that was unstratified was extremely low at 3% in the 10 sec treatment. However, with increased stratification time came increased germination. Eight weeks of stratification produced 18% germination in both the 10 and 30 sec treatments. The highest germination rate came after 16 weeks of stratification in the 15 sec treatment group with 41% germination (Figure 11).

Mechanical Scarification
We scarified seed using an electric scarifier, running batches of seed through the scarifier at 1 second intervals from 1 to 10 sec. Highest germination was reached at the 7 sec scarification with 99% and 98% germination at 8 and 16 week stratification, respectively. However, 93% germination of the unstratified seed (0 wk) was obtained at 10 sec scarification (Figure 12).

Chemical Scarification
Using sulfuric acid we scarified the seed batches for 1 minute intervals from 1 to 10 minutes. The seed were then stratified for the described periods or incubated. The highest germination rate of 27% in the unstratified group was achieved with an 8 min scarification period. Germination of 54% in the 8-week stratification period was achieved with a 10 min scarification period. Overall, the highest germination of 59% was reached with 9 min of scarification and 16 weeks of stratification (Figure 13).

**Figure 11.** Using boiling water scarification, highest germination of streambank wild hollyhock (41%) was achieved with 15 sec boiling water treatment and a 16-week stratification period.

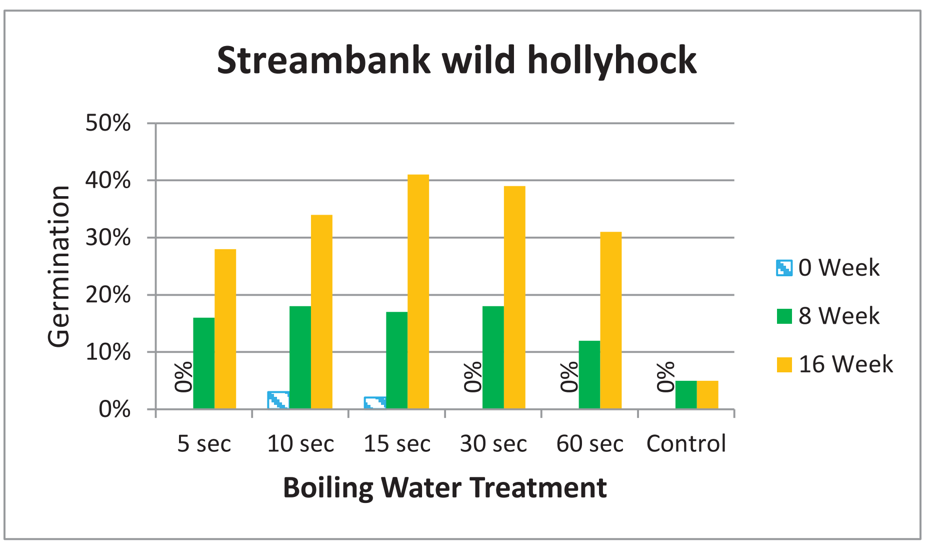


**Figure 12.** Using mechanical technology, the highest germination in steambank wild hollyhock was reached at the 7 sec scarification with 99% and 98% germination at 8 and 16 week stratification, respectively.

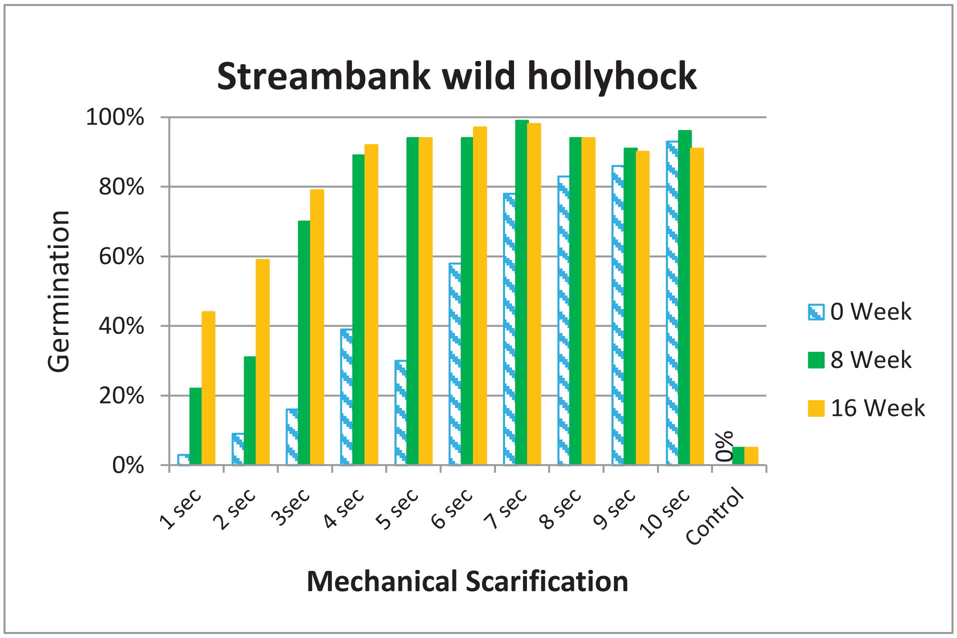
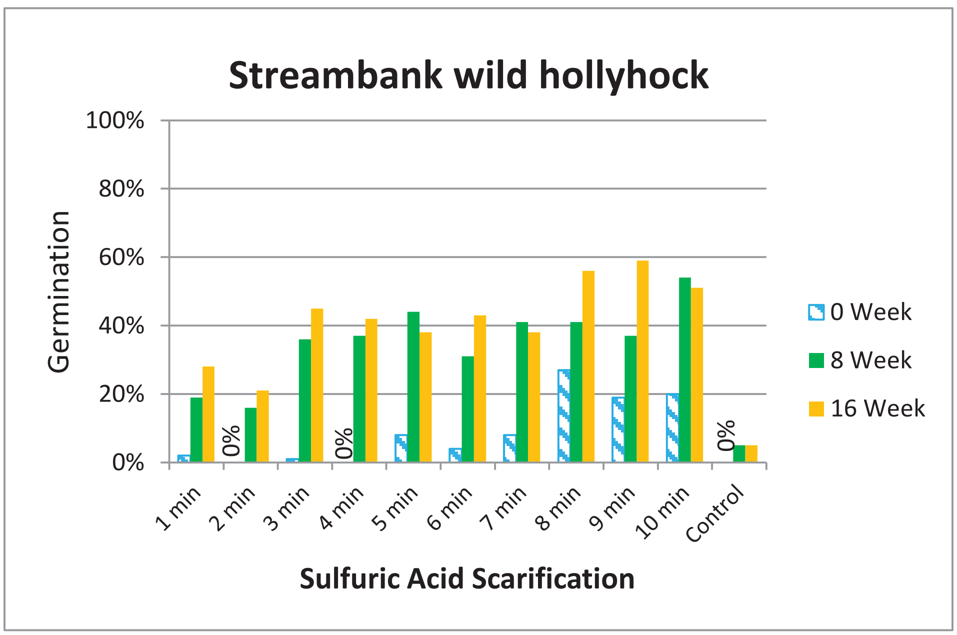



**Figure 13.** Using chemical scarification, highest germination of streambank wild hollyhock (59%) occurred with 9 min sulfuric acid scarification and a 16-week stratification period.




<u>Acknowledgements</u>

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**Publications**

Jensen, S.; Stettler, J. 2012. Applying provisional seed zones to Great Basin forb production, and cultural practice notes. Native Plant Selection and Increase Project FY2011 Progress Report: 70-84. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2011_ProgressReport.pdf

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**Presentations**

Jensen, S.; Stettler, J. 2012. Applying provisional seed zones to plant materials development in the Great Basin and cultural practices. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/projects/PowerPoint_Presentations/2012/Jensen.pdf

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Whittaker, A.; Summers, D.; Stettler, J.; Jensen, S. 2012. Planting methods for establishing native forbs on the landscape. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 22-23, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/projects/PowerPoint_Presentations/2012/Whittaker.pdf

## Management Applications and Seed Production Guidelines

Land Managers

N-sulate® fabric appears to be a potential option to help establish native forbs in a wildland setting particularly on dry sites with minimal cheatgrass or other weedy annual species. 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 a site.

Seed Producers

Longspur and hairy bigleaf lupines are susceptible to iron deficiency chlorosis when grown in basic and calcareous agronomic soils. Our preliminary studies have shown a visual decrease in seedling chlorosis when the seed is pretreated with EDDHA chelated iron. Using a chlorophyll content meter we were able to quantify the increases in chlorophyll content and decreases in chlorosis. We will evaluate if the decreases in chlorosis will increase survival and establishment in 2013. While silky lupine is more tolerant to iron deficiency chlorosis, the seed pretreated with iron chelate EDDHA also improves chlorophyll content.

## Products

- Wildland seed collection
  -52 collections of 30 species of forbs
- Stock Seed Production – Seed Increase Plots
  -62 accessions of 20 native forb species were planted into 107 beds on three Utah farms
- Seed Distribution to Growers
  -*Iliamna rivularis,* Gunnell Farm Logan, UT
  -*Sphaeralcea grossulariifolia,* Gunnell Farm Logan, UT
  -*Sphaeralcea parvifolia,* Gunnell Farm Logan, UT
  -*Penstemon procerus,* Gunnell Farm Logan, UT
  -*Cleome serrulata,* Matt Tabolt Spring City, Utah

**Project Title** Provisional Seed Zone-based Seed Increase

**Project Agreement No.** 11-IA-11221632-077

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**Project Description**

*Wildland Seed Collection*

Seed collection efforts in 2012 focused on four areas: targeted collections of priority species for germplasm increase; bulk collections for distribution to growers; limited biotype collection for species screening, and collections for germplasm preservation for the Seeds of Success (SOS) program. We developed a tiered collecting list based on species priorities, known populations not yet represented in collections, collected populations with limited seed quantity, species of interest, and unverified herbarium locations. Our priority species include:

Bigflower agoseris (*Agoseris grandiflora*), annual agoseris (*Agoseris heterophylla*), Hooker's balsamroot (*Balsamorhiza hookeri*), yellow beeplant (*Cleome lutea*), Rocky Mountain beeplant (*Cleome serrulata*), tapertip hawksbeard (*Crepis acuminata*), gray hawksbeard (*Crepis intermedia*), Western hawksbeard (*Crepis occidentalis),* nakedstem sunray (*Enceliopsis nudicaulis*), Nevada goldeneye (*Heliomeris multiflora* var. *nevadensis*), scarlet gilia (*Ipomopsis aggregata*), Lewis flax (*Linum lewisii* var. *lewisii*), barestem biscuitroot (*Lomatium nudicaule*), smoothstem blazingstar (*Mentzelia laevicaulis*), thickleaf beardtongue (*Penstemon pachyphyllus*) scarlet globemallow (*Sphaeralcea coccinea*), gooseberryleaf globemallow (*Sphaeralcea grossulariifolia*), Monro's globemallow (*Sphaeralcea munroana*).

In 2012, crews visited in excess of 300 sites; however drought conditions throughout the Great Basin resulted in exceptionally poor seed production and just 22 small wildland collections from 10 species were made (Table 1). None were adequately large for either direct distribution to producers or distribution to the SOS germplasm preservation program. These sources will be increased at our farm facilities.

*Seed Distributions*

Seed collected from wildland sites in previous years or increased at farm sites was distributed to private industry for establishment of a commercial seed production field and to partnering organizations for cultural practice studies.

**Table 1.** Wildland seed collections made in 2012.

| Scientific Name | Common Name | 2012 Collections |
|---|---|---|
| *Agoseris heterophylla* | annual goat chicory | 1 |
| *Balsamorhiza hookeri* | Hooker's balsamroot | 2 |
| *Balsamorhiza sagittata* | arrowleaf balsamroot | 2 |
| *Crepis acuminata* | Tapertip hawksbeard | 5 |
| *Enceliopsis nudicaulis* | Nakedstem sunray | 1 |
| *Heliomeris multiflora* var. *nevadensis* | Nevada goldeneye | 3 |
| *Ipomopsis aggregata* | Scarlet gilia | 3 |
| *Linum lewisii* var. *lewisii* | Prairie flax | 2 |
| *Lomatium nudicaule* | Barestem biscuitroot | 1 |
| *Mentzelia laevicaulis* | Smoothstem blazingstar | 2 |

Private Industry

One pooled lot of thickleaf penstemon from the Central Basin and Range ecoregion was distributed to private industry for commercial seed production (Table 2).

**Table 2.** Seed distributions to private sector seed producers.

| Scientific Name | Composition | Provisional Seed Zone | Quantity |
|---|---|---|---|
| *Penstemon pachyphyllus* | Pooled (2)(G0,G1) | 14-24 in precipitation / 70-80ºF | 29 kg (65 lb) |

Great Basin Native Plant Selection and Increase Project (GBNPSIP) Cooperators

Seed of seven species was distributed to cooperators at the Oregon State University Malheur Experiment Station, Ontario, OR for research projects (Table 3).

Seeds of Success

We partner with the Bureau of Land Management SOS program by contributing native forb and grass germplasm from the Great Basin to long-term conservation storage. In 2012, Generation 1 (G1) seed from 11 sources of five species was harvested from production farms (Table 4). This seed was entered into the SOS program with the remainder available for research or distribution to producers.

*Seed Increase*

Strategy

Our seed increase efforts follow the model described by Johnson et al.(2010) to develop locally-adapted and regionally- appropriate native seed sources. Johnson et al. (2010) recommended seed sources be composed of more than 50 parents from at least five populations from the same ecosystem. We selected Bower's (Bower et al. 2010) provisional seed zone (PSZ) map as our surrogate for genecologically-derived seed zones because empirical zones have not been developed for any species currently in our increase program. Our wildland seed collection protocol restricts seed gathering to populations with more than 25 individual plants thus retaining a broad genetic base. Most collections represent hundreds of plants. We assign each species collection site a PSZ based on its mapped location. Seed sources from the same PSZ of the same species are increased without regard for isolation. Sources from different zones are increased at different farms to prevent cross-pollination.

**Table 3.** Seed distributions to GBNPSIP cooperators.

| Scientific Name | Lot # | Purpose of Allocation |
|---|---|---|
| *Ipomopsis aggregata* ssp. *aggregata* | IPAG-G1-P8-2011-Cut | Irrigation trials, establishment trials, herbicide trials |
| | PSSL-57 | |
| | IPAG-G1-P2-07 | |
| *Nicotiana attenuata* Coyote tobacco | PSSL-193 | |
| | NIAT-P1-2008 | |
| | NIAT-G1-2009 | |
| | NIAT-P2-2008 | |
| *Mentzelia albicaulis* Whitestem blazingstar | PSSL-107 | |
| | PSSL-82 | |
| | PSSL-83 | |
| *Phacelia crenulata* var. *corrugata* Cleftleaf wildheliotrope | PHCRC-P1-2009 | |
| *Thelypodium milleflorum* Manyflower thelypodium | THMI5-P1-2008 | |
| | THMI5-P2-2008 | |
| *Heliomeris multiflora* var. *nevadensis* | HEMUN-P7-2009 | |
| | HEMUN-P5-2007 | |
| | PSSL-190 | |
| | HEMUN-B4-2009 | |
| | HEMUN-B3-2008 | |
| *Enceliopsis nudicaulis* | ENNU-G1-B2-2012 | |
| | ENNU-G1-P2-11 | |
| | ENNU-G1-PSSL-138-12 | |

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**Table 4.** Seed provided to SOS for germplasm preservation.

| SOS Reference Number | Common Name, Scientific Name (Common name) |
|---|---|
| PSSL-414 | *Hesperostipa comata (needle and thread)* |
| PSSL-415 | *Hesperostipa comata* |
| PSSL-416 | *Hesperostipa comata* |
| PSSL-417 | *Hesperostipa comata* |
| PSSL-418 | *Hesperostipa comata* |
| PSSL-419 | *Hesperostipa comata* |
| PSSL-420 | *Hesperostipa comata* |
| PSSL-421 | *Penstemon pachyphyllus* |
| PSSL-422 | *Heliomeris multiflora nevadensis* |
| PSSL-423 | *Mentzelia laevicaulis* |
| PSSL-424 | *Erigeron speciosus (aspen fleabane)* |
| PSSL-425 | *Heliomeris multiflora* var. *nevadensis* |

Planting

In 2012 we installed seed increase plantings for 10 species representing 50 source populations and103 beds/rows (Table 5). For all species planted, the recommended number of parental plants (50) was met. Only three species, however, were represented by an adequate number of populations (≥five).

Annual seed collection efforts focus on locating and collecting seed from species/PSZ combinations underrepresented in our increase program. G1 seed, increased under this program, is made available to the private sector through the Utah Crop Improvement program for establishment of commercial seed production fields.

Seed Harvest

In 2009 we began establishing seed increase and evaluation plantings at farm facilities in Juab and Sanpete counties, UT. Information generated from these plantings provides a better understanding of appropriate cultural practices necessary to grow specific plant materials and dramatically increase the quantity of seed available for distribution to researchers and private sector seed producers. In 2012 we harvested seed of 10 species representing 26 different sites (Table 6). In most cases additional quantities are needed before volumes are adequate to permit commercial seed production.

*Cultural Practice Studies*

Effect of Plateau herbicide on individual species

Plateau (BASF) herbicide applied in late fall at 5 oz. per acre to green basal rosettes of thickleaf penstemon prevented seed production the following year. The same effect (no seed production) was observed when Plateau was applied to dormant plants of desert frasera, nakedstem sunray, Nevada goldeneye and tapertip hawksbeard.

**Table 5.** Plots planted in 2012 for seed increase.

| Scientific Name | Common Name | Farm | Provisional Seed Zone Precipitation (in) / Temperature (ºF) | Source / Lot | Beds/ Rows |
|---|---|---|---|---|---|
| *Agoseris heterophylla* | Annual agoseris | Ft. Green | 10-14 / 70-80 | Orovada G2 | 1 bed |
| *Enceliopsis nudicaulis* | Nakedstem sunray | Ephraim | 10-14 / 70-80 | W. of Milford | 4 rows |
| | | Ft. Green | <10 / <80 | Blind Valley | 3 beds |
| | | Ft. Green | <10 / <80 | Painted Pot Road | 2 beds |
| | | Ft. Green | <10 / <80 | Halfway Summit | 2 beds |
| | | Ft. Green | <10 / <80 | Crystal Peak | 1 bed |
| | | Ephraim | 10-14 / 80-90 | Silver King | 2 rows |
| | | Ephraim | 10-14 / 70-80 | Jackrabbit Mine | 1 row |
| | | Ephraim | 10-14 / 70-80 | Patterson Pass | 1 row |
| | | Ft. Green | 10-14 / 70-80 | Newcastle | 3 beds |
| | | Ft. Green | 10-14 / 70-80 | Newcastle Reservior | 1 bed |
| | | Ft. Green | 10-14 / 70-80 | Panaca | 1 bed |
| | | Ft. Green | 10-14 / 70-80 | Pioche | 5 beds |
| | | Ft. Green | 10-14 / 70-80 | Patterson Pass | 4 beds |
| *Ipomopsis aggregata* | Scarlet gilia | Ft. Green | 10-14 / 70-80 | IPAG-G1-P8-2010-cut | 10 beds |
| | | Ft. Green | 10-14 / 70-80 | Secret Valley G1 | 2 beds |
| *Linum lewisii* var. *lewisii* | Prairie flax | Ft. Green | 10-14 / 70-80 | Patterson Pass | 0.5 bed |
| | | Ft. Green | 10-14 / 70-80 | Cave Valley | 0.5 bed |
| | | Ft. Green | 10-14 / 70-80 | Ely | 0.5 bed |
| | | Ft. Green | 10-14 / 70-80 | Major's Place | 0.5 bed |
| | | Ft. Green | 10-14 / 70-80 | Jackrabbit Mine | 0.5 bed |
| | | Ft. Green | 10-14 / 70-80 | Wilson Reservoir | 0.5 bed |
| | | Ft. Green | 10-14 / 70-80 | Long Hill | 1 bed |
| | | Ft. Green | 10-14 / 70-80 | Water Canyon | 1 bed |
| *Penstemon pachyphyllus* | Thickleaf beardtongue | Ephraim | 10-14 / 70-80 | Pleasant Valley | 4 rows |
| | | Ephraim | 10-14 / 70-80 | Ward Mt | 4 rows |
| | | Ephraim | 10-14 / 70-80 | Schellbourne | 4 rows |
| | | Ft. Green | 10-14 / 70-80 | Robinson Pass | 1 bed |
| *Cleome lutea* | Yellow beeplant | Ft. Green | 10-14 / 80-90 | Bradshaw Mountains | 1 bed |
| *Cleome serrulata* | Rocky Mountain beeplant | Ft. Green | <10 / >80 | Pleasant Valley | 2 beds |
| | | Ft. Green | <10 / >80 | Spring Valley | 1 bed |
| | | Ft. Green | <10 / >80 | Tippet | 1 bed |
| *Frasera ablomarginata* | Desert frasera | Ft. Green | 10-14 / 70-80 | North Cave Valley | 3 beds |
| *Hesperostipa comata* | Needle and thread | Ephraim | 10-14 / 70-80 | HECO26-B18-2003 | 2 rows |
| | | Ephraim | 10-14 / 70-80 | HECO26-B9-2003 | 2 rows |
| | | Ephraim | 10-14 / 70-80 | HECO26-U16-2002 | 2 rows |
| | | Ephraim | 10-14 / 70-80 | HECO26-U22-2003 | 2 rows |
| | | Ephraim | 10-14 / 70-80 | HECO26-U27-2003 | 2 rows |
| | | Ephraim | 10-14 / 70-80 | HECO26-U29-2003 | 2 rows |
| | | Ephraim | 10-14 / 70-80 | HECO26-U39-2005 | 2 rows |
| | | Ephraim | 10-14 / 70-80 | HECO26-U41-2005 | 2 rows |
| | | Ephraim | 10-14 / 70-80 | HECO26-U4-1998 | 2 rows |
| | | Ephraim | 10-14 / 70-80 | HECO26-U43-2005 | 2 rows |

**Table 6.** Seed increase harvest in 2012.

| Scientific Name | Lot # | Provisional Seed Zone Precipitation (in) / ºF | Quantity (g) |
|---|---|---|---|
| *Crepis intermedia* | CRAC-U58-G1-FG-12 | 10-14/ 70-80 | * |
| *Enceliopsis nudicaulis* | ENNU-G1-B2-2012 | <10. / <80 | 1053 |
| *Enceliopsis nudicaulis* | ENNU-G1-PSSL-138-2012 | <10 / <80 | 221 |
| *Erigeron speciosus* | ERPS4-G1-P3-12 | 14-24 / <70 | * |
| *Frasera albomarginata* | FRAL5-P4-G1-FG-12 | 10-14 / 70-80 | 97 |
| *Heliomeris multiflora* var. *nevadensis* | HEMUN-G1-P6-12 | 10-14 / 80-90 | * |
| *Heliomeris multiflora* var. *nevadensis* | HEMUN-G1-B3-12 | 10-14 / 70-80 | 336 |
| *Heliomeris multiflora* var. *nevadensis* | HEMUN-P7-G1-12 | 10-14 / 70-80 | 397 |
| *Heliomeris multiflora* var. *nevadensis* | HEMUN-P5-G1-2012 | 14-24 / 70-80 | * |
| *Heliomeris multiflora* var. *nevadensis* | HEMUN-B4-G1-2012 | 14-24 / 70-80 | * |
| *Heliomeris multiflora* var. *nevadensis* | HEMUN-P7-G1-2012 | 14-24 / 70-80 | * |
| *Hesperostipa comata* | HECO26-U17-FG-G1-12 | <10 / <80 | 312 |
| *Hesperostipa comata* | HECO26-U36-FG-G1-12 | <10 / <80 | 840 |
| *Hesperostipa comata* | HECO26-U14-FG-G1-12 | <10 / <80 | 679 |
| *Hesperostipa comata* | HECO26-B17-FG-G1-12 | <10 / <80 | 1041 |
| *Hesperostipa comata* | HECO26-U40-FG-G1-12 | <10 / <80 | 249 |
| *Hesperostipa comata* | HECO26-B13-FG-G1-12 | <10 / <80 | 513 |
| *Hesperostipa comata* | HECO26-B12-FG-G1-12 | <10 / <80 | 300 |
| *Ipomopsis aggregata* ssp. *aggregata* | IPAGA3-PSSL-57-G1-FG-12 | 14-24 / 70-80 | 102 |
| *Ipomopsis aggregata* ssp. *aggregata* | IPAGA3-P8-G1-FG-12 | 14-24 / 70-80 | 208 |
| *Mentzelia laevicaulis* | PSSL-192-SF-G1-12 | 14-24 / 70-80 | 898 |
| *Nicotiana attenuata* | NIAT-PSSL-193-G1-12 | 14-24 / 70-80 | * |
| *Penstemon pachyphyllus* | PEPA6-B4-FG-G1-12 | 10-14 / 70-80 | 1322 |
| *Penstemon pachyphyllus* | PEPA6-P1-FG-G1-12 | 14-24 / <70 | 131 |
| *Penstemon pachyphyllus* | PEPA6-B5-FG-G1-12 | 14-24 / 70-80 | 376 |
| *Penstemon pachyphyllus* | PEPA6-PSSL-178-FG-G1-12 | 14-24 / <70 | 280 |
| | | *quantity not yet known because seed at cleaning facility | |

<u>Can overcompensation resulting in increased seed yield be induced in scarlet gilia through appropriately timed clipping?</u>

Some populations of scarlet gilia are reported to overcompensate from herbivory or simulated herbivory by increasing aboveground biomass and/or seed yield. We tested whether clipping over a 4-week period would result in increased seed yield. Seeds from two central Nevada sources (Secret Valley, Soldier Canyon) were planted at the Utah Division of Wildlife Resources farm facility in Fountain Green, UT. Each source was planted in a configuration of three rows at 19 in spacing onto a 100 ft. raised nursery bed in 2010. Each bed was partitioned into nine blocks with five randomly assigned treatments per block representing 4 weekly sequential cut dates and an uncut control. In 2012, rosettes within each block were hand trimmed to 5 cm (2 in) in height at weekly intervals beginning 25 April 2012. Ripened seed was collected weekly from first ripening through plant senescence (4 w) beginning 12 July 2012 with a badminton racquet and hopper. Seed production was tallied on a weekly basis by source and treatment.

Overcompensation was not observed among any treatments. For the Soldier Canyon site there was no difference in seed yield based on cut date ($p \leq 0.05$, Figure1). Secret Valley decreased in yield with the control and first cut producing a similar quantity of seed, the second and third cuts producing less seed than the control and the fourth cut producing less seed than the control or first cut. Comparing the two sources there were no differences in seed production among similar treatments. Based on this experiment, cutting treatment to increase seed yield through overcompensation would not be beneficial for either of these sources.

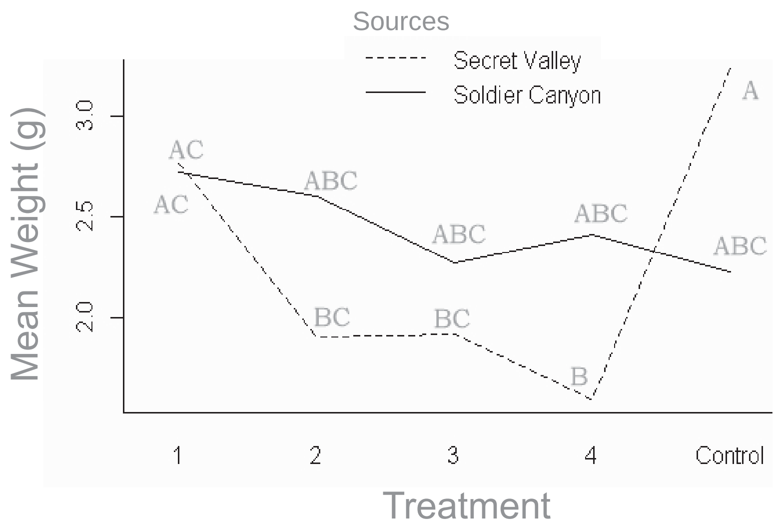


**Figure 1.** Seed yield of two sources of scarlet gilia grown at Fountain Green, UT. Treatment refers to dates of cutting done at weekly intervals beginning 25 April 2012. Treatments and sources with the same letter are not significantly different ($p \leq 0.05$).

Literature cited

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**Publications**

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**Presentations**

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Youtie, B.; Shaw, N.; Fisk, M.; Jensen, S. 2012. A strategy for maximizing native plant material diversity for restoration and genecology research. 8th European Conference on Ecological Restoration. 2012 September 9-14, Ceske Budejovice, Czech Republic. Poster.

**Project Title** Aberdeen Plant Materials Center Report of Activities

**Project Agreement No.** 10-IA-11221632-039, 11-IA-11221632-004

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**Project Description**

Plant Guides

The Aberdeen Plant Materials Center (PMC) is gathering information on selected plant species to create USDA Natural Resources Conservation Service (NRCS) plant guides. Plant guides offer the most recent information on plant establishment methods, as well as seed and plant production suggestions. General information for the species can also be found in the plant guide, including information on potential uses, ethnobotanical significance, adaptation, and pests and potential problems. In 2012, plant guides were completed or revised for arrowleaf balsamroot (*Balsamorhiza sagittata*), cutleaf balsamroot (*Balsamorhiza macrophylla),* Hooker's balsamroot (*Balsamorhiza hookeri*), yellow beeplant (*Cleome lutea*), tapertip hawksbeard (*Crepis acuminata*), barestem biscuitroot (*Lomatium nudicaule*)*,* blue penstemon (*Penstemon cyaneus*) and gooseberryleaf globemallow (*Sphaeralcea grossulariifolia*)*.* In 2013 the Aberdeen PMC will produce plant guides for bigflower agoseris (*Agoseris grandiflora*) and limestone hawksbeard (*Crepis intermedia)*. Plant guides are available at the PLANTS database (www.plants.usda.gov) and at the Aberdeen Plant Materials Center website (www.id.nrcs.usda.gov/programs/plant.html).

Plant Materials Development

*Douglas' dustymaiden*

Fifteen accessions of Douglas' dustymaiden (*Chaenactis douglasii*) were evaluated at the Aberdeen PMC from 2009 to 2010. The accessions were evaluated for establishment, growth, and seed production. Following field evaluations, Accession 9076577 was chosen for selected class release as it ranked at or near the top in percent establishment, plant vigor, height, flower production and seed yield. Accession 9076577 was collected in Boise County, Idaho, near Arrow Rock and Lucky Peak Reservoirs, approximately 0.8 km (0.5 mi) west of the dam on Forest

Road 268. The site is a mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*)/bitterbrush (*Purshia tridentata*) community in coarse granitic soils at 960 m (3150 ft) elevation.

In the fall of 2010, a 500-ft row of weed barrier fabric was planted with seed of Accession 9076577; however, problems encountered during planting resulted in poor germination and establishment. In fall 2011, an additional 1,000 ft of fabric was seeded. Dry winter conditions resulted again in poor establishment (approximately 25%). Seed was harvested by hand and with backpack vacuum cleaners in summer 2012. A total of 1.8 kg (4 lb) dirt weight was cleaned to 0.7 kg (1.5 lb) pure live seed (PLS). Release documentation is being developed and official release will occur once the PMC has produced a sufficient amount of early generation seed.

*Hoary tansyaster*

Nine accessions of hoary tansyaster (*Machaeranthera canescens*) were evaluated from 2009 through 2011 for establishment, plant growth and seed production. Accession 9076670 had the best establishment and stands in 2009 and 2010, the best rated vigor in 2010, and the tallest plants in the study. Although we were not able to evaluate seed production in 2010 due to wind storms when seed was ripening, Accession 9076670 was observed to be an excellent seed producer. Accession 9076670 was collected near the St. Anthony Sand Dunes in Fremont County, Idaho, at 5,000 ft (1,524 m) elevation. The site has sandy soils and supports a bitterbrush, Indian ricegrass (*Achnatherum hymenoides*), yellow rabbitbrush (*Chrysothamnus visiciflorus*), and lemon scurfpea (*Psoralidium lanceolatum*) plant community. The location receives on average between 10 and 15 inches (250 and 380 mm) of annual precipitation.

In 2010, the original population was revisited to collect additional seed to use in a seed increase planting at IDPMC. In 2010, a 500 foot (150 m) row of weed barrier fabric was planted. An additional 1,000 feet (300 m) row was planted in 2011. Dry winter conditions resulted in poor stands and the site was reseeded in the spring of 2012. An additional 0.6 acres (0.25 ha) of hoary tansyaster was drill seeded in spring 2012 to investigate agronomics without using weed barrier fabric. We also planted a small 0.08 acre (0.03 ha) plot of hoary tansyaster with a nurse crop of winter wheat in August 2012 to evaluate late summer seeding and weed control options without fabric.

The 2010 plants were harvested in fall 2012 using a small-plot combine to compare a single combine harvest with multiple vacuum harvests as was done in 2011. The single combining yielded 55 lbs (25 kg) dirt weight which cleaned to 0.72 lbs (0.33 kg) PLS. The single combining method takes less time in the field. However this method yields correspondingly less seed, and significantly more time is required to clean the seed compared to vacuum harvesting. Release documentation is being developed and official release will occur once the PMC has produced a sufficient amount of early generation seed.

*Wyeth or whorled buckwheat*

Thirty-nine accessions of Wyeth and sulphur-flower buckwheat (*Eriogonum heracleoides* and *E. umbellatum*) were compared in a common garden study from 2007 through 2011. Accession 9076546 Wyeth buckwheat showed good establishment, seed production and longevity compared with the other accessions.

In fall 2011, two 500-ft rows of weed barrier fabric were planted with seed of Accession 9076546. Accession 9076546 was collected in Caribou County, Idaho northeast of Soda Springs in an 18-20 inch precipitation area occurring with mountain big sagebrush, three-tip sagebrush (*Artemisia tripartita*), bluebunch wheatgrass (*Pseudoroegneria spicata*) and basin wildrye (*Leymus cinereus*). Germination in 2012 was poor, likely due to drier and warmer than normal winter and early spring conditions. Plants will be propagated in the greenhouse in winter/spring 2013 and transplanted in the weed barrier fabric rows in summer 2013.

**Publications**

St. John, L.; Tilley, D. 2012. Plant guide for Hooker's balsamroot (*Balsamorhiza hookeri*). Aberdeen, ID: USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. 5 p.

St. John, L.; Tilley, D. 2012. Plant guide for cutleaf balsamroot (*Balsamorhiza macrophylla*). Aberdeen, ID: USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. 3 p. http://plants.usda.gov/plantguide/pdf/pg_bama4.pdf

Tilley, D.; Cane, J.; St. John, L.; Ogle, D.; Shaw, N. 2012. Plant guide for yellow beeplant (*Cleome lutea*). Aberdeen, ID: USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. 3 p. http://www.treesearch.fs.fed.us/pubs/41957

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Tilley, D.; St. John, L.; Ogle, D.; Shaw, N. 2012. Plant guide for blue penstemon (*Penstemon cyaneus)*. Aberdeen, ID: USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. 3 p. http://www.treesearch.fs.fed.us/pubs/41955

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Tilley, D.; St. John, L.; Ogle, D.; Shaw, N. 2012. Propagation protocol for production of *Lomatium grayi* (J. M. Coult. & Rose) seeds. Aberdeen, ID: USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. In: Native Plant Network. Moscow, ID: University of Idaho, College of Natural Resources, Forest Research Nursery. http://www.nativeplantnetwork.org

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Tilley, D.; St. John, L.; Ogle, D.; Shaw, N.; Cane, J. 2012. Propagation protocol for production of *Lomatium triternatum* (Pursh) seeds. USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. In: Native Plant Network. Moscow, ID: University of Idaho, College of Natural Resources, Forest Research Nursery. http://www.nativeplantnetwork.org

Tilley, D.; St. John, L.; Shaw, N. 2012. Plant guide for arrowleaf balsamroot (*Balsamorhiza sagittata)*. Aberdeen, ID: USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. 5 p. http://www.treesearch.fs.fed.us/pubs/41958

**Presentations**

Tilley, D.; St. John, L. 2012. Aberdeen PMC report of activities, 2011. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2012.shtml

Simonson, B.; St. John, L. 2012. Mixing seed with rice hulls. Drill calibration workshop, 2012 July 18, Boise, ID.

**Management Applications and Seed Production Guidelines**

Douglas' dustymaiden, hoary tansyaster and Wyeth buckwheat are feasible for commercial seed production. Douglas' dustymaiden establishes well using fall dormant seedings. Hoary tansyaster has no seed dormancy issues and can be established with fall or spring seeding. Weed control in seed production fields of native forbs remains an obstacle, and various control methods are being evaluated. The use of weed barrier fabric is encouraged. Seed ripening is indeterminate and poses problems for a single harvest system. However, high yields can be obtained with multiple harvests conducted by hand or with a vacuum-type harvester followed by a final combining.

**Products**

- Plant Guides are available for arrowleaf balsamroot, barestem biscuitroot, blue penstemon, cutleaf balsamroot, Douglas' dustymaiden, fernleaf biscuitroot (*Lomatium dissectum*), gooseberry leaf globemallow, Gray's biscuitroot (*L. grayi*), hoary tansyaster, Hooker's balsamroot, hotrock or scabland penstemon *(Penstemon deustus*), nineleaf biscuitroot (*L. triternatum*), royal penstemon (*P. speciosus*), Searls' prairie clover (*Dalea searlsiae*), sharpleaf penstemon (*P. acuminatus*), tapertip hawksbeard, and yellow beeplant.
- Propagation protocols are available for Douglas' dustymaiden, hoary tansyaster, nineleaf biscuitroot, fernleaf biscuitroot, Gray's biscuitroot, and Searls' prairie clover.
- Early generation certified seed of hoary tansyaster, Douglas' dustymaiden and Wyeth buckwheat is being produced and will be available through Utah Crop Improvement Association and University of Idaho Foundation Seed Program when release is approved.

**Project Title** Bee Pollination and Breeding Biology Studies

**Project Agreement No.** 11-IA-11221632-010

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**Project Description**

Successful reproduction by flowering plants requires the confluence of several favorable factors. Some are intrinsic to the plant (e.g., age, nutritional status); others are external, either abiotic (e.g., rainfall) or biotic. The survival and performance of perennial sagebrush-steppe forbs after fire is an unknown with great ramifications for pollinators and for management tactics to retain their remnant communities while awaiting establishment of new seedlings. Among biotic factors, insect pollinators are often needed for seed production.

*Fire Impact on Forb Survival*

Changes in the frequency and intensity of fire in the sagebrush steppe have become key factors in degrading native plant communities in basin and foothill habitats. We know that many of the dominant Great Basin shrubs are consumed by fire and do not resprout. Some forbs clearly survive wildfires to thrive and bloom thereafter, but the observations are anecdotal and not related to fire attributes. Hence, we do not know which native forb species survive fires of a particular intensity. To examine the individual plant's response to wildfire, six common Great Basin perennial forb species were experimentally burned at increasing intensities in 2012 using a custom portable propane burner designed to mimic wildfire attributes. The plants were growing at the Oregon State University Malheur Experiment Station in Ontario, Oregon in adjacent 60 meter monoculture rows. Soils are uniform. Plants were mature and of the same age. All members of a species received the same controlled sub-irrigation and pest management. Individuals of basalt milkvetch (*Astragalus filipes*), prairie clover (*Dalea ornata*), sulfur-flower buckwheat (*Eriogonum umbellatum*), fernleaf biscuitroot (*Lomatium dissectum*), blue penstemon (*Penstemon cyaneus*), and gooseberryleaf globemallow (*Sphaeralcea grossulariifolia*) were chosen for their contrasting life histories and morphological traits, as well as their importance to native bees. Prior to treatment application, 1-$m^2$ plots were marked to be burned. The number of plants in each plot to be burned was counted and dead material trimmed to 10 cm height; loose dead vegetation was cleared from the burn zone to equalize combustibles. Six propane fuel prescription treatments were used to mimic wildfire conditions (Table 1). After burning, each plot was sprayed with 1 liter of water to extinguish any embers. Number of surviving plants per plot will be counted in green-up in 2013.

**Table 1.** Propane fuel treatments used on native plants to mimic wildfire conditions.

| **Category** | **Prescription** | **Heat attained ($^o$C)** |
|---|---|---|
| Control | No fuel applied | Ambient |
| Very Low | 7.5 psi, 25 sec | 100 |
| Low | 7.5 psi, 50 sec | 200 |
| Medium | 15 psi, 65 sec | 300 |
| High | 15 psi, 175 sec | 500 |
| Very High | 15 psi, 240 sec | 600 |

*Seed predators*
Pollination is no guarantee of successful reproduction because pre-dispersal frugivores and seed predators often consume or damage maturing seeds in both agricultural fields and wildland environments. Our objective in 2012 was to compile and confirm identities, distributions and prevalence of seed beetles collected by us in the field over the past 7 years from the seed and flowers of forbs that have begun to be cultivated for seed for wildland restoration. Seed beetles were prevalent among our rangeland collections of legume seed from across the Great Basin; our samples include many new plant host, county and state records. All observed seed beetles are miniscule. For prairie clover sampled across Idaho, Oregon and Washington, 18 of 22 bulk seed samples had mostly mixed infestations of the seed beetles *Apion amaurum* and *Acanthoscelides oregonensis*. At 29 sites where sampled populations of basalt milkvetch hosted seed beetles, only one seed beetle species, *Acanthoscelides pullus*, was nearly ubiquitous. It has a wider host range than many congenerics. Several other less common seed beetle species were taken from basalt milkvetch, including adults of two species of the weevil genus *Tychius*. From umbels bearing young developing seeds of fernleaf biscuitroot, we collected adult *Smicronyx* weevils, and from several species of globemallow, we obtained adults of the seed weevil *Macrorhoptus hispidus*. Most of these species pupate and overwinter in the seeds. There is therefore the risk of them being transported to storage warehouses and distributed to new seedings unless they are first detected and controlled. None seem able to infest stored seed, so they should not harm seed already in storage.

<u>Future plans</u>
1) In the spring of 2013, we will collect survival data from the forb burning experiment. Plant mortality by species will be scored and then compared among burning treatments using logistic regression. The list of perennial forbs that we could burn is limited by their availability in uniform cultivation; newly available species can be added if a thermal gradient effect is detected. Knowing which species will succumb to or survive fires of measured intensities will guide the composition of seed mixes for post-fire restoration (e.g. surviving species need not be reseeded).

2) We will begin exploring a novel trap-cropping technique for seed beetle control to help growers avoid broadcast insecticide sprays during bloom that also kill needed pollinators. Because the beetles are specialists, using alternative hosts for trapping will not work. Instead, we will try advancing bloom on a short cultivated row of a given forb under a portable grow tunnel.

We will remove the cover at bloom, when the rest of the crop remains in bud, to determine whether it  will attract and concentrate fresh adult beetles on the new flowers where control can be focused, possibly even by simple sweep netting.

3) After several failed attempts, we successfully established 50 transplanted silverleaf phacelia (*Phacelia hastata*) in our common garden, a number of which bloomed by late summer. In 2013, we will cage them and, through manual pollinations, establish the species' breeding biology. Some rows outside the cage will be observed for bee visitation and tracked for seed set. Wild populations will be sampled in our region for their complement of pollinators.

**Publications**

Cane, J. H.; Love, B.; Swoboda, K. A. 2012. Breeding biology and bee guild of Douglas' dustymaiden, *Chaenactis douglasii* (Asteraceae, Helenieae). Western North American Naturalist 72: 563-568.

Cane, J. H.; Weber, M.; Miller, S. 2012. Breeding biologies, pollinators and seed beetles of two prairie-clovers, *Dalea ornata* and *D. searlsiae* (Fabaceae: Amorpheae), from the Intermountain West USA. Western North American Naturalist 72: 16-20.

**Presentations**

Cane, J. 2012. Gardening and landscaping for native bees. Idaho Horticulture Expo, 2012 January 19-21, Boise, ID. Invited speaker.

Cane, J. 2012. Native bees for wildflower seed farming and large-scale wildland restoration in the western USA. International Symposium on Pollinator Conservation, 2012 January 25-28, Fukuoka, Japan. Invited speaker.

Cane, J. 2012. Breeding biology and pollinators of dusty maiden, *Chaenactis douglasii*. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT.

Love, B. 2012. Win-win strategies: integrating native pollinators in conservation and land management practices. Utah Native Pollinator Workshop, 2012 September 12, Logan, UT. Invited speaker.

Love, B. 2012. Response of bees to wildfire: Rockin' the shock phase. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT. Presentation.

**Management Applications and Seed Production Guidelines**

We now know to expect seed beetles in collections of wild seed, and eventually, on many farms that utilize the seed. Small seed collections can be easily fumigated with dichlorvos strips ("Nuvan", formerly "Vapona", Amvac Chemical Corp, Los Angeles, CA). If producers contact us when large infestations of harvested seed are found, then we can use them to evaluate practical methods for killing beetles without killing seed, likely by freezing shock.

**Products**

- Tilley, D.; Cane, J.; St. John, L.; Ogle, D; Shaw, N. 2012. Plant guide for yellow beeplant (*Cleome lutea*). Aberdeen, ID: U. S. Department of Agriculture, Natural Resources Conservation Service. 3 p. Available online: http://plants.usda.gov/plantguide/pdf/pg_cllu2.pdf
- Cane, J. H. 2012. Gardening for bees in Utah and beyond. Utah Pests Fact Sheet ENT-133-09. Logan, UT: Utah State University Extension and Utah Plant Pest Diagnostic Laboratory. 9 p. Available online: http://extension.usu.edu/files/publications/factsheet/plants-pollinators09.pdf

  Two programs on Wild About Utah**,** a weekly nature series produced by Utah PBS Available online: http://www.bridgerlandaudubon.org/wildaboututah/archive.htm

  -From flood to fire, Utah's evolving role in mending rangelands, aired 2012 December 29.

  -Reseeding the West after Fire, aired 2012 November 29.

**Project Title**

Seed Production of Great Basin Native Forbs:

A. Eight Years Evaluating the Irrigation Requirements for Native Wildflower Seed Production
B. Preliminary Estimates of the Irrigation Requirements for Novel Native Wildflower Seed Production
C. Direct Surface Seeding Strategies for the Establishment of Two Native Legumes of the Intermountain West
D. Five Years of Tolerance of Sulphur-flower Buckwheat to Rates and Mixtures of Postemergence Herbicides, 2008–2012

**Agreement No.** 12-JV-11221632-066

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## A. Eight Years of Evaluating the Irrigation Requirements for Native Wildflower Seed Production

### Project Description

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.

On native 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 well adapted to croplands as they are often not competitive with crop weeds in cultivated fields. Poor competitiveness 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. Sprinkler and furrow irrigation can lead to the loss of plant stand and seed production due to fungal pathogens. By burying drip tapes at a 12-inch depth and avoiding wetting 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.

<u>Materials and Methods</u>

Plant Establishment

Seed of 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, Idaho. The plan was to plant the seed in the fall of 2004, but due to excessive rainfall in October, ground preparation was not completed and planting was postponed to early 2005. To try to ensure germination, the seed was submitted to cold stratification. Seed was soaked overnight in distilled water on January 26, 2005, after which the water was drained and the seed was soaked for 20 min 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* (see Table 1 for common names) had started to sprout.

In late February, 2005 drip tape (T-Tape TSX 515-16-340) was buried at a 12-inch depth between two 30-inch rows on a Nyssa silt loam with a pH of 8.3 and 1.1 percent organic matter. The drip tapes were 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 in apart, resulting in a water application rate of 0.066 in/hour.

On March 3, seed of all species was planted in 30-inch rows using a custom-made experimental 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 inches/h. 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. 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 empty lengths of row were replanted by hand in the *E. umbellatum* and *Penstemon* spp. plots. The entire row lengths of the *Lomatium* spp. plots were replanted using the planter. The seed was replanted on October 26, 2005. In spring 2006, plant stands of the replanted species, except for *P. deustus,* were excellent.

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. The field was sprinkler irrigated until emergence. Emergence was poor. In late August 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 and on November 10, they 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 |
|---|---|
| *Astragalus filipes* | Basalt milkvetch |
| *Dalea ornata* | Blue Mountain prairie clover, western prairie clover |
| *Dalea searlsiae* | Searls' prairie clover |
| *Eriogonum umbellatum* | Sulphur-flower buckwheat |
| *Lomatium dissectum* | Fernleaf biscuitroot |
| *Lomatium grayi* | Gray's biscuitroot, Gray's lomatium |
| *Lomatium triternatum* | Nineleaf biscuitroot, nineleaf desert parsley |
| *Penstemon acuminatus* | Sharpleaf penstemon |
| *Penstemon deustus* | Scabland penstemon, hotrock penstemon |
| *Penstemon speciosus* | Royal penstemon |
| *Sphaeralcea coccinea* | Scarlet globemallow, red globemallow |
| *Sphaeralcea grossulariifolia* | Gooseberryleaf globemallow |
| *Sphaeralcea parvifolia* | Smallflower globemallow |

Irrigation for Seed Production

In April, 2006 each planted strip of each forb species was divided into plots 30 ft long. Each plot contained four rows of each species. The experimental design for each species was a randomized complete block with four replicates. The three irrigation treatments were a nonirrigated 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 length of time necessary to deliver 1 or 2 inches through the drip system. Irrigations were regulated with a controller and solenoid valves. After each irrigation, the amount of water applied was read on a water meter and recorded to ensure correct water applications.

In March 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. Irrigation treatments for all species were continued until the last irrigation on June 24, 2007.

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. Regression equations were then used to transform the neutron probe readings 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 in Table 3. The plant stand for *P. deustus* was too poor to provide reliable seed yield estimates. Replanting *P. deustus* in fall 2006 did not result in adequate plant stand in spring 2007.

*Eriogonum umbellatum* seeds did not separate from the flowering structures in the combine; the unthreshed seed was taken to the USFS Lucky Peak Nursery, Boise, Idaho, 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. 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 nitrogen (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 for lygus bug control on May 14 and 29. Irrigations for each species were initiated and terminated on different dates (Table 2). Harvesting and seed cleaning methods for each species are listed in Table 3. All plots of the *Sphaeralcea* spp. 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 0.1 lb 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 2). Harvesting and seed cleaning methods for each species are listed in Table 3.

Cultural Practices in 2009

On March18, 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 to the three *Lomatium* species through the drip irrigation system.

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

Cultural Practices in 2010

The flowering, irrigation, and harvest timing of the established forbs were recorded for each species (Table 2). Harvesting and seed cleaning methods for each species are listed in Table 3. On November 17, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural Practices in 2011

On May 3, 2011, 50 lb N/acre was applied to all *Lomatium* spp. plots as Uran (urea ammonium nitrate) injected through the drip tape. The timing of flowering, irrigations, and harvests varied by species (Table 2). Harvesting and seed cleaning methods for each species are listed in Table 3. On November 9, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural Practices in 2012

The soil volumetric water content was very low in 2012 prior to the onset of irrigation for each species. Iron deficiency symptoms were prevalent in 2012. On April 13, 50 lb N/acre, 10 lb

P/acre, and 5 lb Fe/acre was applied to all *Lomatium* spp. plots as liquid fertilizer injected through the drip tape.

**Table 2.** Native forb flowering, irrigation, and seed harvest dates by species in 2006–2011, Malheur Experiment Station, Oregon State University, Ontario, OR.

| Species | Flowering | | | Irrigation | | Harvest |
|---|---|---|---|---|---|---|
| | Start | Peak | End | Start | End | |
| | | | | 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* | | | | | | |
| *Sphaeralcea 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 |
| *Sphaeralcea 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 |
| *Sphaeralcea 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 2 (cont.).** Native forb flowering, irrigation, and seed harvest dates by species in 2006–2012. Malheur Experiment Station, Oregon State University, Ontario, OR.

| Species | Flowering | | | Irrigation | | Harvest |
|---|---|---|---|---|---|---|
| | start | peak | end | start | end | |
| | **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 |
| *Sphaeralcea 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 speciosus* | 14-May | | 20-Jun | 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 |
| *Sphaeralcea 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 |
| | **2011** | | | | | |
| *Eriogonum umbellatum* | 8-Jun | 30-Jun | 20-Jul | 20-May | 5-Jul | 1-Aug |
| *Penstemon speciosus* | 25-May | 30-May | 30-Jun | 20-May | 5-Jul | 29-Jul |
| *Lomatium dissectum* | 8-Apr | 25-Apr | 10-May | 21-Apr | 7-Jun | 20-Jun |
| *Lomatium triternatum* | 30-Apr | 23-May | 15-Jun | 21-Apr | 7-Jun | 26-Jul |
| *Lomatium grayi* | 1-Apr | 25-Apr | 13-May | 21-Apr | 7-Jun | 22-Jun |
| *Sphaeralcea parvifolia* | 26-May | 15-Jun | 14-Jul | 20-May | 5-Jul | 29-Jul |
| *Sphaeralcea grossulariifolia* | 26-May | 15-Jun | 14-Jul | 20-May | 5-Jul | 29-Jul |
| *Sphaeralcea coccinea* | 26-May | 15-Jun | 14-Jul | 20-May | 5-Jul | 29-Jul |
| | **2012** | | | | | |
| *Eriogonum umbellatum* | 30-May | 20-Jun | 4-Jul | 30-May | 11-Jul | 24-Jul |
| *Penstemon speciosus* | 2-May | 20-May | 25-Jun | 2-May | 13-Jun | 13-Jul |
| *Lomatium dissectum* | 9-Apr | 16-Apr | 16-May | 13-Apr | 24-May | 4-Jun |
| *Lomatium triternatum* | 12-Apr | 17-May | 6-Jun | 13-Apr | 24-May | 21-Jun |
| *Lomatium grayi* | 15-Mar | 25-Apr | 16-May | 13-Apr | 24-May | 14-Jun |

**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[c] |
| *Penstemon acuminatus* | 1 | combine[d] | none | combine | mechanical[c] |
| *Penstemon deustus* | 1 | combine[a] | mechanical[c] | hand[e] | mechanical[c] |
| *Penstemon speciosus*[f] | 1 | combine[d] | none | combine | mechanical[c] |
| *Lomatium dissectum* | 1 | hand | hand | none | mechanical[c] |
| *Lomatium triternatum* | 1 – 2 | hand | hand | none | mechanical[c] |
| *Lomatium grayi* | 1 – 2 | hand | hand | none | mechanical[c] |
| *Sphaeralcea parvifolia* | 1 – 3 | hand or combine[d] | none | combine | none |
| *Sphaeralcea grossulariifolia* | 1 – 3 | hand or combine[d] | none | combine | none |
| *Sphaeralcea coccinea* | 1 – 3 | hand or combine[d] | none | combine | none |
| *Dalea searlsiae* | 0 or 2 | hand | none | dewinger | mechanical[c] |
| *Dalea ornate* | 0 or 2 | hand | none | dewinger | mechanical[c] |

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

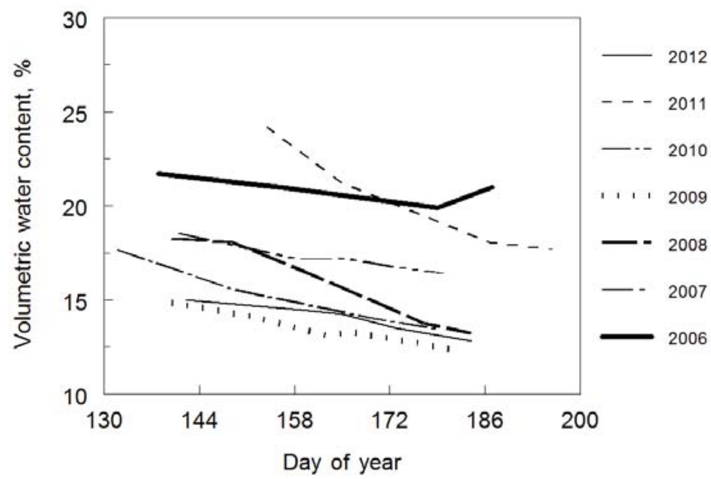
Very low precipitation in November and December 2011 was followed by close to average precipitation from January through June 2012 resulting in a dry spring and in lower soil volumetric water content early in the wildflower growing season. For example, in 2012 the soil water in the non-irrigated plots of *Eriogonum umbellatum* was much drier compared to wetter years such as 2006 and 2011 (Figure 1). The soil volumetric water content for all species started very dry in 2012 but responded to the irrigation treatments (Figures 2-6). The accumulated precipitation and growing degree days (50-86 °F) from January through June 2012 were close to the average (Table 4, Figures 7 and 8). The relatively dry soil at the beginning of the growing season may have been detrimental to the seed yield of all species in 2012.

### 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°F base) are accumulated. Data collected by an AgriMet weather station adjacent to the field indicated 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). Root rot affected the wetter plots of *P. speciosus* in 2009, but the stand partially recovered due to natural reseeding.

The three *Sphaeralcea* spp. (globemallow) flowered over a long 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* spp. starting in fall 2007 was done annually to induce a more concentrated flowering, allowing only one mechanical harvest. Precipitation in June 2009 (2.27 inches) and 2010 (1.95 inches) was substantially higher than average (0.76 inches). Rust (*Puccinia sherardiana*) infected all three *Sphaeralcea* spp. in June 2009 and 2010, causing substantial leaf loss and reduced vegetative growth.

**Figure 1.** Soil volumetric water content in non-irrigated *Eriogonum umbellatum* in 7 years (2006-2012) by Julian day. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths.



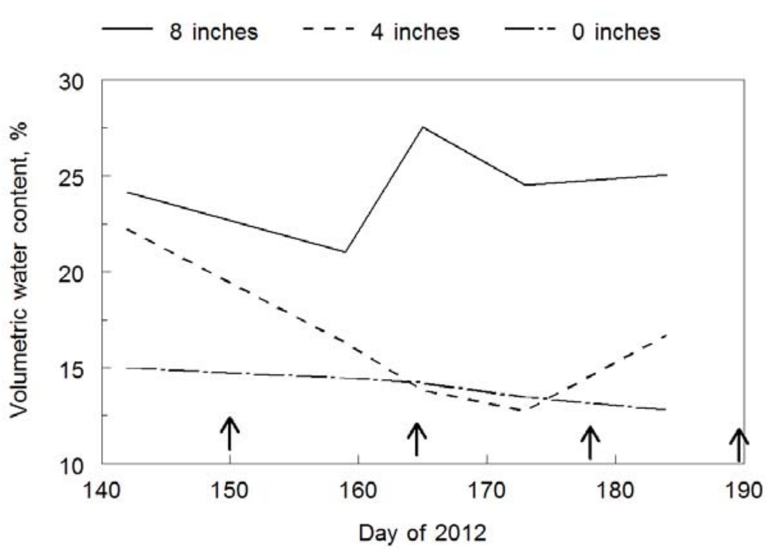




**Figure 2.** Soil volumetric water content for *Eriogonum umbellatum* over time in 2012 by Julian day. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 30 and ended on July 11. Arrows denote irrigations. *E. umbellatum* was harvested on July 24 (day 205).

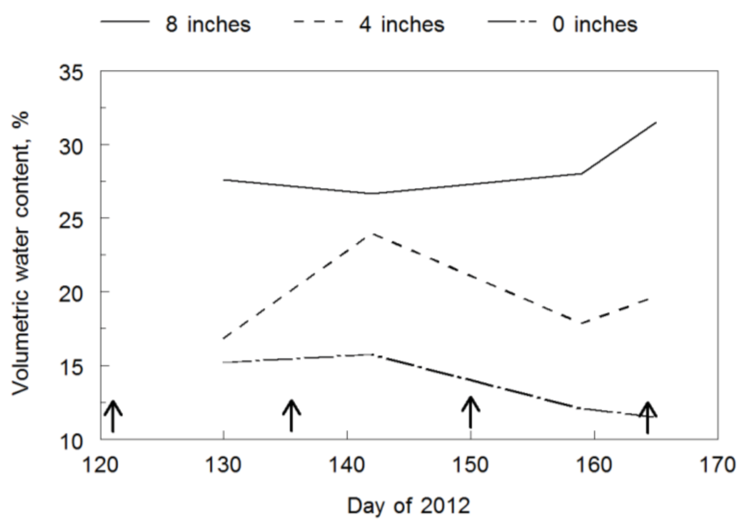



**Figure 3.** Soil volumetric water content for *Penstemon speciosus* over time in 2012 by Julian day. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 2 and ended on June 13. Arrows denote irrigations. *P. speciosus* was harvested on July 13 (day 194).

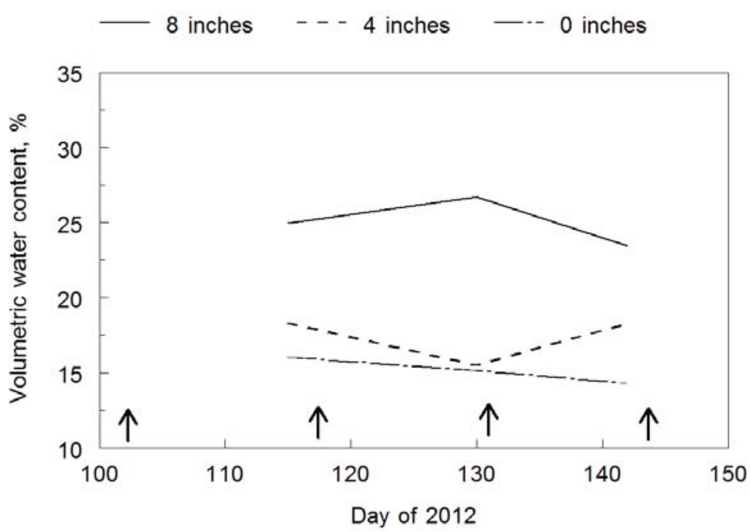



**Figure 4.** Soil volumetric water content for *Lomatium triternatum* over time in 2012 by Julian day. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 13 and ended on May 24. Arrows denote irrigations. *L. triternatum* was harvested on June 21 (day 172).

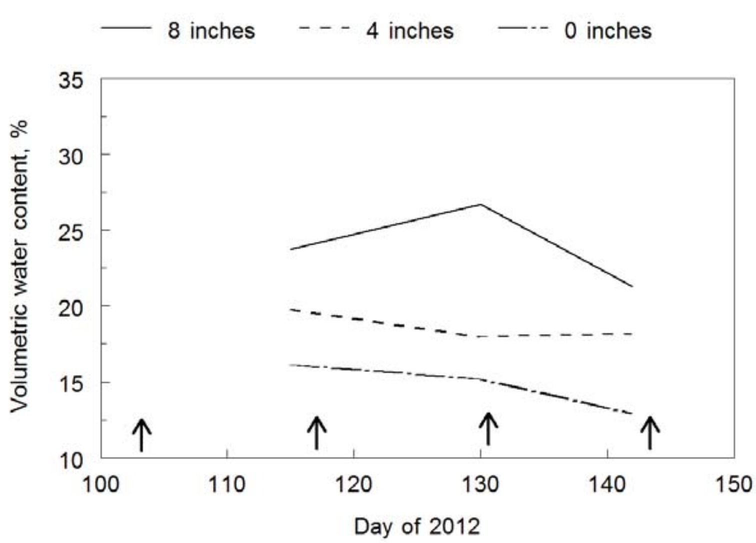



**Figure 5.** Soil volumetric water content for *Lomatium grayi* over time in 2012 by Julian day. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 13 and ended on May 24. Arrows denote irrigations. *L. grayi* was harvested on June 14 (day 165).

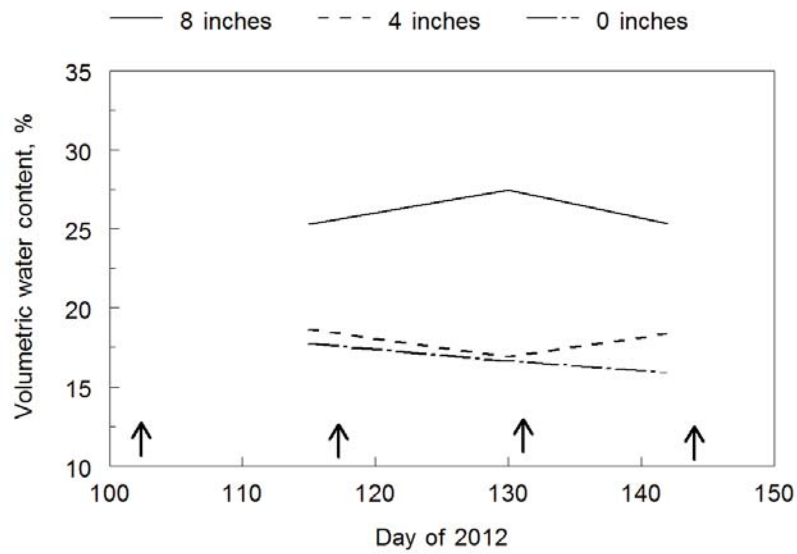



**Figure 6.** Soil volumetric water content for *Lomatium dissectum* over time in 2012 by Julian day. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 13 and ended on May 24. Arrows denote irrigations. *L. dissectum* was harvested on June 4 (day 155).

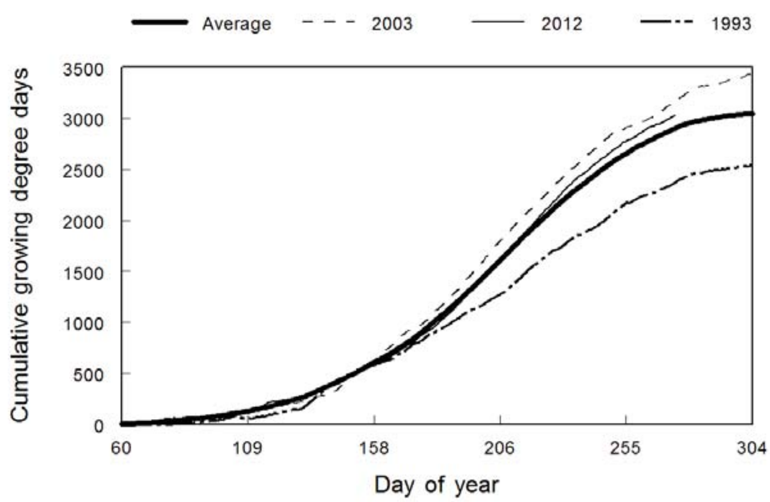



**Figure 7.** Cumulative annual and 22-year average growing degree-days by Julian day at the Malheur Experiment Station, Oregon State University, Ontario, OR.

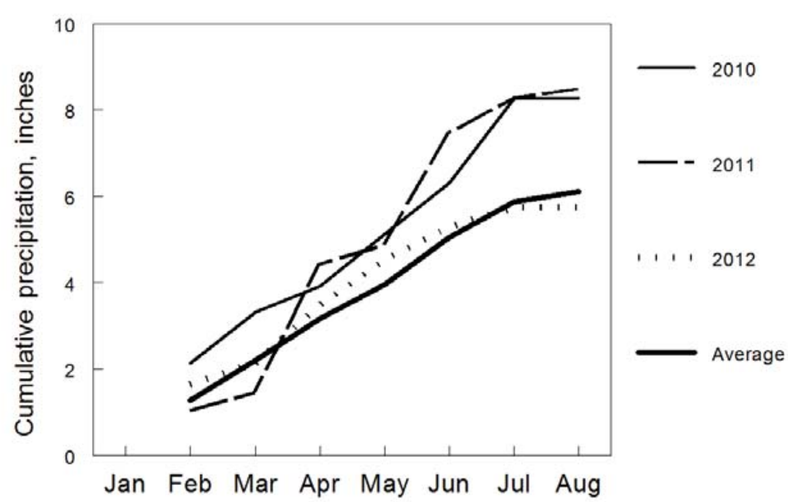


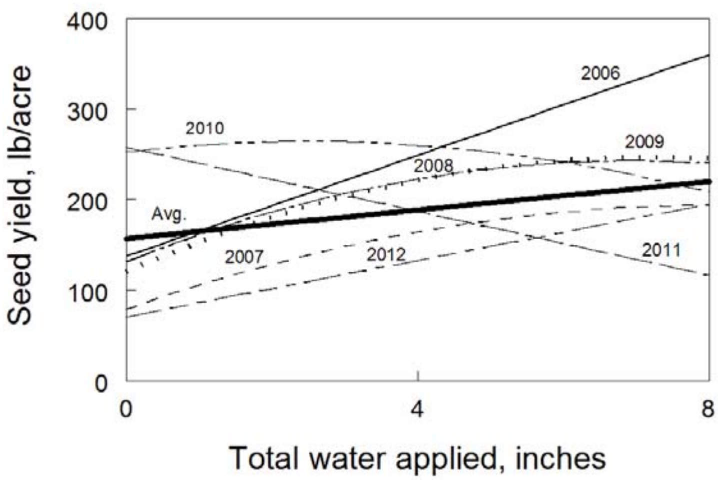

**Figure 8.** Cumulative annual and 68-year average precipitation from January through July at the Malheur Experiment Station

Seed Yields

*Eriogonum umbellatum*

In 2006, seed yield of *Eriogonum umbellatum* increased with increasing water application, up to 8 inches, the highest amount tested (Table 5, Figure 9). In 2007-2009 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. In 2011, seed yield was highest with no irrigation. The 2010 and 2011 seasons had unusually cool (Table 4, Figure 1) and wet weather (Figure 2). The accumulated precipitation in April through June 2010 and 2011 was greatest over the years of the trial (Table 4). The relatively high seed yield of *E. umbellatum* in the nonirrigated treatment in 2010 and 2011 seemed to be related to the high spring precipitation.

The negative effect of irrigation on seed yield in 2011 might have been related to the presence of rust. Irrigation could have exacerbated the rust and resulted in lower yields. In 2006, seed yield of *Eriogonum umbellatum* increased with increasing water application, up to 8 inches, the highest amount tested (Table 5, Figure 9). Averaged over 7 years, seed yield of *E. umbellatum* increased with increasing water applied up to 8 inches, the highest amount tested (Figure 9). The quadratic seed yield responses most years suggests that additional irrigation above 8 inches would not be beneficial.



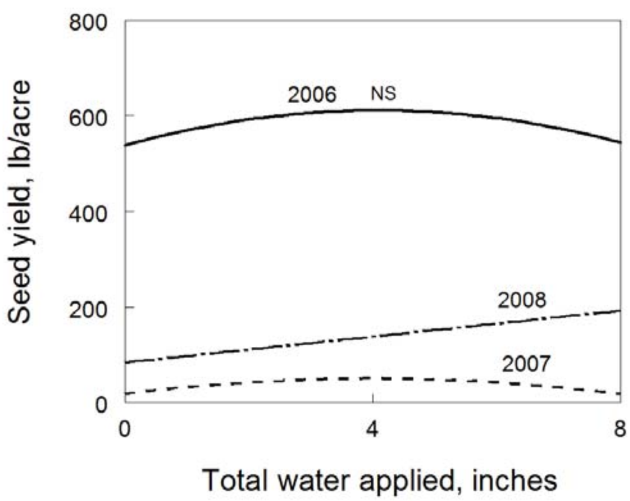

Regression equations:
2006: $Y = 137.9 + 27.8X$, $R^2 = 0.68$, $P = 0.01$
2007: $Y = 79.6 + 28.3X - 1.75X^2$, $R^2 = 0.69$, $P = 0.05$
2008: $Y = 121.3 + 34.6X - 2.4X^2$, $R^2 = 0.73$, $P = 0.01$
2009: $Y = 132.3 + 31.9X - 2.3X^2$, $R^2 = 0.60$, $P = .05$
2010: $Y = 252.9 + 9.21X - 1.8X^2$, $R^2 = 0.08$, P = NS
2011: $Y = 232.7 - 16.0X$, $R^2 = 0.58$, $P = 0.01$
2012: $Y = 71.2 + 15.5X$, $R^2 = 0.61$, $P = 0.01$

7-year average:
$Y = 157.2 + 7.9X$, $R^2 = 0.68$, $P = 0.01$.

**Figure 9.** Average annual *Eriogonum umbellatum* seed yield response to irrigation water applied in 7 years (2006-2012) and averaged over 7 years.

*Penstemon acuminatus*

There was no significant difference in seed yield between irrigation treatments for *P. acuminatus* 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, seed yield showed a quadratic response to irrigation rate (Figure 10). Seed yields were maximized by 4.0 inches of water applied in 2007. In 2008 seed yield showed a linear response to applied water. 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 contained only dead plants. Measurements in each plot showed that plant death increased with increasing irrigation rate. The stand loss was 51.3, 63.9, and 88.5 percent 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.

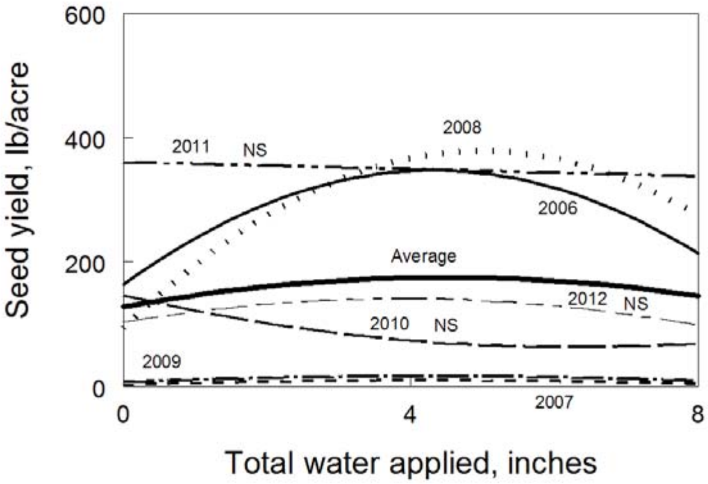



Regression equations:
2006: $Y = 538.4 + 35.6X - 4.4X^2$, $R^2 = 0.03$, P = NS
2007: $Y = 19.3 + 15.4X - 1.9X^2$, $R^2 = 0.44$, $P = 0.10$
2008: $Y = 84.5 + 13.6X$, $R^2 = 0.49$, $P = 0.05$

**Figure 10.** Annual *Penstemon acuminatus* seed yield response to irrigation water.

*Penstemon speciosus*
In 2006-2009 seed yield of *P. speciosus* showed a quadratic response to irrigation rate (Figure 11, Tables 5 and 6). 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, 2011, and 2012 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 and 2011, due in part to natural reseeding, especially in the nonirrigated plots. Averaged over the 7 years, seed yield was maximized by 4.5 inches of water applied.

*Penstemon deustus*
There was no significant difference in seed yield between irrigation treatments for *P. deustus* 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 plots with very low and uneven stands. The planting was disked out.



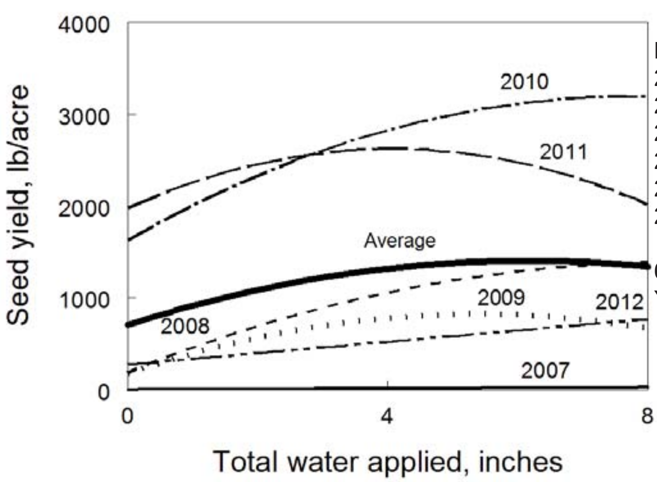

Regression equations:
2006: Y = 163.5 + 85.1X – 9.9X$^2$, $R^2$ = 0.66, P = 0.05
2007: Y = 2.5 + 3.2X – 0.38X$^2$, $R^2$ = 0.48, P = 0.10
2008: Y = 94.1 + 113.7X – 11.4X$^2$, $R^2$ = 0.56, P = 0.05
2009: Y = 6.8 + 4.4X – 0.52X$^2$, $R^2$ = 0.54, P = 0.05
2010: Y = 147.2 + 29.81X – 2.1X$^2$, $R^2$ = 0.35, P = NS
2011: Y = 360.6 – 2.82X, $R^2$ = 0.01, P = NS
2012: Y = 103.8 + 19.3X – 2.5X$^2$, $R^2$ = 0.30, P = NS

7-year average:
Y = 127.8 + 21.2X – 2.4X$^2$; $R^2$ = 0.37, P = NS

**Figure 11.** Annual and 7-year average *Penstemon speciosus* seed yield response to irrigation water.

*Lomatium triternatum*

*Lomatium triternatum* showed a trend for increasing seed yield with increasing irrigation rate in 2007 (Table 5). The highest irrigation rate resulted in significantly higher seed yield than the nonirrigated check treatments. Seed yields of *L. triternatum* were substantially higher in 2008-2011 (Tables 5 and 6). In 2008–2011, seed yields of *L. triternatum* showed a quadratic response to irrigation rate (Figure 12). Seed yields were estimated to be maximized by 8.4, 5.4, 7.8, and 4.1 inches of water applied in 2008, 2009, 2010, and 2011, respectively. In 2012, seed yield increased with increasing water applied up to the highest amount of 8 inches. Averaged over 6 years, seed yield of *L. triternatum* was estimated to be maximized by 6.2 inches of applied water. Irrigation requirements were lower in 2011.




Regression equations:
2007: Y = 3.26 + 3.06X, $R^2$ = 0.52, P = 0.01
2008: Y = 195.3 + 283.9X – 16.9X$^2$, $R^2$ = 0.77, P = 0.01
2009: Y = 181.6 + 237.4X – 22.0X$^2$, $R^2$ = 0.83, P = 0.001
2010: Y = 1637.2 + 401.5X – 25.9X$^2$, $R^2$ = 0.83, P = 0.001
2011: Y = 1982.932 + 315.1X – 38.7X$^2$, $R^2$ = 0.45, P = 0.10
2012: Y = 277.8 + 61.8X, $R^2$ = 0.49, P = 0.05

6-year average:
Y = 706.3 + 227.1X – 18.5X$^2$, $R^2$ = 0.80, P = 0.001

**Figure 12.** Annual and 6-year average *L. triternatum* seed yield response to irrigation water.

*Lomatium grayi*

*Lomatium grayi* showed a trend for increasing seed yield with increasing irrigation rate in 2007 (Table 5). The highest irrigation rate resulted in significantly higher seed yield than the nonirrigated 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 (Figure 13). 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 in the nonirrigated 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. grayi* plants from an adjacent area in the spring of 2010. To reduce their attractiveness to voles, the plants were mowed after becoming dormant in early fall of 2010. In 2011, seed yield again did not respond to irrigation. The spring of 2011 was unusually cool and wet. In 2012, seed yields of *L. grayi* showed a quadratic response to irrigation rate, with a maximum seed yield at 5.5 inches of applied water (Figure 13). Averaged over 6 years, seed yield of *L. grayi* was estimated to be maximized by 5.2 inches of applied water. More appropriately, irrigation probably should be variable according to precipitation.

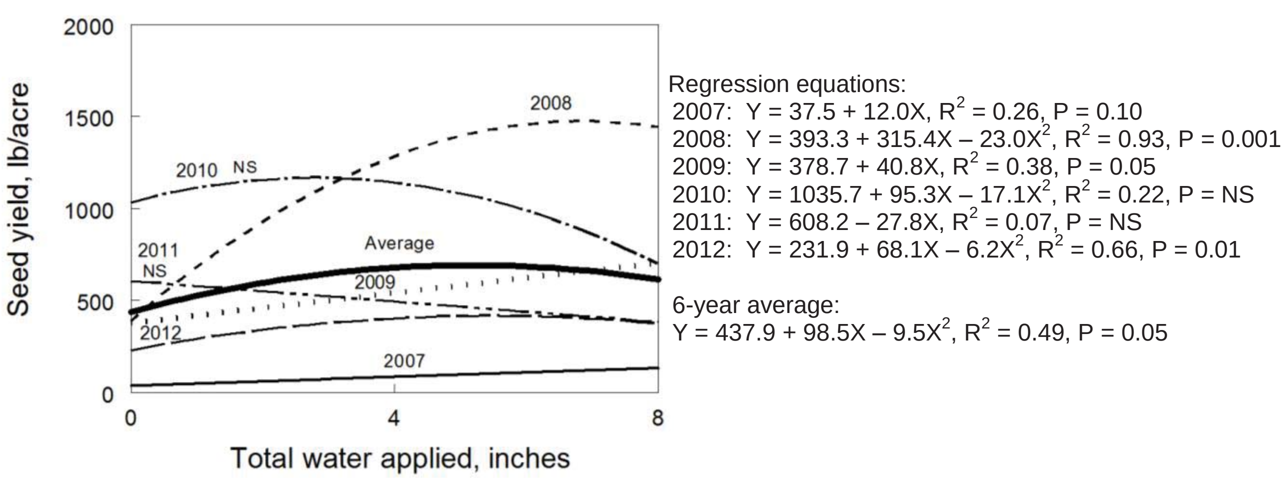



**Figure 13.** Annual and 6-year average *L. grayi* seed yield response to irrigation water.

*Lomatium dissectum*

*Lomatium dissectum* had very poor vegetative growth in 2006-2008, and produced only very small amounts of flowers in 2008. In 2009, vegetative growth and flowering for *L. dissectum* were greater. Seed yield of *L. dissectum* showed a linear response to irrigation rate in 2009 (Figure 14). Seed yield with the 4-inch irrigation rate was significantly higher than with the nonirrigated check, but the 8-inch irrigation rate did not result in a significant increase above the 4-inch rate. In 2010 and 2011, seed yields of *L. dissectum* showed a quadratic response to irrigation rate. Seed yields were estimated to be maximized by 5.4 and 5.1 inches of applied water in 2010 and 2011, respectively. In 2012, seed yields of *L. dissectum* were not responsive to irrigation rate (Figure 14). Averaged over the 4 years, seed yield showed a quadratic response to irrigation rate and was estimated to be maximized by 5.1 inches of applied water.

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.

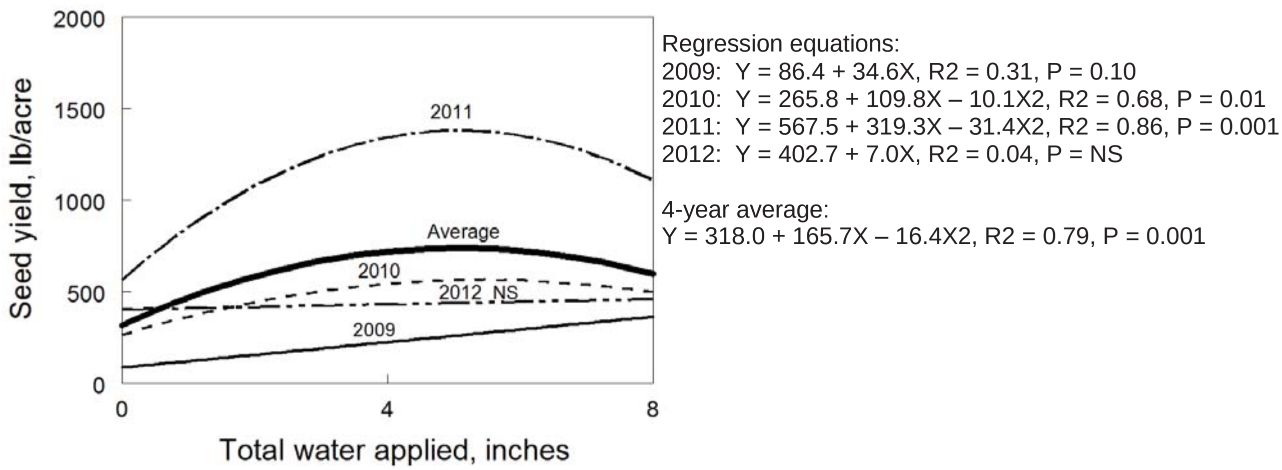



**Figure 14.** Annual and 3-year average *L. dissectum* seed yield response to irrigation water.

*Sphaeralcea* spp.
In 2007-2011 there were no significant differences in seed yield among irrigation treatments for the three *Sphaeralcea* species (Tables 5 and 6). Stand of the three *Sphaeralcea* species was poor in 2012 and the planting was eliminated.

<u>Conclusions</u>
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 often be 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 (Table 7). The *Sphaeralcea* spp. and *Penstemon acuminatus* did not respond to irrigation in these trials. Natural rainfall was sufficient to maximize seed production in the absence of weed competition.

*Lomatium dissectum* required approximately 6 inches of irrigation. *Lomatium grayi*, *L. triternatum*, and *Eriogonum umbellatum* responded quadratically to irrigation with the optimum varying by year. The other species tested had insufficient plant stands to reliably evaluate their response to irrigation.

**Management Applications and Seed Production Guidelines**

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

**Table 4.** Precipitation and growing degree-days at the Malheur Experiment Station, Ontario, OR.

| | Precipitation (inches) | | Growing degree-days (50-86°F) |
|---|---|---|---|
| Year | Jan-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 |
| 2011 | 8.3 | 3.9 | 671 |
| 2012 | 5.8 | 2.3 | 979 |
| 67-year average | 5.8 | 2.7 | 1028[a] |

[a]25-year average.

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

| | 2006 | | | | 2007 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | 0 inches | 4 inches | 8 inches | LSD (0.05) | 0 inches | 4 inches | 8 inches | LSD (0.05) | 0 inches | in |
| | ------------------------------------------------- lb/acre ---------------------------- | | | | | | | | | |
| *Eriogonum umbellatum*[a] | 155.3 | 214.4 | 371.6 | 92.9 | 79.6 | 164.8 | 193.8 | 79.8 | 121.3 | 22 |
| *Penstemon acuminatus*[a] | 538.4 | 611.1 | 544.0 | NS | 19.3 | 50.1 | 19.1 | 25.5[b] | 56.2 | 1: |
| *Penstemon deustus*[c] | 1,246.4 | 1,200.8 | 1,068.6 | NS | 120.3 | 187.7 | 148.3 | NS | --- very p | |
| *Penstemon speciosus*[a] | 163.5 | 346.2 | 213.6 | 134.3 | 2.5 | 9.3 | 5.3 | 4.7[b] | 94.0 | 36 |
| *Lomatium dissectum*[d] | ---- no flowering ---- | | | | --- no flowering --- | | | | - very littl | |
| *Lomatium triternatum*[d] | ---- no flowering ---- | | | | 2.3 | 17.5 | 26.7 | 16.9[b] | 195.3 | 1,0 |
| *Lomatium grayi*[d] | ---- no flowering ---- | | | | 36.1 | 88.3 | 131.9 | 77.7[b] | 393.3 | 1,2 |
| *Sphaeralcea parvifolia*[e] | | | | | 1,062.6 | 850.7 | 957.9 | NS | 436.2 | 5 |
| *Sphaeralcea grossulariifolia*[e] | | | | | 442.6 | 324.8 | 351.9 | NS | 275.3 | 1 |
| *Sphaeralcea coccinea*[e] | | | | | 279.8 | 262.1 | 310.3 | NS | 298.7 | 3 |

[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
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.

**Table 6.** Native forb seed yield response to irrigation rate (inches/season) in 2009, 2010, 2011, 2012, and 2- to 6-
Malheur Experiment Station, Oregon State University, Ontario, OR.

| Species | 2009 | | | | 2010 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 inches | 4 inches | 8 inches | LSD (0.05) | 0 inches | 4 inches | 8 inches | LSD (0.05) | 0 inches |
| | ---------------------------------------------- lb/acre ---------------------------- | | | | | | | | |
| *Eriogonum umbellatum*[a] | 132.3 | 223.0 | 240.1 | 67.4 | 252.9 | 260.3 | 208.8 | NS | 248.7 |
| *Penstemon acuminatus*[a] | 20.7 | 12.5 | 11.6 | NS | -- Stand disked out -- | | | | |
| *Penstemon speciosus*[a] | 6.8 | 16.1 | 9.0 | 6.0[b] | 147.2 | 74.3 | 69.7 | NS | 371.1 |
| *Lomatium dissectum*[d] | 50.6 | 320.5 | 327.8 | 196.4[b] | 265.8 | 543.8 | 499.6 | 199.6 | 567.5 |
| *Lomatium triternatum*[d] | 181.6 | 780.1 | 676.1 | 177.0 | 1,637.2 | 2,829.6 | 3,194.6 | 309.4 | 1,982.9 |
| *Lomatium grayi*[d] | 359.9 | 579.8 | 686.5 | 208.4 | 1,035.7 | 1,143.5 | 704.8 | NS | 570.3 |
| *Sphaeralcea parvifolia*[e] | 285.9 | 406.1 | 433.3 | NS | 245.3 | 327.3 | 257.3 | NS | 81.6 |
| *Sphaeralcea grossulariifolia*[e] | 270.7 | 298.9 | 327.0 | NS | 310.5 | 351.0 | 346.6 | NS | 224.0 |
| *Sphaeralcea coccinea*[e] | 332.2 | 172.1 | 263.3 | NS | 385.7 | 282.6 | 372.5 | NS | 89.6 |

| Species | 2012 | | | | 2- to 7-year averages | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 inches | 4 inches | 8 inches | LSD (0.05) | 0 inches | 4 inches | 8 inches | LSD (0.05) |
| *Eriogonum umbellatum*[a] | 61.2 | 153.2 | 185.4 | 84.4 | 154.5 | 194.2 | 217.4 | 30.8 |
| *Penstemon acuminatus*[a] | | | | | 163.8 | 204.8 | 189.9 | NS |
| *Penstemon speciosus*[a] | 103.8 | 141.1 | 99.1 | NS | 127.8 | 174.8 | 145.8 | 30.5[b] |
| *Lomatium dissectum*[d] | 388.1 | 460.3 | 444.4 | NS | 318.0 | 719.1 | 596.4 | 179.4 |
| *Lomatium triternatum*[d] | 238.7 | 603.0 | 733.2 | 323.9 | 706.3 | 1319.3 | 1341.0 | 192.4 |
| *Lomatium grayi*[d] | 231.9 | 404.4 | 377.3 | 107.4 | 437.9 | 679.3 | 615.5 | 185.5 |
| *Sphaeralcea parvifolia*[e] | | | | | 449.9 | 495.9 | 495.8 | NS |
| *Sphaeralcea grossulariifolia*[e] | | | | | 339.5 | 323.4 | 309.4 | NS |
| *Sphaeralcea coccinea*[e] | | | | | 320.5 | 275.8 | 284.2 | NS |

[a] Planted M
replanted l
[b] LSD (0.10
[d] Planted M
replanted i
[e] Planted sp
replanted i

**Table 7.** Amount of irrigation water for maximum native wildflower seed yield, years to seed set, and life span. A summary of multi-year research findings, Malheur Experiment Station, Oregon State University, Ontario, OR.

| Species | Optimum amount of irrigation | Years to first seed set | Life span |
|---|---|---|---|
| | inches/season | from fall planting | years |
| *Eriogonum umbellatum* | 0 in wet years, 7 to 8 in dry years | 1 | 7+ |
| *Penstemon acuminatus* | no response | 1 | 3 |
| *Penstemon speciosus* | 0 in wet years, 4 in dry years | 1 | 3 |
| *Lomatium dissectum* | 5 | 4 | 7+ |
| *Lomatium triternatum* | 4 to 8 depending on precipitation | 2 | 7+ |
| *Lomatium grayi* | 0 in wet years, 5 in dry years | 2 | 7+ |
| *Sphaeralcea parvifolia* | no response | 1 | 5 |
| *Sphaeralcea grossulariifolia* | no response | 1 | 5 |
| *Sphaeralcea coccinea* | no response | 1 | 5 |

## B. Preliminary Estimates of Irrigation Requirements for Novel Native Wildflower Seed Production

### Project Description

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.

On native 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 well adapted to croplands as they are often not competitive with crop weeds in cultivated fields. Poor competitiveness 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 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 10 native forb species (Table 1) planted in 2009.

<u>Materials and Methods</u>

Plant Establishment

In November 2009, drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth between two 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 November 25, 2009, seed of nine perennial species (Table 1) was planted in 30-inch rows using a custom-made small-plot grain drill with disk openers. All seed was planted on the soil surface at 20-30 seeds/ft of row. After planting, sawdust was applied in a narrow band over the seed row at 0.26 oz/ft of row (558 lb/acre). Following planting and sawdust application, the beds were covered with row cover. The row cover (N-sulate, DeWitt Co., Inc., Sikeston, MO) covered four rows (two beds) and was applied with a mechanical plastic mulch layer. The field was irrigated for 24 hours on December 2, 2009, due to very dry soil conditions.

Cultural Practices in 2010

After the newly planted forbs had emerged, the row cover was removed in April. The irrigation treatments were not applied to these forbs in 2010. Stands of *Penstemon cyaneus*, *Penstemon pachyphyllus*, and *Eriogonum heracleoides* were not adequate for an irrigation trial. Gaps in the rows were replanted by hand on November 5. The replanted seed was covered with a thin layer of a mixture of 50 percent sawdust and 50 percent hydro-seeding mulch (Hydrostraw LLC, Manteno, IL) by volume. The mulch mixture was sprayed with water using a backpack sprayer. On November 18, 2010, seed of *Cleome serrulata* was planted as previously described.

Cultural Practices in 2011

Seed from the middle two rows in each plot of *Penstemon deustus* and *Eriogonum heracleoides* was harvested with a small plot combine. Seed from the middle two rows in each plot of the other species was harvested manually. On November 11, 2011, seed of *Cleome serrulata* was planted as previously described. On December 5, 2011, seed of *Cleome lutea* was planted as previously described.

Cultural Practices in 2012

Many areas of the wildflower seed production was suffering from severe iron deficiency early in the spring of 2012. On April 13, 2012, 50 lb N/acre, 10 lb P/acre, and 5 lb Fe/acre was applied to all plots of *Lomatium nudicaule, Cymopterus bipinnatus, Penstemon deustus, Penstemon cyaneus,* and *Penstemon pachyphyllus* as liquid fertilizer injected through the drip tape. On April 23, 2012, 5 lb Fe/acre was applied to all plots of *Penstemon deustus, Penstemon cyaneus, Penstemon pachyphyllus, Eriogonum heracleoides, Dalea searlsiae, Dalea ornata,* and *Astragalus filipes* as liquid fertilizer injected through the drip tape.

Flea beetles were observed feeding on leaves of *Cleome serrulata* and *Cleome lutea* in April. On April 29, all plots of *Cleome serrulata* and *Cleome lutea* were sprayed with Capture at 5 oz/acre to control flea beetles. On June 11, *C. serrulata* was again sprayed with Capture at 5 oz/acre to control a reinfestation of flea beetles.

A substantial amount of plant death occurred in the *Penstemon deustus* plots during winter and spring 2011/2012. For *P. deustus*, only the undamaged parts in each plot were harvested. Seed of all species was harvested and cleaned manually.

**Table 1.** Forb species planted in the fall of 2009 at the Malheur Experiment Station, Oregon State University, Ontario, OR. All species are perennial except *Cleome serrulata* and *Cleome lutea*.

| Species | Common names |
|---|---|
| *Astragalus filipes* | Basalt milkvetch |
| *Cleome lutea* | Yellow beeplant |
| *Cleome serrulata* | Rocky Mountain beeplant |
| *Cymopterus bipinnatus* | Hayden's cymopterus |
| *Dalea ornata* | Blue Mountain prairie clover |
| *Dalea searlsiae* | Searls' prairie clover |
| *Eriogonum heracleoides* | Parsnipflower buckwheat |
| *Lomatium nudicaule* | Barestem lomatium |
| *Penstemon cyaneus* | Blue penstemon |
| *Penstemon deustus* | Scabland penstemon, hotrock penstemon |
| *Penstemon pachyphyllus* | Thickleaf beardtongue |

Irrigation for Seed Production

In April 2011, each strip of each forb species was divided into plots 30 ft long. Each plot contained four rows of each species. The experimental design for each species was a randomized complete block with four replicates. The three irrigation treatments were a nonirrigated 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 length of time necessary to deliver 1 or 2 inches through the drip system. Irrigations were regulated with a controller and solenoid valves. After each irrigation, the amount of water applied was read on a water meter and recorded to ensure correct water applications.

The drip-irrigation system was designed to allow separate irrigation of the species due to different timings of flowering and seed formation. The three *Penstemon* spp. were irrigated together and the two *Dalea* spp. were irrigated together. *Eriogonum heracleoides* and *Astragalus filipes* were irrigated individually. Flowering, irrigation, and harvest dates were recorded (Table 2). *Lomatium nudicaule* flowered in 2012; irrigation treatments were applied and seed was harvested. *Cymopterus bipinnatus* has not flowered as of 2012, but differential irrigation treatments were applied to *Cymopterus bipinnatus* in 2012.

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, for each soil depth. Regression equations were then used to transform the neutron probe readings during the season into volumetric soil water content.

**Table 2.** Native forb flowering, irrigation, and seed harvest dates by species.

| Species | Flowering | | | Irrigation | | Harvest |
|---|---|---|---|---|---|---|
| | start | peak | end | start | end | |
| | | | | 2011 | | |
| *Penstemon cyaneus* | 23-May | 15-Jun | 8-Jul | 13-May | 23-Jun | 18-Jul |
| *Penstemon pachyphyllus* | 10-May | 30-May | 20-Jun | 13-May | 23-Jun | 15-Jul |
| *Penstemon deustus* | 23-May | 20-Jun | 14-Jul | 13-May | 23-Jun | 16-Aug |
| *Eriogonum heracleoides* | 26-May | 10-Jun | 8-Jul | 27-May | 6-Jul | 1-Aug |
| *Dalea searlsiae* | 8-Jun | 20-Jun | 20-Jul | 27-May | 6-Jul | 21-Jul |
| *Dalea ornata* | 8-Jun | 20-Jun | 20-Jul | 27-May | 6-Jul | 22-Jul |
| *Astragalus filipes* | 20-May | 26-May | 30-Jun | 13-May | 23-Jun | 18-Jul |
| *Cleome serrulata* | 25-Jun | 30-Jul | 15-Aug | 21-Jun | 2-Aug | 26-Sep |
| *Lomatium nudicaule* | | No flowering | | | | |
| *Cymopterus bipinnatus* | | No flowering | | | | |
| | | | | 2012 | | |
| *Penstemon cyaneus* | 16-May | 30-May | 10-Jun | 27-Apr | 7-Jun | 27-Jun |
| *Penstemon pachyphyllus* | 23-Apr | 2-May | 10-Jun | 27-Apr | 7-Jun | 26-Jun |
| *Penstemon deustus* | 16-May | 30-May | 4-Jul | 27-Apr | 7-Jun | 7-Aug |
| *Eriogonum heracleoides* | 23-May | 30-May | 25-Jun | 11-May | 21-Jun | 16-Jul |
| *Dalea searlsiae* | 23-May | 10-Jun | 30-Jun | 11-May | 21-Jun | 10-Jul |
| *Dalea ornata* | 23-May | 10-Jun | 30-Jun | 11-May | 21-Jun | 11-Jul |
| *Astragalus filipes* | 28-Apr | 23-May | 19-Jun | 11-May | 21-Jun | 5-Jul |
| *Cleome serrulata* | 12-Jun | 30-Jun | 30-Jul | 13-Jun | 25-Jul | 24-Jul to 30-Aug |
| *Cleome lutea* | 16-May | 15-Jun | 30-Jul | 2-May | 13-Jun | 12-Jul to 30-Aug |
| *Lomatium nudicaule* | 12-Apr | 1-May | 30-May | 18-Apr | 30-May | 22-Jun |
| *Cymopterus bipinnatus* | | No flowering | | | | |

## Results and Discussion

### Seed Yields in 2011

Seed yield of all species, except *Cleome serrulata*, either had a negative response to irrigation (*Dalea searlsiae* and *Penstemon deustus*) or did not respond to irrigation (*Dalea ornata* and *Astragalus filipes*) (Table 3, Figures 1-3). Seed yield of *Cleome serrulata* was highest with the highest amount of water applied (8 inches). The higher than average winter moisture and precipitation in March and May reduced the effect of the irrigation treatments for the species that flowered in May and June (Figure 4). *Cleome serrulata* started flowering in late June and peaked in August, when precipitation was lower. Seed yields of *Penstemon cyaneus* and *P. pachyphyllus* did not respond to irrigation, but the results might be compromised by the poor stand in many plots.

### Seed Yields in 2012

Precipitation was lower in 2012 than in 2011(Figure 4) and the accumulated growing degree days was higher in 2012 than in 2011 (Figure 5). Very low precipitation in November and December of 2011 was followed by close to average precipitation from January through June in 2012 resulting in a dry spring and in lower soil volumetric water content early in the wildflower growing season. The soil volumetric water content was very low for *Penstemon deustus* (Figure

6) at the start of the growing season. The soil volumetric water content responded to the irrigation treatments on each species (Figures 7-12).

Seed yield of *Penstemon cyaneus* was highest with the highest amount of water applied. Seed yield of *Dalea searlsiae* increased with increasing irrigation rate up to 6.6 inches of water applied (Table 3, Figure 13). Seed yield of *D. ornata* increased with increasing irrigation rate up to 7.7 inches of water applied (Table 3, Figure 14). None of the other species tested had statistically significant seed yield responses to irrigation in 2012.

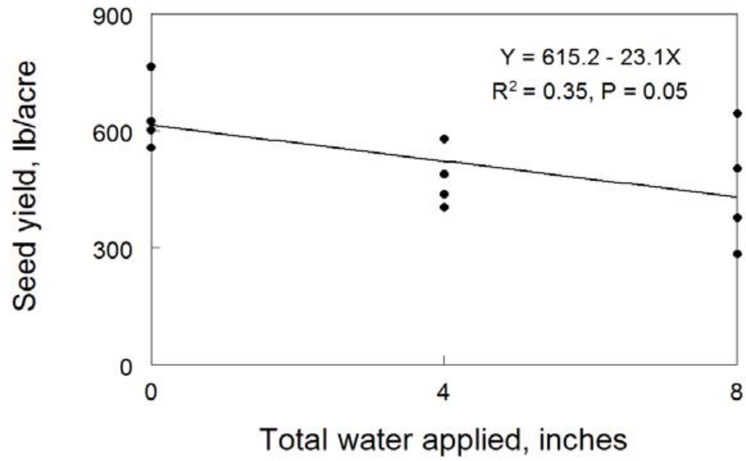



**Figure 1.** *Penstemon deustus* seed yield response to irrigation water applied in 2011. Malheur Experiment Station, Oregon State University, Ontario, OR.

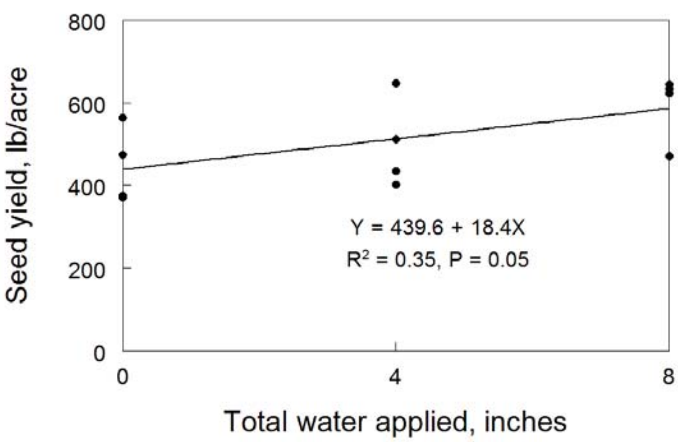



**Figure 2.** *Cleome serrulata* seed yield response to irrigation water applied in 2011. Malheur Experiment Station, Oregon State University, Ontario, OR.

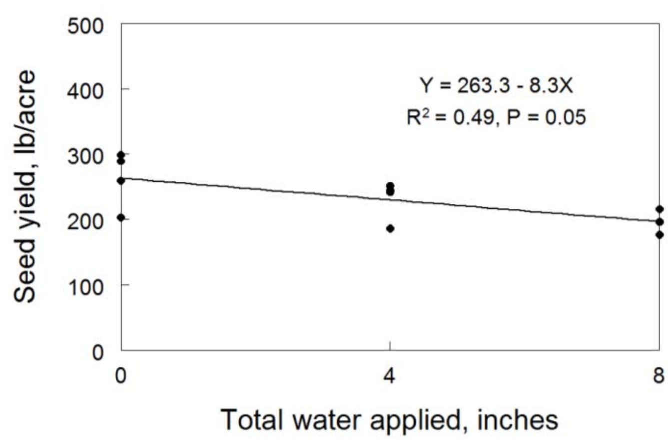
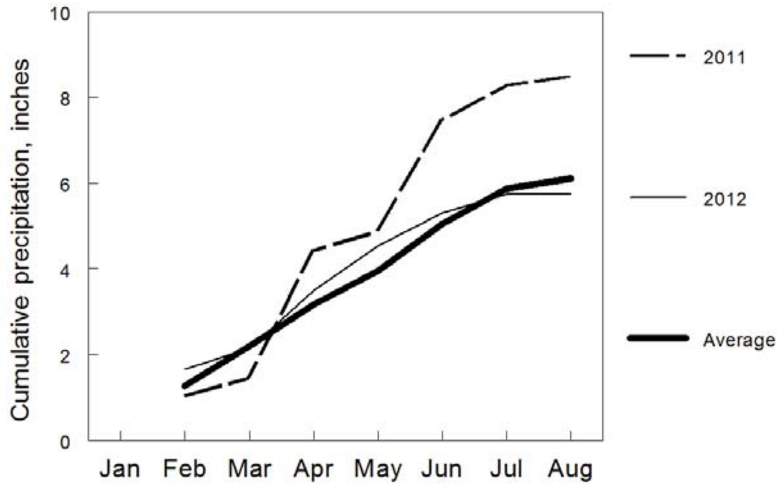



**Figure 3.** *Dalea searlsiae* seed yield response to irrigation water applied in 2011. Malheur Experiment Station, Oregon State University, Ontario, OR.

**Figure 4.** Cumulative annual (2011 and 2012) and 66-year average precipitation from January through July at the Malheur Experiment Station, Oregon State University, Ontario, OR.



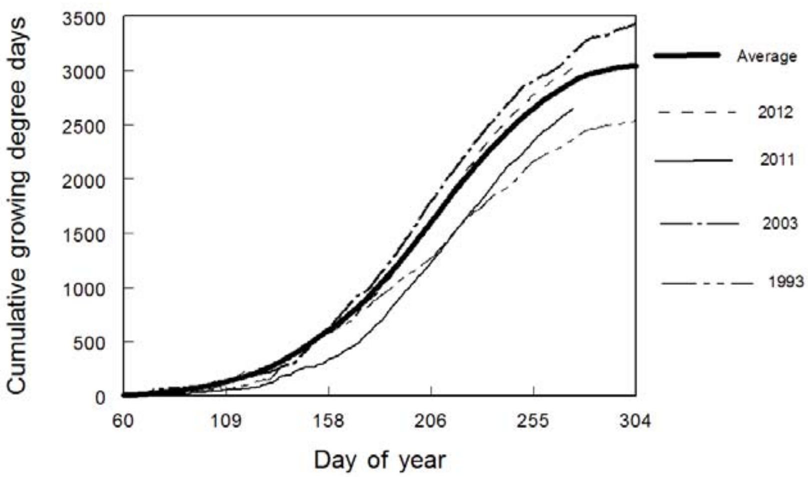
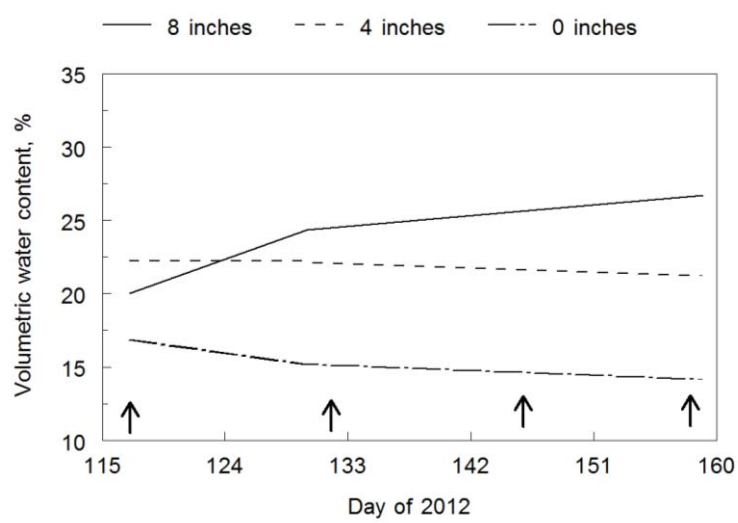




**Figure 5.** Cumulative growing degree-days (50–86 °F ) for selected years and 20-year average at the Malheur Experiment Station, Oregon State University, Ontario, OR.

**Figure 6.** Soil volumetric water content for *Penstemon deustus* by Julian day in 2012. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 27 and ended on June 7. Arrows denote irrigations. *P. deustus* was harvested on August 7 (day 219). Malheur Experiment Station, Oregon State University, Ontario, OR, 2012.



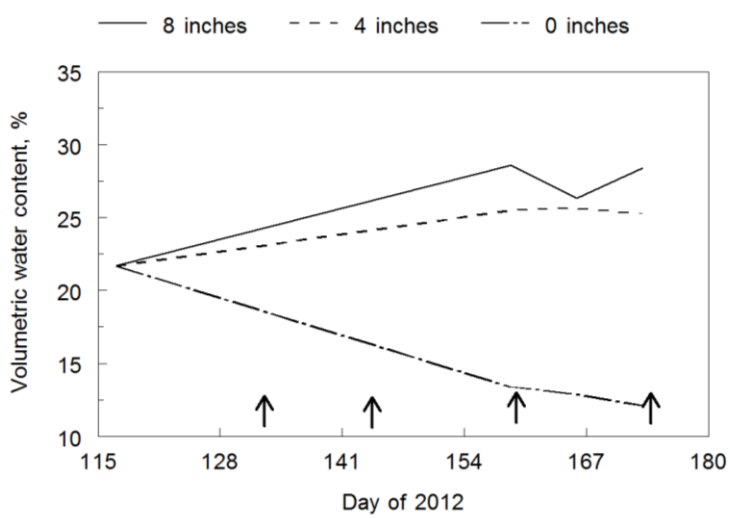



**Figure 7.** Soil volumetric water content for *Eriogonum heracleoides* by Julian day in 2012. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 11 and ended on June 21. Arrows denote irrigations. *E. heracleoides* was harvested on July 16 (day 197). Malheur Experiment Station, Oregon State University, Ontario, OR, 2012.

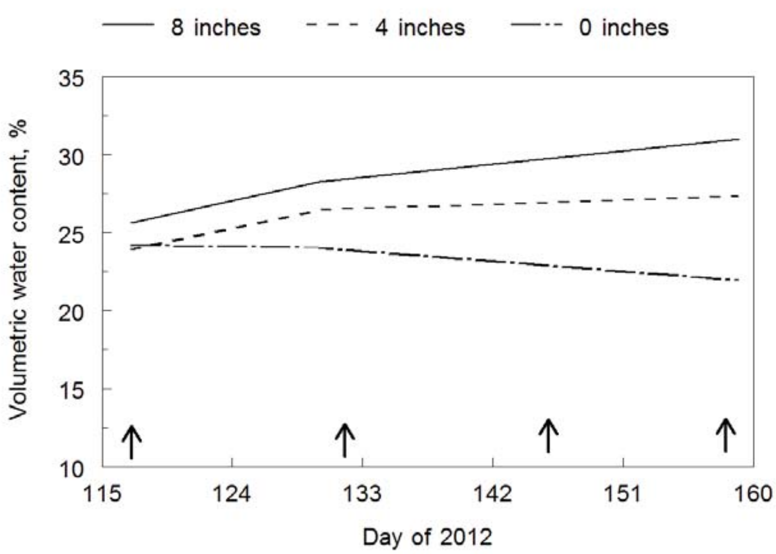



**Figure 8.** Soil volumetric water content for *Penstemon cyaneus* by Julian day in 2012. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 27 and ended on June 7. Arrows denote irrigations. *P. cyaneus* was harvested on June 27 (day 178). Malheur Experiment Station, Oregon State University, Ontario, OR, 2012.

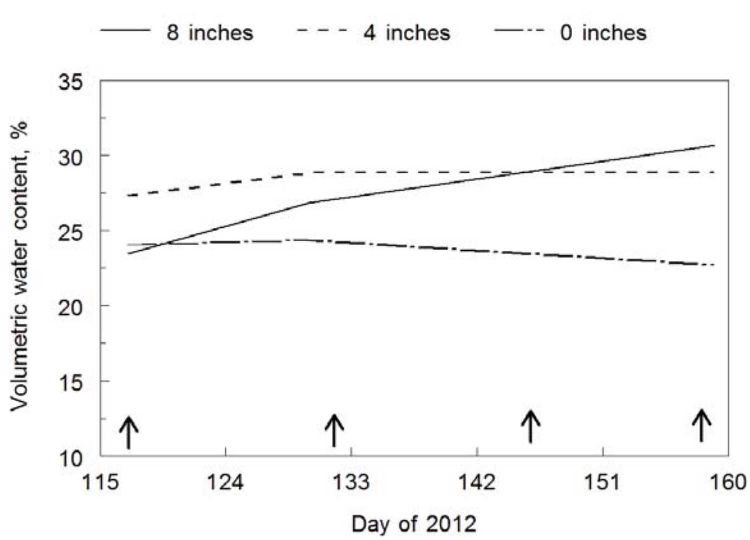
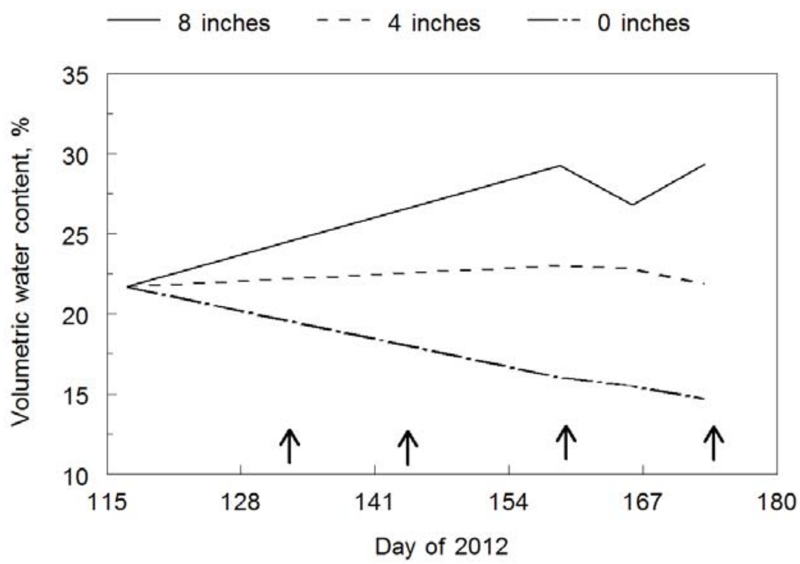



**Figure 9.** Soil volumetric water content for *Penstemon pachyphyllus* by Julian day in 2012. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 27 and ended on June 7. Arrows denote irrigations. *P. pachyphyllus* was harvested on June 26 (day 177). Malheur Experiment Station, Oregon State University, Ontario, OR, 2012.

**Figure 10.** Soil volumetric water content for *Dalea searlsiae* by Julian day in 2012. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 11 and ended on June 21. Arrows denote irrigations. *D. searlsiae* was harvested on July 10 (day 191). Malheur Experiment Station, Oregon State University, Ontario, OR, 2012.



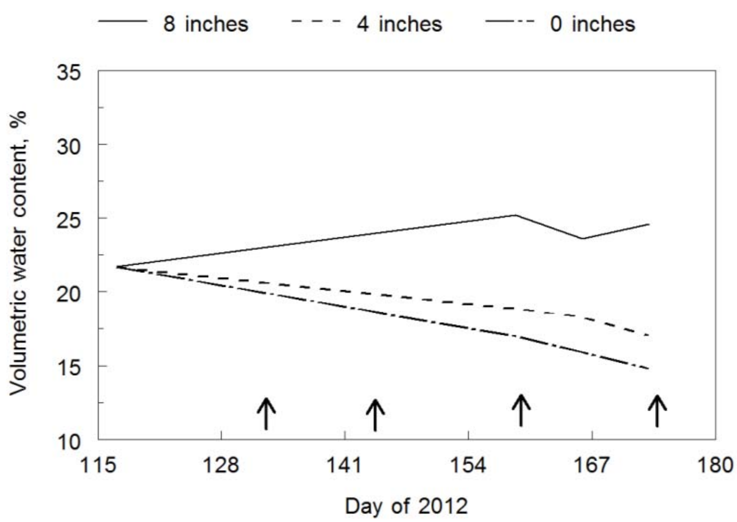




**Figure 11.** Soil volumetric water content for *Dalea ornata* by Julian day in 2012. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 11 and ended on June 21. Arrows denote irrigations. *D. ornata* was harvested on July 11 (day 192). Malheur Experiment Station, Oregon State University, Ontario, OR, 2012.

**Figure 12.** Soil volumetric water content for *Astragalus filipes* by Julian day in 2012. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 11 and ended on June 21. Arrows denote irrigations. *A. filipes* was harvested on July 5 (day 186). Malheur Experiment Station, Oregon State University, Ontario, OR, 2012.

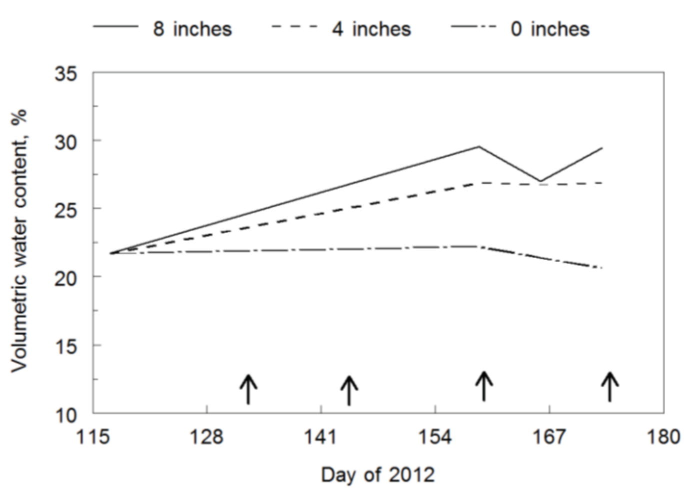


**Table 3.** Native forb seed yield response to irrigation rate (inches/season). Malheur Experiment Station, Oregon
Ontario, OR.

| | 2011 | | | | 2012 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | 0 inches | 4 inches | 8 inches | LSD (0.05) | 0 inches | 4 inches | 8 inches | LSD (0.05) | 0 inches | inc |
| | --------- lb/acre --------- | | | | --------- lb/acre --------- | | | | --------- lb/ | |
| *Penstemon cyaneus* | 857.2 | 821.4 | 909.4 | NS | 343.3 | 474.6 | 581.2 | 202.6[b] | 600.3 | 64 |
| *Penstemon pachyphyllus* | 569.9 | 337.6 | 482.2 | NS | 280.5 | 215.0 | 253.7 | NS | 425.2 | 27 |
| *Penstemon deustus* | 637.6 | 477.8 | 452.6 | NS | 308.7 | 291.8 | 299.7 | NS | 512.7 | 40 |
| *Eriogonum heracleoides* | 55.2 | 71.6 | 49.0 | NS | 252.3 | 316.8 | 266.4 | NS | 153.8 | 19 |
| *Dalea searlsiae* | 262.7 | 231.2 | 196.3 | 50.1 | 175.5 | 288.8 | 303.0 | 93.6 | 219.1 | 26 |
| *Dalea ornata* | 451.9 | 410.8 | 351.7 | NS | 145.1 | 365.1 | 431.4 | 189.3 | 298.5 | 38 |
| *Astragalus filipes* | 87.0 | 98.4 | 74.0 | NS | 22.7 | 12.6 | 16.1 | NS | 87.0 | 9 |
| *Lomatium nudicaule* | | | | | 53.8 | 123.8 | 61.1 | NS | | |
| *Cleome serrulata* | 446.5 | 499.3 | 593.6 | 100.9[b] | 184.3 | 162.9 | 194.7 | NS | 154.5 | 19 |
| *Cleome lutea* | | | | | 111.7 | 83.7 | 111.4 | NS | | |

[b]LSD (0.10)

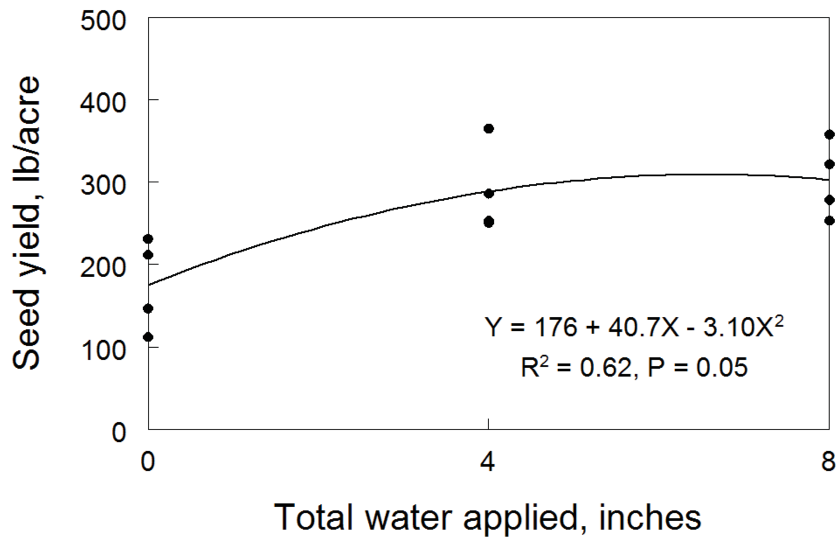



**Figure 13.** *Dalea searlsiae* seed yield response to irrigation water applied in 2012. Malheur Experiment Station, Oregon State University, Ontario, OR.

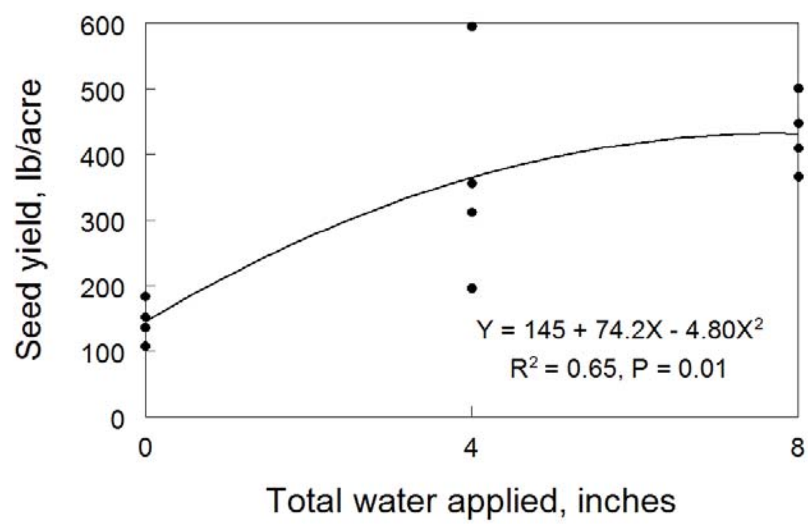



**Figure 14.** *Dalea ornata* seed yield response to irrigation water applied in 2012. Malheur Experiment Station, Oregon State University, Ontario, OR.

## C. Direct Surface Seeding Strategies for the Establishment of Two Native Legumes of the Intermountain West

### Project Description

Legumes provide an important role for restored 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, especially for certain species. Rangeland legumes have been extremely difficult to establish.

In established native perennial seed 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. Seed of some legumes has a hard seed coat that slows germination. Scarification of the seed coat might improve water penetration and improve emergence. Fall planting is important for many native plant species because their seed requires a period of cold to break dormancy (vernalization). Loss of soil moisture, soil crusting, and bird damage are some detrimental factors hindering emergence of fall planted seed. Row cover can be a protective barrier against soil desiccation and bird damage. Seed treatment can protect the emerging seed from fungal pathogens that might cause seed decomposition or seedling damping off. This trial tested the effect of timing of planting (fall vs. spring), seed scarification, row cover, and seed treatment on germination of surface-planted seed of two legume species, Blue Mountain prairie clover (*Dalea ornata*) and basalt milkvetch (*Astragalus filipes*), that are native to Malheur County and surrounding rangelands and for which stand establishment has been problematic.

Materials and Methods

Two selected germplasms of Blue Mountain prairie clover, Majestic and Spectrum, and one selected germplasm of basalt milkvetch, NBR-1, were included in the stand establishment trials. One seed lot of each of these three plant materials was scarified by immersion for 5 min in 98 percent sulfuric acid. After scarification, seed packets of each seed lot were prepared with 120 seeds per packet. Half of the seed from each scarified and non-scarified packet was treated briefly with a liquid mix of the fungicides Allegiance (metalaxyl) and Captan (100 g Allegiance, 100 g Captan in 1 liter of water) then dried. The seed packets were assigned to one of six treatments (Tables 1-3). Seed was planted manually on November 11, 2011 and again on February 28, 2012. Immediately before the spring 2012 planting, a manual clodbuster was run over the surface of the beds to break the crust formed over the winter. The experimental design was a randomized complete block with four replications. Plots were one 30-inch-wide by 5-ft-long bed. Each plot had 120 seeds planted in 5 feet of two rows on the bed.

After planting, some of the beds were covered with row cover. The row cover (N-sulate, DeWitt Co., Inc., Sikeston, MO) covered four rows (two beds) and was applied with a mechanical plastic mulch layer.

On March 12, 2012, the row cover was removed and emergence counts were made in each plot. Emergence counts were again taken on March 22, April 2, April 12, April 24, and May 8, 2012.

The row cover for the fall-planted seed was replaced after the March 12 count. The row cover for the spring planted seed was replaced after the March 12 and March 22 counts.

Tetrazolium tests were conducted to determine seed viability of each species. Seed viability was 89 percent for unscarified and 91percent for scarified *Dalea ornata* (Spectrum germplasm, 2010), 88 percent for unscarified and 92 percent for scarified *Dalea ornata* (Majestic germplasm, 2009), and 97 percent for unscarified and 95 percent for scarified *Astragalus filipes* (Lot No. NBR-1 2010). The tetrazolium results were used to correct the emergence data to emergence of viable seed.

Data were analyzed using analyses 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).

## Results and Discussion

The winter of 2011/2012 at the Malheur Experiment Station had no snowfall compared to the 68-year winter (October to March) average of 18 inches. Snow cover may reduce fluctuations in temperature and moisture and thus may be an important factor in vernalization of surface planted seed. Precipitation from October 2011 through March 2012 (6.1 inches) was close to the 68-year average of 6.4 inches.

### *Dalea ornata*

Emergence and stand for both *D. ornata* selected germplasms was very poor for the fall-planted seed for all treatments (Tables 1 and 2). There were no statistically significant differences in stand between treatments for the fall-planted seed. Emergence and stand for the spring-planted seed was significantly better than for the fall-planted seed, but was nevertheless poor. The highest stand for the spring-planted seed was achieved with row cover and scarified seed with no fungicide (24% for Spectrum and 34.7% for Majestic). For the spring-planted seed, row cover resulted in significantly higher stand than uncovered seed for both germplasms. Scarified seed resulted in significantly higher stand than non-scarified seed for both germplasms. Seed treatment resulted in lower stand than untreated seed for both germplasms.

### *Astragalus filipes*

Fall planting resulted in higher stand than spring planting (Table 3). Emergence and stand for the fall planted seed was nevertheless poor. The highest stand for the fall-planted seed was achieved with row cover and scarified, untreated seed (36.2%). For the fall-planted seed, row cover resulted in significantly higher stand than uncovered seed. Scarified seed resulted in significantly higher stand than non-scarified seed. Seed treatment resulted in lower stand than untreated seed.

## Conclusions

Stand survivability was very poor for both species. By May 8, 2012 stand was 10% or less for all treatments and both germplasms of *D. ornata* and 12% or less for all treatments of *A. filipes*.

**Table 1.** Stand of *Dalea ornata* (Majestic selected germplasm) in response to timing of planting and three treatments. Oregon State University, Malheur Experiment Station, Ontario, OR. Stand counts were based on live plants as a percent of live seed planted.

| Timing | Row cover | Scarification | Seed treatment | 12-Mar | 22-Mar | 2-Apr | 12-Apr | 24-Apr | 8-May |
|---|---|---|---|---|---|---|---|---|---|
| | | | | ----------------------------- | % stand | | | ------------------------- | |
| Fall 2011 | no | no | no | 0.00 | 0.24 | 0.24 | 0.00 | 0.00 | 0.00 |
| | no | no | yes | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | no | avg | | 0.00 | 0.12 | 0.12 | 0.00 | 0.00 | 0.00 |
| | no | yes | no | 0.00 | 0.00 | 0.00 | 0.23 | 0.00 | 0.00 |
| | no | yes | yes | 0.00 | 0.00 | 0.23 | 0.45 | 0.00 | 0.00 |
| | no | avg | | 0.00 | 0.00 | 0.11 | 0.34 | 0.00 | 0.00 |
| | avg | | | 0.00 | 0.06 | 0.12 | 0.17 | 0.00 | 0.00 |
| | yes | no | no | 3.31 | 0.00 | 0.95 | 0.71 | 0.00 | 0.47 |
| | yes | no | yes | 2.37 | 0.24 | 0.47 | 1.89 | 0.00 | 0.24 |
| | yes | avg | | 2.84 | 0.12 | 0.71 | 1.30 | 0.00 | 0.36 |
| | yes | yes | no | 1.81 | 0.91 | 0.91 | 0.91 | 0.00 | 0.00 |
| | yes | yes | yes | 4.08 | 1.59 | 1.59 | 0.68 | 0.23 | 0.23 |
| | yes | avg | | 2.94 | 1.25 | 1.25 | 0.79 | 0.11 | 0.11 |
| | avg | | | 2.89 | 0.68 | 0.98 | 1.05 | 0.06 | 0.23 |
| avg | | | | 1.45 | 0.37 | 0.55 | 0.61 | 0.03 | 0.12 |
| Spring 2012 | no | no | no | 0.00 | 0.00 | 0.71 | 0.24 | 0.47 | 0.00 |
| | no | no | yes | 0.00 | 0.00 | 0.00 | 0.47 | 1.18 | 0.00 |
| | no | avg | | 0.00 | 0.00 | 0.36 | 0.36 | 0.83 | 0.00 |
| | no | yes | no | 0.00 | 1.59 | 8.38 | 12.23 | 3.85 | 3.17 |
| | no | yes | yes | 0.00 | 0.00 | 1.13 | 6.57 | 3.17 | 2.72 |
| | no | avg | | 0.00 | 0.79 | 4.76 | 9.40 | 3.51 | 2.94 |
| | avg | | | 0.00 | 0.40 | 2.56 | 4.88 | 2.17 | 1.47 |
| | yes | no | no | 0.00 | 2.60 | 3.08 | 3.79 | 2.84 | 0.24 |
| | yes | no | yes | 0.00 | 0.24 | 0.24 | 0.24 | 0.00 | 0.24 |
| | yes | avg | | 0.00 | 1.42 | 1.66 | 2.01 | 1.42 | 0.24 |
| | yes | yes | no | 0.00 | 33.97 | 34.65 | 22.87 | 17.66 | 5.89 |
| | yes | yes | yes | 0.00 | 2.94 | 7.02 | 14.49 | 0.45 | 0.23 |
| | yes | avg | | 0.00 | 18.46 | 20.83 | 18.68 | 9.06 | 3.06 |
| | avg | | | 0.00 | 9.94 | 11.25 | 10.35 | 5.24 | 1.65 |
| avg | | | | 0.00 | 5.17 | 6.90 | 7.61 | 3.70 | 1.56 |
| LSD (0.05) | | | | | | | | | |
| Species x timing | | | | 2.92 | 2.55 | 2.48 | 2.02 | 2.21 | 1.27 |
| Species x timing x row cover | | | | 4.13 | 3.60 | 3.51 | 2.86 | 3.13 | NS |
| Species x timing x row cover x scarification | | | | 1.49 | 3.85 | 4.19 | NS | 2.81 | NS |
| Species x timing x row cover x scarif. x seed treatment | | | | 4.71 | 7.98 | 5.41 | NS | 2.38 | NS |

**Table 2.** Stand of *Dalea ornata* (Spectrum selected germplasm) in response to timing of planting and three treatments. Oregon State University, Malheur Experiment Station, Ontario, OR. Stand counts were based on live plants as a percent of live seed planted.

| Timing | Row cover | Scarification | Seed treatment | 12-Mar | 22-Mar | 2-Apr | 12-Apr | 24-Apr | 8-May |
|---|---|---|---|---|---|---|---|---|---|
| | | | | % stand | | | | | |
| Fall 2011 | no | no | no | 0.00 | 0.00 | 0.00 | 0.23 | 0.23 | 0.00 |
| | no | no | yes | 0.00 | 0.00 | 0.00 | 0.47 | 0.00 | 0.00 |
| | no | avg | | 0.00 | 0.00 | 0.00 | 0.35 | 0.12 | 0.00 |
| | no | yes | no | 0.00 | 0.23 | 0.00 | 0.23 | 0.00 | 0.00 |
| | no | yes | yes | 0.00 | 0.00 | 0.00 | 0.23 | 0.00 | 0.00 |
| | no | avg | | 0.00 | 0.11 | 0.00 | 0.23 | 0.00 | 0.00 |
| | avg | | | 0.00 | 0.06 | 0.00 | 0.29 | 0.06 | 0.00 |
| | yes | no | no | 3.75 | 0.23 | 2.81 | 1.87 | 0.23 | 0.70 |
| | yes | no | yes | 3.51 | 0.70 | 2.57 | 4.45 | 2.11 | 2.34 |
| | yes | avg | | 3.63 | 0.47 | 2.69 | 3.16 | 1.17 | 1.52 |
| | yes | yes | no | 3.21 | 0.69 | 1.14 | 1.37 | 0.23 | 0.23 |
| | yes | yes | yes | 4.35 | 0.23 | 1.14 | 1.37 | 0.00 | 0.00 |
| | yes | avg | | 3.78 | 0.46 | 1.14 | 1.37 | 0.11 | 0.11 |
| | avg | | | 3.70 | 0.46 | 1.92 | 2.27 | 0.64 | 0.82 |
| avg | | | | 1.85 | 0.26 | 0.96 | 1.28 | 0.35 | 0.41 |
| Spring 2012 | no | no | no | 0.00 | 0.00 | 0.47 | 2.57 | 1.17 | 0.23 |
| | no | no | yes | 0.00 | 0.00 | 0.00 | 0.47 | 0.70 | 0.23 |
| | no | avg | | 0.00 | 0.00 | 0.23 | 1.52 | 0.94 | 0.23 |
| | no | yes | no | 0.00 | 0.00 | 2.98 | 6.87 | 5.95 | 2.29 |
| | no | yes | yes | 0.00 | 0.00 | 0.00 | 0.23 | 0.00 | 0.69 |
| | no | avg | | 0.00 | 0.00 | 1.49 | 3.55 | 2.98 | 1.49 |
| | avg | | | 0.00 | 0.00 | 0.86 | 2.54 | 1.96 | 0.86 |
| | yes | no | no | 0.00 | 2.11 | 0.94 | 2.11 | 1.87 | 0.47 |
| | yes | no | yes | 0.00 | 0.00 | 1.40 | 3.51 | 0.94 | 0.47 |
| | yes | avg | | 0.00 | 1.05 | 1.17 | 2.81 | 1.40 | 0.47 |
| | yes | yes | no | 0.00 | 16.48 | 24.04 | 16.94 | 11.68 | 3.89 |
| | yes | yes | yes | 0.00 | 0.00 | 2.75 | 4.35 | 1.60 | 1.14 |
| | yes | avg | | 0.00 | 8.24 | 13.39 | 10.65 | 6.64 | 2.52 |
| | avg | | | 0.00 | 4.65 | 7.28 | 6.73 | 4.02 | 1.49 |
| avg | | | | 0.00 | 2.32 | 4.07 | 4.63 | 2.99 | 1.18 |
| LSD (0.05) | | | | | | | | | |
| Species x timing | | | | 2.92 | 2.55 | 2.48 | 2.02 | 2.21 | 1.27 |
| Species x timing x row cover | | | | 4.13 | 3.60 | 3.51 | 2.86 | 3.13 | NS |
| Species x timing x row cover x scarification | | | | 1.49 | 3.85 | 4.19 | NS | 2.81 | NS |
| Species x timing x row cover x scarif. x seed treatment | | | | 4.71 | 7.98 | 5.41 | NS | 2.38 | NS |

**Table 3.** Stand of *Astragalus filipes* (NBR-1 selected germplasm) in response to timing of planting and three treatments. Oregon State University, Malheur Experiment Station, Ontario, OR. Stand counts were based on live plants as a percent of live seed planted.

| Timing | Row cover | Scarification | Seed treatment | 12-Mar | 22-Mar | 2-Apr | 12-Apr | 24-Apr | 8-May |
|---|---|---|---|---|---|---|---|---|---|
| | | | | ----------- | ----------- | ----------- | % stand | ----------- | ----------- |
| Fall 2011 | no | no | no | 0.00 | 0.43 | 0.00 | 0.64 | 0.64 | 0.64 |
| | no | no | yes | 0.00 | 0.21 | 0.21 | 0.43 | 0.00 | 0.21 |
| | no | avg | | 0.00 | 0.32 | 0.11 | 0.54 | 0.32 | 0.43 |
| | no | yes | no | 0.00 | 4.17 | 1.10 | 2.41 | 3.07 | 2.41 |
| | no | yes | yes | 0.44 | 3.51 | 0.22 | 2.41 | 2.19 | 0.66 |
| | no | avg | | 0.22 | 3.84 | 0.66 | 2.41 | 2.63 | 1.54 |
| | avg | | | 0.11 | 2.08 | 0.38 | 1.47 | 1.48 | 0.98 |
| | yes | no | no | 13.75 | 12.03 | 9.24 | 8.81 | 4.30 | 4.08 |
| | yes | no | yes | 5.58 | 8.38 | 2.36 | 4.08 | 2.36 | 0.43 |
| | yes | avg | | 9.66 | 10.20 | 5.80 | 6.44 | 3.33 | 2.26 |
| | yes | yes | no | 29.82 | 36.18 | 28.29 | 24.78 | 17.54 | 11.40 |
| | yes | yes | yes | 14.91 | 14.91 | 8.99 | 8.99 | 5.04 | 5.04 |
| | yes | avg | | 22.37 | 25.55 | 18.64 | 16.89 | 11.29 | 8.22 |
| | avg | | | 16.02 | 17.88 | 12.22 | 11.66 | 7.31 | 5.24 |
| avg | | | | 8.06 | 9.98 | 6.30 | 6.57 | 4.39 | 3.11 |
| Spring 2012 | no | no | no | 0.00 | 0.00 | 0.00 | 0.43 | 0.64 | 0.00 |
| | no | no | yes | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | no | avg | | 0.00 | 0.00 | 0.00 | 0.21 | 0.32 | 0.00 |
| | no | yes | no | 0.00 | 0.00 | 0.00 | 0.44 | 0.22 | 1.10 |
| | no | yes | yes | 0.00 | 0.00 | 0.00 | 0.44 | 0.88 | 0.88 |
| | no | avg | | 0.00 | 0.00 | 0.00 | 0.44 | 0.55 | 0.99 |
| | avg | | | 0.00 | 0.00 | 0.00 | 0.33 | 0.44 | 0.49 |
| | yes | no | no | 0.00 | 0.00 | 0.21 | 2.58 | 1.72 | 1.07 |
| | yes | no | yes | 0.00 | 0.21 | 0.00 | 0.86 | 0.21 | 0.21 |
| | yes | avg | | 0.00 | 0.11 | 0.11 | 1.72 | 0.97 | 0.64 |
| | yes | yes | no | 0.00 | 1.32 | 4.82 | 14.25 | 3.07 | 2.85 |
| | yes | yes | yes | 0.00 | 0.22 | 1.32 | 3.29 | 0.44 | 0.66 |
| | yes | avg | | 0.00 | 0.77 | 3.07 | 8.77 | 1.75 | 1.75 |
| | avg | | | 0.00 | 0.44 | 1.59 | 5.25 | 1.36 | 1.20 |
| avg | | | | 0.00 | 0.22 | 0.79 | 2.79 | 0.90 | 0.85 |
| LSD (0.05) | | | | | | | | | |
| Species x timing | | | | 2.92 | 2.55 | 2.48 | 2.02 | 2.21 | 1.27 |
| Species x timing x row cover | | | | 4.13 | 3.60 | 3.51 | 2.86 | 3.13 | NS |
| Species x timing x row cover x scarification | | | | 1.49 | 3.85 | 4.19 | NS | 2.81 | NS |
| Species x timing x row cover x scarif. x seed treatment | | | | 4.71 | 7.98 | 5.41 | NS | 2.38 | NS |

## D. Five years of Tolerance of Sulphur-flower Buckwheat (*Eriogonum umbellatum*) to Rates and Mixtures of Postemergence Herbicides, 2008-2012

### Project Description

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 considerable 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 trial evaluated the tolerance of sulphur-flower buckwheat (*Eriogonum umbellatum*) to the herbicides Select® (clethodim), Prowl® (pendimethalin), and Outlook® (dimethenamid).

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 in native forb seed production.

<u>Materials and Methods</u>

The trial was 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 30-inch rows. The drip tapes were buried 5 ft apart in alternating inter-row spaces. 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.

In the fall of 2006, sulphur-flower buckwheat was planted in an area 10 ft wide and 220 ft long. The seeds were planted at 0.25 inch depth in 4 rows 30 inches apart. The field previously had been disked, ground hogged, and marked in rows 30 inches apart. A total of 4 drip irrigations applying 1 inch of water each were applied at 2-week intervals in 2007–2010. Drip irrigations were started when the flowering began. The trial was not irrigated in 2011.

On March 12, 2008; March 20, 2009; April 7, 2010; April 1, 2011; and April 10, 2012, thirteen 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 in a randomized complete block design with four replications.

Treatments were applied at 30 psi, 2.63 mph, and 20 gal/acre using 8002 nozzles with 6 nozzles spaced 20 inches apart. Seed was harvested at maturity from the middle two rows in each plot each year.

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

Treatment differences were compared using analysis of variance and protected least significant differences at the 95 percent confidence level, LSD (0.05), using NCSS Number Cruncher software (NCSS, Kaysville, UT).

Results and Discussion
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 sulphur-flower buckwheat in this trial 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 any year. 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 in 2008 and 2009 (Table 1). In 2010, Prowl at 1.43 lb ai/acre produced a higher seed yield than the check. In 2011, Prowl at 1.43 lb ai/acre and the mixture of Prowl at 1.19 lb ai/acre with Outlook at 0.84 lb ai/acre had a higher yield than the check. These herbicide treatments could have provided better weed control than the check, had the check not been kept weed free by hand weeding. In 2012, there were no significant differences in seed yield between the herbicide treatments and the untreated check.

Summary
Sulphur-flower buckwheat was tolerant to Prowl and Outlook applied as post-emergence treatments at the rate and timing and on the soils used in these trials. Prowl and Outlook are broad-spectrum, soil-active herbicides that prevent weed emergence during the growing 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 sulphur-flower buckwheat. Further tests are warranted to describe the range of safety for these herbicides and whether or not they have any undesirable interactions.

Seed yields in 2012 were low. The soil water started very low in April, which may have had a detrimental effect on the seed yield of all of the treatments.

**Table 1.** Seed yield (lb/acre) of sulphur-flower buckwheat (*Eriogonum umbellatum*) in response to repeated post-emergence herbicides applied on March 12, 2008; March 20, 2009; April 7, 2010; April 1, 2011; and April 10, 2012. Malheur Experiment Station, Oregon State University, Ontario, OR. Prowl and Outlook are soil active and Select is a foliar-contact grass herbicide.

| Treatment | Rate | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| | (lbs ai/acre) | | | ---------------- lb/acre ----------------- | | |
| Weed free, untreated control | | 276.5 | 430.0 | 622.6 | 346.2 | 89.5 |
| Select 2.0 EC[a] | 0.094 | 149.1 | 475.2 | 618.1 | 285.3 | 141.2 |
| Prowl | 0.95 | 387.2 | 440.8 | 549.7 | 406.9 | 120.9 |
| Prowl | 1.19 | 533.1 | 596.6 | 736.5 | 356.0 | 105.1 |
| Prowl | 1.43 | 250.6 | 596.4 | 988.8 | 502.3 | 105.9 |
| Outlook | 0.84 | 319.8 | 474.5 | 725.2 | 440.1 | 89.7 |
| Outlook | 0.98 | 143.5 | 501.4 | 627.4 | 251.7 | 137.1 |
| Prowl + Outlook | 0.95 + 0.66 | 300.9 | 555.5 | 795.5 | 357.0 | 154.9 |
| Prowl + Outlook | 0.95 + 0.84 | 440.0 | 763.8 | 861.3 | 464.0 | 61.2 |
| Prowl + Outlook | 0.95 + 0.98 | 330.9 | 569.1 | 614.8 | 436.0 | 59.8 |
| Prowl + Outlook | 1.19 + 0.66 | 244.0 | 699.8 | 618.5 | 433.7 | 129.7 |
| Prowl + Outlook | 1.19 + 0.84 | 336.7 | 556.0 | 592.2 | 513.6 | 57.9 |
| Prowl + Outlook | 1.19 + 0.98 | 285.6 | 506.2 | 684.3 | 367.0 | 126.3 |
| Average | | 307.5 | 551.2 | 695.0 | 396.9 | 106.1 |
| LSD (0.05) | | NS | NS | 241.7 | 149.5 | NS |

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

## Publications

Shock, C. C.; Feibert, E. B. G.; Parris, C.; Saunders, L. D.; Johnson, D.; Bushman, S.; Shaw, N. 2012. Evaluation of seed scarification for the establishment of three Intermountain West native legumes. In: Shock, C. C., ed. Malheur Experiment Station Annual Report 2011, Department of Crop and Soil Science Ext/CrS 141. Corvallis, OR: Oregon State University Agricultural Experiment Station. p. 136-138. http://www.cropinfo.net/AnnualReports/2011/ForbEmergenceLegumes2011.php

Shock, C. C.; Feibert, E. B. G.; Parris, C.; Saunders, L. D.; Shaw, N. 2012. Direct surface seeding strategies for establishment of Intermountain West native plants for seed production. In: Shock, C. C., ed. Malheur Experiment Station Annual Report 2011, Department of Crop and Soil Science Ext/CrS 141. Corvallis, OR: Oregon State University Agricultural Experiment Station. p. 130-135. http://www.cropinfo.net/AnnualReports/2011/Forbemergence2011.php

Shock, C. C., Feibert, E.B.G.; Saunders, L. D.; Shaw, N. 2012. Tolerance of sulphur-flower buckwheat (*Eriogonum umbellatum*) to rates and mixtures of postemergence herbicides, 2008-2011. In: Shock, C. C., ed. Malheur Experiment Station Annual Report 2011, Department of Crop and Soil Science Ext/CrS 141. Corvallis, OR: Oregon State University Agricultural Experiment Station. p. 171-173. http://www.cropinfo.net/AnnualReports/2011/ERUMProwlOutlook2011.php

Shock, C. C.; Feibert, E. B. G; Saunders, L. D.; Shaw, N.; Sampangi, R. S. 2012. Irrigation requirements for native wildflower seed production. In: Shock, C. C., ed. Malheur Experiment Station Annual Report 2011, Department of Crop and Soil Science Ext/CrS 141. Corvallis, OR: Oregon State University Agricultural Experiment Station. p. 139-160 http://www.cropinfo.net/AnnualReports/2011/ForbIrrigation2011.php

Shock, C. C.; Feibert, E. B. G.; Saunders, L. D.; Shaw, N.; Sampangi, R. S. 2012. Irrigation requirements for novel native wildflower seed production. In: Shock, C.C., ed. Malheur Experiment Station Annual Report 2011, Department of Crop and Soil Science Ext/CrS 141. Corvallis, OR: Oregon State University Agricultural Experiment Station. p. 161-170. http://www.cropinfo.net/AnnualReports/2011/ForbIrrigationNew2011.php

Shock, M. P.; Shock, C. C.; Feibert, E. B. G.; Parris, C. A.; Saunders, L. D.; Sampangi, R. K.; Shaw, N. L.; Welch, T. K. 2012. Fernleaf biscuitroot, *Lomatium dissectum* (LODI). Sustainable Agriculture Techniques. Ext/CrS 138. Corvallis, OR: Oregon State University, Department of Crop and Soil Science. 6 p. http://www.cropinfo.net/FernleafBiscuitroot.pdf

Shock, M. P.; Shock, C.C.; Feibert, E. G. B.; Shaw, N. L.; Saunders, L. D.; Sampangi, R. K. 2012. Cultivation and irrigation of fernleaf biscuitroot (*Lomatium dissectum*) for seed production. HortScience. 47: 1525-1528.

**Presentations**

Feibert, E.B.G.; Shock, C. C. 2012. Establishing plant stands. Native Plant Seed Production Field Day, Oregon State University, Malheur Experiment Station, 2012 May 16, Ontario, OR.

Sampangi, R. K.; Mohan, S. K.; Shock, C. C. 2012. Diagnosing abiotic disorders of native plants. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT.

Shock, C. C. 2012. Native plant irrigation for seed production. Native Plant Seed Production Field Day. Oregon State University, Malheur Experiment Station, 2012 May 16, Ontario, OR.

Shock, C. C. 2012. Wildflower and native plant seed production. Summer Farm Festival, Oregon State University, Malheur Experiment Station, 2012 July 11, Ontario, OR.

Shock, C. C.; Feibert, E. B. G.; Saunders, L. D.; Parris, C.; Shaw, N. L. 2012. Stand establishment of native forb species for seed production. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT.

Shock, C. C., Feibert, E. B. G.; Saunders, L. D.; Parris, C.; Shaw, N. L. 2012. Planting systems for improved stands of fall planted native perennials. American Society of Horticultural Science, 2012 July 31-August 3, Miami, FL.

Shock, C. C.; Feibert, E. B. G.; Saunders, L. D.; Sampangi, R. K.; Shaw, N. L. 2012. Irrigation requirements of native forb species for seed production. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22. Salt Lake City, UT.

Shock, C. C., Felix, J.; Saunders, L. D.; Doniger, A.; Ishida, J.; Shaw, N. 2012. Oregon 2011 report. W2128 Microirrigation for Sustainable Water Use, 2012 November 1-3, Orlando, FL.

Shock, C. C., Saunders, L. D.; Shaw, N. L.; Sampangi, R. S. 2012. Long term SDI for seed production of western rangeland native wildflowers. International Irrigation Show, 2012 November 4-6, Orlando, FL.

**Products**

- Seed produced from these planting was used to establish commercial seed production fields.
- A field tour for growers was conducted in May 2012.
- A tour of the seed production trials was incorporated into the annual Malheur Experiment Station Field Day activities in July of 2012.
- Five research reports on seed production of native perennials were published in the Annual Experiment Station Bulletin, one report was published in a peer-reviewed journal, and one extension bulletin was published.
- Continued improvement of the native plant database on the internet: http://www.malag.aes.oregonstate.edu/wildflowers/
- Three presentations were made at national meetings and three at regional meetings.

**Project Title** Stock Seed Production and Inventory of Native Plants for the Great Basin

**Project Agreement No.** 09-JV-11221632-268

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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 USDA Forest Service, Rocky Mountain Research Station, Boise, ID and the Utah Crop Improvement Association (UCIA), initiated in fall 2003 and renewed with additional funds in fall 2004 and fall 2007. A new joint venture agreement titled "Stock Seed Production of Native Plants for the Great Basin" was completed on 17 August 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.

A synopsis of the Stock Seed Buy-Back Program follows, applicable to the period 1 January-31 December 2012.

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 Great Basin Native Plant Selection and Increase Project (GBNPSIP), are 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, and a detailed procedure has been outlined in previous GBNPSIP reports.

In addition, some species germplasms are distributed to growers without specific agreements for stock seed buyback. In these cases, UCIA prints Source Identified certification tags from information provided by the germplasm developer on the UCIA Stock Materials Tagging Information Form (Appendix II). This legitimizes the seed transfer and the grower can enter the field for certification, whether the production is meant to have a buy-back contract written or not.

**Publications**

Young, S.; Bouck, M. 2012. Stock seed production of native plants for the Great Basin. In: Great Basin Native Plant Selection and Increase Project FY2011 Progress Report: 135-138. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2011_ProgressReport.pdf

**Presentations**

Young, S. 2012. GBNPSIP Germplasms: Successes in developing plant materials that are available in the marketplace. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012, February 21-22, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2012.shtml

**Management Applications and Seed Production Guidelines**

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, make the stock 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.

The seed market status of grasses and forbs that have been forwarded to growers under the auspices of the GBNPSIP for the periods 2002-2011 and updated for 2012 are summarized in Table 1. Grasses are easier to produce, and are generally used in greater quantities than forbs in reclamation plantings. The stock seed quantities in the table reflect this. Seed increase, stock seed, and commercial availability are detailed in Appendix III.

**Table 1.** Great Basin Native Plant Selection and Increase Project stock seed inventory and distribution, 2004-20

| Species/Crop | Variety/Germplasm ID | Class/ Generation | Lot # | 2004-2011 Distributed from inventory | 2 Add Inve |
|---|---|---|---|---|---|
| | | | | bulk lbs | bu |
| *Achillea millefolium* | Eagle ?? Germplasm | S G3 | ACMI2-RMRS-63-G3-ERSTROM-10 | | |
| *Achillea millefolium* | Eagle Germplasm | S G3 | RMRS-ACMI2-11 | 0.5 | |
| *Achillea millefolium* | Eagle Germplasm | S G2 | NWS-1-YAR-FDN | 12.0 | |
| *Achillea millefolium* | Eagle Germplasm | S G1 | NSW4-1-EMY1-1 | 6.5 | |
| *Achnatherum thurberianum* | Orchard Idaho Site | SI G1 | 2005.0394-1 | 13.0 | |
| *Achnatherum thurberianum* | Orchard Idaho Site | SI G1 | 2005.0394-2 | | |
| *Achnatherum thurberianum* | Orchard Idaho Site | SI G1 | 2005.0394-C | | |
| *Achnatherum thurberianum* | Orchard Idaho Site | SI G1 | 2007.0498 | 1.0 | |
| *Balsamorhiza hookeri* | BAHO B1 | SI G0 | BAHO B1-02 | 0.6 | |
| *Balsamorhiza hookeri* | BAHO B1 | SI G1 | 2009.0426 | | |
| *Elymus elymoides* | Little Sahara | SI/ G0 | Lot # CU-907 | | |
| *Elymus elymoides* | Toe Jam Creek Germplasm | S G4 | Lot # LHS1B2G-335 | 40.2 | |
| *Elymus elymoides* | Fish Creek Germplasm | S G3 | Lot # LHS1B2H-335 | 47.1 | |
| *Elymus elymoides* | Toe Jam Creek Germplasm | S G4 | Lot # LHS1B2J-337 | 127.5 | |
| *Elymus elymoides* | Fish Creek Germplasm | S G3 | Lot # LHS1B2K-337 | 113.5 | |
| *Eriogonum heracleoides* | NBR/SRP | SI G1 | BFI-10-10139687 | | |
| *Leymus cinereus* | UDWR Intermountain Tetra Germplasm | S/G2 | BFI-11-1159676 | | |
| *Lomatium dissectum* | NBR | SI/G1 | LODI TD-10 | 1.2 | |
| *Penstemon cyaneus* | PECY B6-02 | SI G1 | 2009-0570 | 6.1 | |
| *Penstemon cyaneus* | PECY B6-02 | SI G1 | 2004.0448 | 16.0 | |
| *Penstemon cyaneus* | PECY B6-02 | SI G2 | 2006.0413 | 5.0 | |
| *Penstemon cyaneus* | PECY B6-02 | SI G2 | PPI-04-1 | 3.0 | |
| *Penstemon deustus* | PEDE B11 Banks | SI G2 | CD-12-265 | | |
| *Penstemon pachyphyllus* | Pine Hollow Canyon | SI G1 | A5-4-P1 | 11.9 | |
| *Penstemon palmerii* | Cedar Variety | Foundation | CPP KL-05-3, GBRI 36 | | |
| *Penstemon palmerii* | Cedar Variety | Foundation | CPP KL-05-2, GBRI 26 | | |
| *Penstemon palmerii* | Cedar Variety | Foundation | CPP KL-05-1, GBRI 16 | 46.5 | |
| *Penstemon speciosus* | PESP-NBR-PO1-RMRS | SI | BFI-12-10178761 | | |
| *Poa secunda* | Mountain Home Germplasm | S/ G1 | NBS-RR8-MTH-1 | 514.0 | |
| *Poa secunda* | Mountain Home Germplasm | S/ G1 | NBS-RR9-MTH-1 | | |
| *Poa secunda* | Mountain Home Germplasm | SI G2 | 557-215-31A | 304.0 | |
| *Poa secunda* | Mountain Home Germplasm | SI G2 | 016-215-611A | 112.0 | |
| *Pseudoroegneria spicata* | Anatone Germplasm | SI G1 | JA-03, UCIA 44 | 300.0 | |
| *Sphaeralcea grossulariifolia* | SPGR-U63-2007 | ?? | SPGR2-U63-2007-2012 | | |
| *Sphaeralcea grossulariifolia* | CBR | SI G1 | GBGM-12 | | |
| *Sphaeralcea munroana* | NBR | SI G1 | MGM-12-B | | |
| *Sphlaeralcea parvifolia* | SPGR U14 | SI G1 | S04-2-4 | 5.0 | |

**Project Title** A Strategy for Maximizing Native Plant Material Diversity for Ecological Restoration, Germplasm Conservation and Genecology Research

**Project Agreement No.** 12-JV-11221632-044

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**Project Description**

This project is comprised of three distinct, but interrelated components: A. Use of the Provisional Seed Zone Map, B. Seed Collection, and C. Liaison Work with Seed Growers.

Selection of native plant materials that are ecologically appropriate and genetically diverse is a vital element of any restoration project. Adapted materials are essential for restoring healthy, self-sustaining ecosystems with the diversity required to provide resiliency in the face of climate change and other environmental perturbations (Johnson et al. 2010). Species-specific seed zones are used to select plant materials for restoration that are best adapted to current and projected future climatic and environmental conditions (St. Clair et al. 2005). Genecology research, including common garden and reciprocal transplant studies, has long been conducted in the United States and elsewhere to develop and refine species-specific seed zones for tree species. Common garden studies aim to correlate observed intraspecific genetic variation to source environments to suggest adaptive traits determined by natural selection (Johnson et al. 2004). Adaptive genetic variation is then mapped over the area of interest to delineate species-specific seed transfer zones.

Seed harvested from within a seed zone can be planted directly, increased in agricultural seed fields or propagated in a nursery to provide seed or plants for restoration projects. Collection from at least 50 widely separated plants in each of five or more populations within a seed zone is recommended to provide genetically diverse material (Johnson et al. 2010) for restoration. In addition, species-specific seed zone maps can be used to identify collection gaps for genecology studies and strategies for *in situ* and *ex situ* germplasm conservation.

*A. Use of the Provisional Seed Zone Map for Planning Seed Collection – Examples from the Great Basin*

Common garden studies for development of species-specific seed zones have only recently been initiated for grasses, forbs and shrubs (Erickson et al. 2004, Johnson et al. 2012). Because emphasis on the use of native species is increasing, the number of species utilized for restoration is large, and genecology studies are costly and time-consuming, surrogate tools are required for making decisions regarding seed source selections. Provisional seed zones are one tool that can be used when genetic research is lacking (Bower et al. 2010). These zones are based precipitation and temperature that are known to influence adaptation and plant distributions (Figure 1).

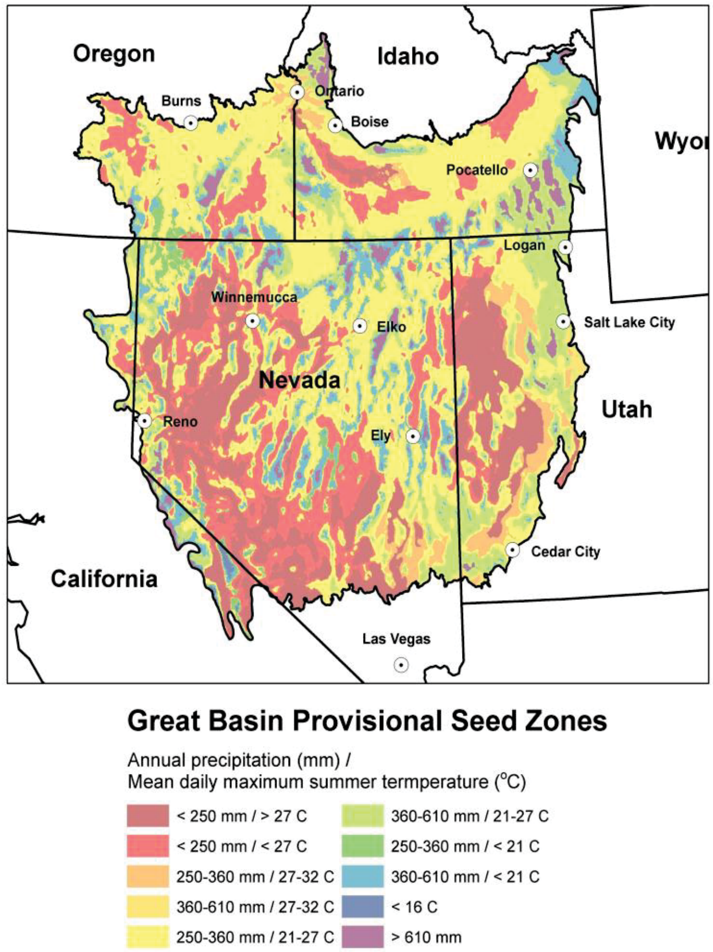


**Figure 1.** Great Basin provisional seed zone map (Bower et al. 2011). Seed zones were delineated using mean maximum daily growing season temperatures (April through September) and annual precipitation (PRISM, http://www.prismclimate.org) derived from climate normals for 1971-2000.

We selected three widespread native forbs that are candidates for restoration use in the Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) ecosystem of the northern Great Basin to illustrate the use of provisional seed zones. These were sharpleaf penstemon (*Penstemon acuminatus*), royal penstemon (*P. speciosus*) and Douglas'dustymaiden (*Chaenactis douglasii*).

Methods

Location data for each of the populations of sharpleaf penstemon, royal penstemon, and Douglas' dustymaiden was extracted from the Great Basin Native Plant Selection and Increase Project (GBNPSIP) database and plotted on the provisional seed zone map. These data consist of the GBNPSIP collection sites only and are not all known populations for the species (e.g., herbarium collections). Maps were examined to identify dominant seed zone(s) of our populations and delineate gaps where additional seed collection is needed.

## Results

*Sharpleaf penstemon*: Populations (n=37) are largely restricted to sandy and sandy loam soils in two provisional seed zones (< 250 mm/< 27$^{o}$C and < 250 mm/> 27$^{o}$C; Figure 2). Northern populations in each zone are adequate in number and distribution to provide seed collections that can be pooled to prepare restoration plant materials. Northern populations can also be selected for *in situ* or *ex situ* conservation or for common garden studies. Although the species is not known from Utah, it is widely distributed in Nevada (USDA-NRCS 2012) where currently identified sites are confined to locations along a single highway corridor. Further reconnaissance and collection in Nevada may be facilitated by use of the provisional seed zone map combined with examination of floras, herbarium databases, soil surveys, ecological site descriptions, and consultation with local authorities.

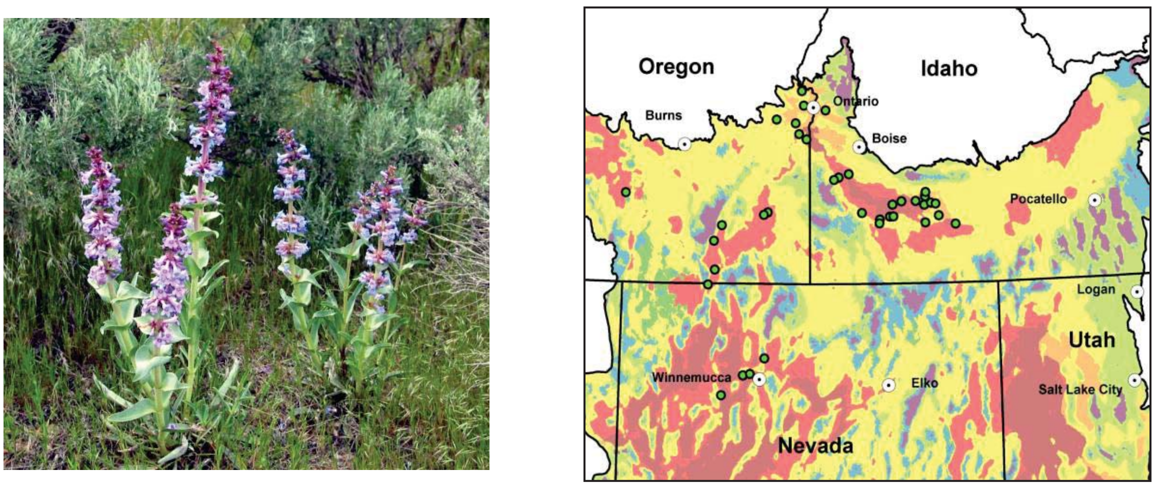


**Figure 2.** Sharpleaf penstemon plant and collections sites (green points) in the Great Basin.

*Royal penstemon*: Populations are widespread within the Wyoming big sagebrush ecosystem. They are located primarily within the 250-370 mm/21-27$^{o}$C seed zone on loam to fine sandy loam soils (Figure 3).

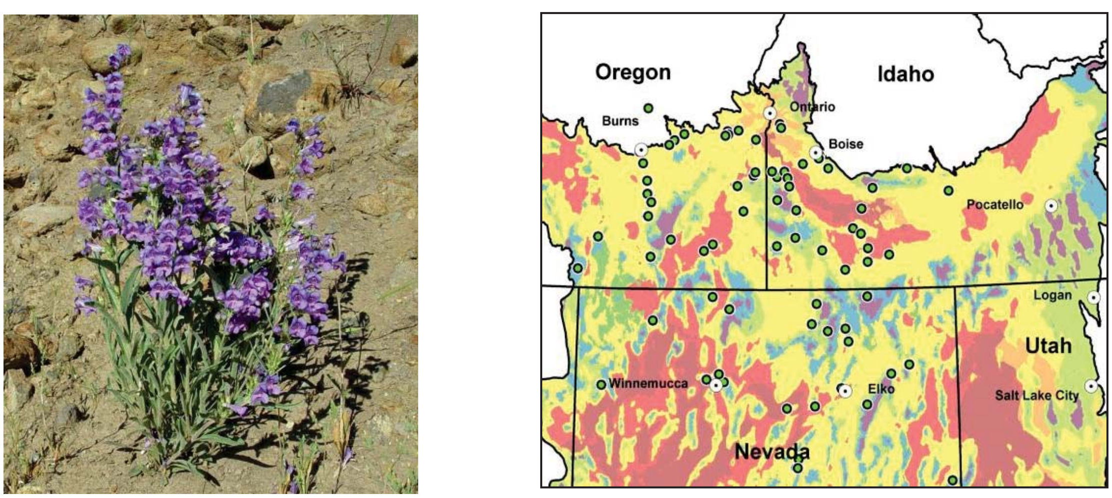


**Figure 3.** Royal penstemon plant and collection sites (green points) in the Great Basin.

Known collection sites may be selected for *in situ* or *ex situ* germplasm conservation. However, because the species occurs over a large area and several seed zones, identification of additional populations is desirable to provide a better distribution of populations if accessions are to be pooled to prepare restoration plant materials. A larger number of populations from the Wyoming big sagebrush ecosystem plus populations from higher elevation plant communities where the species also occurs would be essential for genecological research to develop a species-specific seed zone map for the Great Basin.

*Douglas' dustymaiden*: This species occurs widely across the Great Basin on dry, sandy, gravelly, and rocky sites and on recent disturbances in communities ranging from salt desert shrublands on basin floors to alpine ridges (Morefield 2006; Figure 4). Collection efforts were only recently initiated and focused on the Wyoming big sagebrush ecosystem. Site descriptions for known populations, the provisional seed zone map, and other available resources should be consulted to guide future surveys. Because of the species' wide distribution, areas where the species is most abundant and restoration needs greatest should be defined and targeted for development of restoration seed sources.

Unlike the two penstemon species, Douglas' dustymaiden includes overlapping subspecific taxa, Douglas' dustymaiden (*C. d. douglasii*) and alpine dustymaiden (*C. d. alpina*) (Morefield 2006). Furthermore, some polyploid populations have been found at lower elevations of the species' range and on Pleistocene disturbances (Mooring 1980). These factors impose additional restrictions on seed transfer.


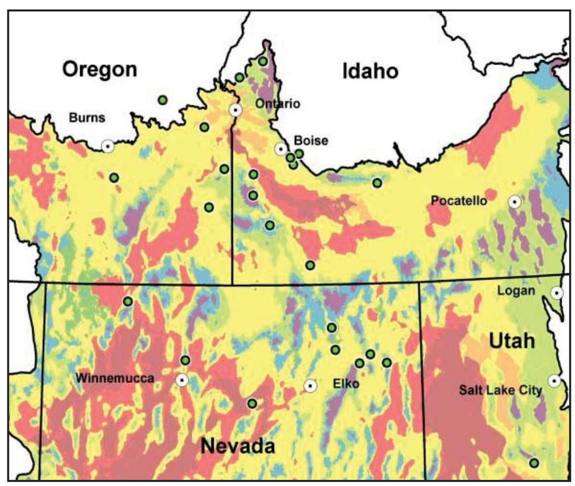


**Figure 4.** Douglas' dustymaiden plant and collection sites (green points) in the Great Basin.

*B. Seed Collection*
<u>Methods</u>
Prioritization of seed collection effort was determined based on identified gaps and on needs and considerations by GBNPSIP scientists, including:

a) Common garden studies and germplasm conservation:
   What is the relationship of current collections to the distribution of the species?
b) Seed increase or immediate use in restoration:

Are restoration materials needed for a specific seed zone?

- If materials are needed, what are the past, ongoing, or anticipated disturbances in this seed zone and what local species are appropriate for restoring them? Consider life forms, functional traits, etc.
- If few or no collections of a species have been located within a seed zone, does the distribution map or do other resources indicate that the species is abundant in that seed zone? Are there other species that are more abundant that would fill the same niche in restoration seeding?

How many collections do we need from a seed zone?

- Geneticists recommend pooling seeds from at least 5 and preferably up to 20 populations within each seed zone to provide the genetic variation required to meet future environmental challenges (Johnson et al. 2004, 2010). This also minimizes the risk of inbreeding or outbreeding depression as planted genotypes will be from the same zone as local vegetation near the planting site.

How do we pool our populations for initial increase needs?

- Consider pooling or subdividing collections from within a single seed zone or combining collections from more than one zone.
    - Consider characteristics of the seed zone—geographic extent, weather pattern variation, geology, and soils.
    - Consider the species biology—gene flow, breeding system, seed dispersal, generation time.

Consider climate change—is there a need to add populations, for example material from an adjoining warmer zone that will pre-adapt restoration materials to changing conditions?

<u>Results</u>

Fifteen seed lots from ten target species for GBNPSIP 2012 collecting were harvested by Eastern Oregon Stewardship Services (EOSS) (Tables 1 and 2) for scientists collaborating in the GBNPSIP and delivered to the USFS Rocky Mountain Research Station Laboratory in Boise, ID.

*C. Liaison Work with Seed Growers*

I visited three native seed farms in the Columbia Basin of Washington in May 2012 and evaluated the seed production status of forb seed production fields of hoary aster (*Machaeranthera canescens*), royal penstemon (*Penstemon speciosus*), basalt milkvetch (*Astragalus filipes*), parsnipflower buckwheat (*Eriogonum heracleiodes*), sulfur-flower buckwheat (*Eriogonum umbellatum*), Douglas' dustymaiden (C*haenactis douglasii*), Blue Mountain prairie clover (*Dalea ornata*), and Lewis flax (*Linum lewisii*). Growers were concerned about finding markets for the forb species they were already growing. After the current year BLM seed buy list with its greater variety of forb species than in previous years was released, growers were much more interested in continuing to experiment with and grow native forbs.

**Table 1.** Forb species collected in 2012 for use by Great Basin Native Plant Selection and Increase Project collaborators.

| Scientific name | Common name |
|---|---|
| *Chaenactis douglasii* | Douglas' dustymaiden |
| *Lomatium dissectum* | Fernleaf biscuitroot |
| *Lomatium nudicaule* | Barestem lomatium |
| *Lomatium triternatum* | Nineleaf biscuitroot |
| *Machaeranthera canescens* | Hoary tansyaster |
| *Mentzelia laevicaulis* | Smoothstem blazing star |
| *Penstemon acuminatus* | Sharpleaf penstemon |
| *Phacelia hastate* | Silverleaf phacelia |
| *Phacelia heterophylla* | Varileaf phacelia |
| *Phacelia linearis* | Threadleaf phacelia |

**Table 2.** Bulk seed lots collected in southeastern Oregon during the 2012 field season for Great Basin Native Plant Selection and Increase Project.

| EOSS site number | Collection location and county | Collection date | No. plants |
|---|---|---|---|
| CHDO1BY12S | Owyhee Dam Road, Malheur Co. | 6/28/12 | 75 |
| CHDO1BY09 | Castle Rock, Malheur Co. | 7/20/12 | 1000 |
| LODI1BY12S | Sag Road, Halfway, Baker Co. | 7/13/12 | 75 |
| LONU2BY08 | Castle Rock, Malheur Co. | 7/1/12 | 75 |
| LOTR39 | Castle Rock, Malheur Co. | 7/1/12 | 100 |
| MACA1BY12S | Juniper Gulch, Juntura, Malheur Co. | 10/11/12 | 800 |
| MACA2BY12S | Brogan Hill, Malheur Co. | 10/12/12 | 300 |
| MELA1BY12S | Brogan Hill, Malheur Co. | 9/15/12 | 50 |
| MELA2BY12S | Juniper Gulch, Juntura, Malheur Co. | 9/27/12 | 50 |
| PEAC1BY12S | Halliday Road, Malheur Co. | 6/30/12 | 20 |
| PEAC11 | Keeney Pass, Malheur Co. | 6/30/12 | 75 |
| PHHA1BY10 | Owyhee Dam Road, Malheur Co. | 6/28/12 | 75 |
| PHHE1BY12S | Brogan Hill, Malheur Co. | 6/30/12 | 50 |
| PHHE2BY12S | Ranch out of Ironside, Malheur Co. | 6/30/12 | 150 |
| PHLI2BY10 | Owyhee Dam Road, Malheur Co. | 6/8/12 | 75 |

Conclusions

The Great Basin provisional seed zone map provides a valuable decision support tool that can aid in making germplasm collection and conservation decisions when genetic research is lacking. Local knowledge of physiography and plant ecology can be used to adjust provisional seed zone boundaries. Knowledge of a species' biology and edaphic and biotic factors influencing its distribution should direct surveys and deployment of restoration material within each zone.

Most restoration species do not occur in all seed zones. In addition, the scale of restoration occurring in each zone varies. Thus, it may be possible to limit initial survey efforts to priority areas and zones to expedite development of urgently needed plant materials.

Provisional seed zone maps for the United States and completed species-specific seed zone maps and associated literature are available on the USDA Forest Service Western Wildlands Environmental Threat Assessment Center Seed Mapper website: http://www.fs.fed.us/wwetac/threat_map/SeedZones_Intro.html. Mapping applications are available in formats ranging from geobrowser to ArcGIS ArcMap to facilitate user applications

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**Publications**

Youtie, B.; Shaw, N.; Fisk, M.; Jensen, S. [Submitted]. Strategy for maximizing native plant material diversity for restoration and genecology research. SER Europe Knowledge Base on Ecological Restoration in Europe.

**Presentations**

Youtie, B. 2012. Coordination of GBNPSIP plant materials development, seed increase and use 2011. Great Basin Native Plant Selection and Increase Project Annual Meeting. 2012 February 21-22, Salt Lake City, UT.

Youtie, B.; Shaw, N.; Fisk, M.; Jensen, S. 2012. A strategy for maximizing native plant material diversity for restoration and genecology research. 8th European Conference on Ecological Restoration. 2012 September 9-14, Ceske Budejovice, Czech Republic. Poster.

**Management Applications and Seed Production Guidelines**

Increased communications 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. USFS preliminary seed zone maps for the Great Basin are used for developing seed accessions for on-the-ground restoration.

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

**Project No.** 08-JV-11221632-226

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**Project Description**

Seed harvesting has become an important part of restoration on public lands and increasing seed production of native wildland shrub populations would be beneficial for this effort. 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 (*Artemisia tridentata* ssp. *wyomingensis*). The specific objective of this research is to determine if treated native stands of Wyoming big sagebrush can increase seed yield over natural stands of sagebrush. Removal of competition between shrubs has been the best application for increasing seed yield. Therefore the objectives of this research are: 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 increasing seed production. 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.

Two sites were chosen for this study based on area ($\geq$ 20 ha or 50 acres), sagebrush stand uniformity, and sagebrush density. Both sites are in Utah. The first site is approximately 16 km (10 mi) south of Scipio along the I-15 corridor. The second site is found approximately 16 km southeast at the main entrance to the Little Sahara Recreation Area. Treatments in this study are: 1- Control (natural stand undisturbed); 2- General mechanical thinning (Figure 1); 3- Mechanical kill in 3.05-m (10-ft) strips; 4- General chemical thinning; and 5- Chemical kill in 3.05-m strips (Figure 2). All treatments were established during summer 2010. See Table 1 for details. Control areas were left untouched.

**Figure 1**. Mechanical thin where the Dixie Harrow was dragged once- over the stand to reduce shrub density.

**Figure 2**. Chemical kill application. Note the variation of live foliage to the dead area where the chemical has been applied.

Based on one year of data, we saw an improvement in seed yield through the use of general mechanical strip thinning at one location. The same results did not occur at the second location where there were no differences among the treatments.

**Table 1**. Wyoming big sagebrush stand treatments at applied in summer 2010 near Scipio and the Little Sahara Recreation Area, Utah.

| Treatment | Procedure | Chemical Application Rate | Adjuvant Oil Added |
|---|---|---|---|
| Control | Untreated | N/A | N/A |
| General mechanical thinning | Dixie harrow pulled once across plot 46 m x 213 m (150 ft x 700 ft) area to thin the shrubs. | N/A | N/A |
| Mechanical kill strips | Dixie harrow pulled across 3.05-m (10-ft) strips three times in opposite successive passes. | N/A | N/A |
| Chemical | 2,4-D applied foliarly to thin the stand. | 2-4D at 10 liters/ha in 275L of water/ha | N/A |
| Chemical | 2,4-D applied to 3.05-m (10-ft) strips. Adjuvant oil added to increase kill. | 2-4D at 10 liters/ha in 275L of water/ha | Surfactant at 0.8 liters/ha |

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## Presentations

Elder, K.; Geary, B.; Anderson, V.; Nicholson, J.; Fugal, R.; Nordin, A. 2012. Increasing seed yield in big sagebrush by mechanical and chemical treatments. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT.

## Management Implications

Seed production will need to be monitored for several years in order to determine the true effects of the treatments. In treatment areas, the increase in cheatgrass was obvious and is a concern because of the increased fire potential.

## Products

- Research locations are open as demonstration sites, and these locations will be monitored for several years to determine treatment effects on long-term seed production.

**Project Title** Managing Pests of Native Plant Seed Production

**Project Agreement No.** 10-CR-11221632-070

**Principal Investigators and Contact Information**

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**Project Description**

Seed-feeding insects impacting globemallow seed production

Weevils (*Anthonomus sphaeralciae* Fall [Coleoptera: Curculionidae]), which attack flowers and developing seeds, can significantly impact globemallow (*Sphaeralcea* spp. A. St.-Hil. [Malvaceae]) seed production without a grower even noticing there was insect damage. This weevil damaged almost one-quarter of the flowers in a seed production field in Delta County, Colorado, during 2007 (Hammon and Franklin 2012a).

Some insects affecting penstemon seed production

Beardtongue (*Penstemon* spp. Schmidel [Scrophulariaceae]) seeds are often produced without apparent damage from pests, but several species of native insects can adversely impact seed production fields. Tarnished plant bug (*Lygus lineolaris* Palisot) and western plant bug (*Lygus hesperus* Knight [Hemiptera: Miridae]), penstemon weevil (*Hesperobaris* sp. Casey [Coleoptera: Curculionidae]), penstemon clearwing moth (*Penstemonia* spp. [Lepidoptera: Sesiidae)), and ebony bug (*Corimelaena extenso* Uhler [Hemiptera: Thyreocoridae]) have all been recorded as pests in penstemon seed production fields in the western U.S. (Hammon and Franklin 2012b).

**Publications**

Hammon, R.; Franklin, M. 2012a. Seed-feeding insects impacting globemallow seed production. Native Plants Journal 13: 95-97.

Hammon, R.; Franklin, M. 2012b. Some insects affecting Penstemon seed production. Native Plants Journal 13: 107-111.

**Project Title** Native Annual Species for Retail Nurseries and Landscaping

**Project Agreement No.** 11-CR-11221632-008

**Principal Investigators and Contact Information**

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**Project Description**

Introduction

A common problem for sellers of native plants to the public is that many native plants are not looking their best at the time of sale, making them less desirable for purchase. Annual flowers are one of the most valuable aspects of a retail nursery or garden center because they provide instant color and stimulate impulse purchases by consumers. A strategy for retail nurseries to increase the sale of native plants for landscaping is to include native annual flowers in their inventory. They can market native annual flowers to the public by citing the following facts:

- Native annuals provide quick and reliable color to the landscape.
- Many native annuals re-seed and return year after year.
- Native annuals provide a naturalized look to a garden space and enhance the "native feel" of the landscape.
- Native annuals are attractive to and provide food and shelter for native pollinators.
- Native annuals are safe to use within the defensible space zone (within 30 feet of the home) because they have a high moisture content during the growing season and die back to the ground at the end of the season when wildfire risk is greatest.

Objectives

- Determine germination constraints of the five native annuals.
- Investigate flower induction strategies for efficient production for point-of-sale marketing.

Methods

We investigated the nursery production and landscape value of five native annual species: Botta's clarkia (*Clarkia bottae*: Onagraceae), purple Chinese houses (*Collinsia heterophylla*: Scrophulariaceae), bird's-eye gilia (*Gilia tricolor*: Polemoniaceae), baby blue eyes (*Nemophila menziesii*: Hydrophyllaceae), and desertbells (*Phacelia campanularia*: Hydrophyllaceae). Seeds were purchased from the Theodore Payne Foundation in Sun Valley, California. Seeds were germinated by direct-seeding into standard peat-based potting mix in 3.8-cm (1.5-inch) by 20.3-cm (8-inch) cone-tainers that were kept moist on a greenhouse misting bench. Half the seeds of each species were cold-, moist-stratified for 2 weeks prior to seeding;

Results and Discussion
Although stratification simulates natural winter conditions necessary for some species to germinate, none of the species required cold, moist stratification for germination (Table 1). Examination of floral induction is ongoing.

*Species responses*:
Botta's clarkia – The species germinates easily and flowers early and profusely. It does seem to require extra water but could be used to draw customers in and encourage native plant purchases.

Purple Chinese houses – Plants produce beautiful flowers, but flower induction is touchier - we did not experience good results. It requires regular watering to keep it looking good, so it is not a species that will be pursued further in this project.

Bird's-eye gilia – This species germinates easily and has gorgeous flower. It may be marketable, but needs more work on flower induction strategy.

Baby blue eyes – Under proper conditions it germinates quite well and flowers easily and profusely. It is native to the Great Basin so it should do well and be highly marketable here. The species requires further investigation.

Desertbells – This species has potential but requires further investigatation into its flowering response, as flowering did not occur under the conditions we tested.

**Table 1.** Germination and flower induction requirements for five native annuals.

| Species | Germination | Flower Induction[1] | | |
|---|---|---|---|---|
| | | Photoperiod | Light intensity | Temperature |
| Botta's clarkia | Germinates with or without stratification | Response unknown | Irradiation Indifferent | 18.3-23.9°C (65-75°F) |
| Purple Chinese houses | Germinates with or without stratification; requires light | Facultative long-day | Irradiation indifferent | Response unknown |
| Bird's-eye gilia | Germinates with or without stratification | Response unknown | Irradiation indifferent | Response unknown |
| Baby blue eyes | Germinates with or without stratification; inhibited by high temperature (>65°F) and light | Day neutral | Irradiation indifferent | 18.3-23.9°C (65-75°F) |
| Desertbells | Germinates with or without stratification; inhibited by high temperature (>65°F) and light | Day neutral | Irradiation indifferent | Response unknown |

[1]Currey et al. (2011). Observation and inference by H. Kratsch relative to Reno, NV environmental conditions.

Future Plans
The above work will be continued with inclusion of species more conducive to the southern Great Basin region. We are also completing a native plant module that will be included in our core master gardener volunteer training. This will be available online by way of the e-Xtension website (www.extension.org) and shared with western states by way of the multistate project: Western Education/Extension and Research Activity (WERA 1013), Intermountain Regional Evaluation and Introduction of Native Plants.

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Kratsch, H; Skelly, J. A. 2011. Designing landscapes for northern Nevada's arid climate. University of Nevada Cooperative Extention (UNCE) Special Publication: SP-11-15. Reno, NV. 9 p. http://www.unce.unr.edu/publications/files/ho/2011/sp1115.pdf

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**Presentations**
Kratsch, H. A. 2012. UNCE master gardener native plant club: connecting master gardeners to the university using native plants. 5th Annual Meeting of the Multistate Research Project, WERA 1013: Intermountain Regional Evaluation and Introduction of Native Plants, 2012 October 12, El Paso, TX.

Kratsch, H. A. 2012. Nevada master gardeners volunteer their expertise to facilitate on-campus student learning. Workshop: Master gardener volunteer program management and project ideas that work. Annual Conference of the American Society for Horticultural Science, 2012 July 31, Miami, FL. Invited presentation.

**Products**
- A list of intermountain regional native plant growers has been revised and sent to the WERA 1013 website http://www.uwyo.edu/wera1013/

**Project Title** RMRS-CWI Research and Demonstration Gardens and Student Training Program

**Project Agreement No.** 11-CR-11221632-142

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**Project Description**

*The USFS Great Basin Research Site*

The U.S. Forest Service (USFS) Great Basin Research Site is a 0.8 ha (2 ac) plot of land near the College of Western Idaho (CWI) Horticulture Center, Boise, Idaho. The site is used for research studies by USFS, Boise State University (BSU), Idaho State University, University of Idaho (UI), and CWI.

CWI helps maintain the site through student employees, student interns, and senior project programs. Several studies have been conducted at the site including, in 2012, BSU and UI graduate research projects on sagebrush. The site is ideal for visiting scientists to view experimental plots of mature *Eriogonum* and *Lomatium*.

*Demonstration Garden and CWI Horticulture Internship and Senior Project Programs*
RMRS, in collaboration with CWI, has created a demonstration garden of plants used for restoration within big sagebrush and associated Great Basin plant communities. The garden serves as an educational tool for CWI horticulture students and for community education. RMRS has been working closely with CWI in helping to develop knowledge and skill sets of the students to expand their breadth of knowledge and gain real-world experience.

The majority of the students' time is spent working on developing the Great Basin Demonstration garden. However, students also participate in on-going projects within RMRS. Activities may involve data collection on field projects, helping with cooperative projects, learning to collect seeds from shrubs and forbs, helping set up study sites, plant research, or anything found to be of practical use or interest to help develop their skills.

RMRS utilizes the CWI Internship and Senior Project programs as an effective way to allow students to have a measure of creative freedom while experiencing the development of a native garden. This helps them to communicate the purpose of the garden and the plants within it throughout the community. Additionally, this gives students the ability to practice skills learned in their academic environment while applying practical applications of time management, native plant care, propagation and community out-reach.

To date, three students have participated in program.

The Great Basin Demonstration Garden will be featured as a stop in the Boise Spring Garden Tour in June 2013.

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

**Project Agreement No.** 09-IA-11221632-170

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## Project Description

Background

In arid systems, facilitation may be an important component of vegetation recovery after disturbance. Establishment of native perennial species in disturbed western rangelands is desirable, but is severely limited by the presence of the highly competitive exotic annual grass, cheatgrass (*Bromus tectorum*). Greater restoration success may be achieved with seed mixes that mimic natural succession in Great Basin systems, which include native annuals as a key component of the post-disturbance community. Due to overlapping phenology, there is the potential for strong competitive interactions between native and exotic annuals, which could indirectly facilitate establishment of perennial species.

Objectives

The objectives of this study were to (1) Determine the effect of select native annual forbs on the performance of cheatgrass and big squirreltail (*Elymus multisetus*) under field and greenhouse conditions and (2) Determine if the presence of native annual forbs increases the performance of big squirreltail when grown with cheatgrass.

Methods

In greenhouse and field experiments, seedlings of a native perennial grass, big squirreltail, were grown individually with each of five native annual forbs (bristly fiddleneck [*Amsinckia tesselata*], common fiddlehead [*A. intermedia*], Veatch's blazingstar [*Mentzelia veatchiana*], rough eyelashweed [*Blephariappus scaber*], and western tansymustard [*Descurania pinnata*]) and with an annual forb mix (bristly fiddleneck, Veatch's blazingstar, wingnut cryptantha [*Cryptantha pterocarya*], and Great Basin woollystar [*Eriastrum sparsiflorum*]). Half of the replicates were seeded with cheatgrass. We recorded the number of green leaves on big squirreltail plants after planting to assess treatment effects on growth rate and measured aboveground biomass of big squirreltail and neighboring plants after one growing season. Additionally, cheatgrass was grown with native annuals in the greenhouse and field to determine the effect of native annual forbs on cheatgrass biomass and seed production. Structural equation modeling (SEM) was also used to examine the direct and indirect effects of native annual forbs on big squirreltail performance under greenhouse and field conditions.

Results

Bristly fiddleneck and common fiddleneck were the most competitive native annuals with cheatgrass, suppressing biomass and seed production more than other forb species (Figure 1). In the greenhouse, big squirreltail growth and seasonal biomass production were lower when grown with cheatgrass than with any of the native annuals. Additionally when in competition with cheatgrass, big squirreltail's growth performance was best when Veatch's blazingstar was also present, and growth rates were significantly greater when any of the annual forbs were also present. Although bristly fiddleneck was beneficial to big squirreltail in the greenhouse, under field conditions, the fiddleneck had a negative effect on the squirreltail performance. However, over time, these negative effects decreased and could potentially lead to facilitation of big squirreltail later in the season because of its perennial habit and longer growing season.

**Figure 1.** Bristly fiddleneck outcompeting cheatgrass in a field experiment.

Conclusions

The results of our greenhouse and field experiments support the hypothesis that some native annual forbs can be effective at suppressing cheatgrass and that the presence of certain native annual forbs can enhance the establishment of big squirreltail under some circumstances. Native annual forbs are often overlooked as restoration materials, in part because they are weedy, ruderal species. However, these same characteristics may pre-empt space and resources and result in reduced recruitment of exotic species like cheatgrass. The important difference between native annual forbs and other introduced annuals is that they have evolved with the more desirable native plants that we are trying to establish and are themselves desirable for pollinator communities, insects, and wildlife. Native annual forbs may naturally decrease in abundance over time, remaining in the seed bank until future disturbance occurs. In this way, the restoration of native annual forbs in seriously degraded systems could improve both the restoration success of seeding in a given year, as well as provide site resilience to future disturbances. 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 understand germination strategies and competitive abilities of additional native annual forb species so that recommendations can be made to seed growers and land managers regarding which species to invest in.

## Publications

Goergen, E., Leger, E.A., and Forbis, T. [Submitted] Native annual forbs reduce *Bromus tectorum* biomass and indirectly facilitate establishment of a native perennial grass. Journal of Applied Ecology.

## Management Applications and Seed Production Guidelines

This research examines an ecologically rational strategy for management of cheatgrass-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) producing an ecological and economic benefit to land managers through increased restoration success. Understanding if native annual forbs can increase establishment of perennial grasses such as big squirreltail 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 big squirreltail , (2) for seed increase programs, target annual forbs that have the greatest positive effect on big squirreltail and negative effects on cheatgrass biomass and reproduction, 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. Future research should determine the feasibility of growing these native forbs in cultivation, as well as testing the efficacy of annual forbs in large-scale restorations.

## Products

- Research featured in: Ogburn, S. 2012. Weed Wackers. High Country News. September 2012: 16-20.

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

**Project Agreement No.** 10-CR-11221632-117

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**Project Description**

Objectives of this research include:

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

Methods

*Study Site*

The study site, approximately 15 mi southeast of Elko, Nevada, is located within the 8–10 inch precipitation zone on sandy loam soil (Orovada Puett association) and was formerly dominated by Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*). The area was seeded to crested wheatgrass (*Agropyron cristatum*) 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 and is fenced to eliminate livestock grazing.

*Crested Wheatgrass Control and Revegetation Treatments*

A randomized block, split-split plot design is being used to examine crested wheatgrass control and revegetation treatments in crested wheatgrass stands. The study is comprised of five 5-acre blocks. Within 1-acre plots in each block, the following methods of control (mechanical and chemical) and revegetated verses 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 three-way disked or herbicide-treated plots, these each divided into unseeded and seeded sub-plots.
3. Completely controlled crested wheatgrass plots split into combined three-way disked and herbicide-treated plots or combined spring and fall herbicide-treated plots, these each divided into unseeded and seeded sub-plots.

*Treatment Implementation and Sampling*
The disked-only plots were three-way disked in November 2007. The spring-applied herbicide plots and combined disk + herbicide plots were sprayed with 66 oz glyphosate (Roundup®)/acre) in May 2008. In early October 2008, combined spring + fall-applied herbicide plots were sprayed with 66 oz glyphosate/acre. 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-seeded 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 broadcast seeds into the soil surface. The seed mixture used is identified in Table 1.

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.

During the summers of 2009 through 2012, 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.

## Preliminary Results

Preliminary results based on the 2009 and 2910 data were presented in the 2011 Great Basin Native Plant Selection and Increase Project report (McAdoo 2012) and are summarized below.

*2009*
Complete (100%) control/mortality of crested wheatgrass was not obtained with any of the control treatments. However, 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 wheatgrass density ($p < 0.05$), again with no significant differences among the three treatments. However, crested wheatgrass density was significantly greater on disked plots ($p < 0.05$) than on the untreated plots and plots receiving the other treatments, whereas cover was not significantly different ($p > 0.05$) between disked and untreated plots.

Preliminary observations showed the following: (1) four of the six seeded native grass species established (basin wildrye, bluebunch wheatgrass, squirreltail, and Indian ricegrass); (2) each of the seeded forb species (western yarrow, Lewis flax, and Munro's globemallow) 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 the first growing season.

**Table 1.** Seed mix for South Fork study plots, Elko County, NV, on sandy loam soil (Orovada Puett association), approximately 8 inch 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] (*Leymus 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's 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* spp. *wyomingensis*) | | 0.20 | 2.5 |
| Spiny hopsage[5] (*Grayia spinosa*) | | 0.50 | 6.25 |
| **Totals** | | **11.9** | **148.8** |

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

*2010*

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

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. 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 ($p < 0.05$).

*2011 - 2012*
Data analysis is currently in progress for data collected in 2011-2012. We noted an obvious increase in exotic annual forbs during the 2011 growing season, especially tansy mustard (*Sisymbrium altissimum*). During 2012, the mustard infestation was considerably reduced. Preliminary indications are that, based on the second trial, glyphosate was more effective for reducing crested wheatgrass than either imazapic or chlorsulfuron + sulfometuron.

*2013*
During 2013, we will continue to collect vegetation data, as described above, for both treatment trials (fifth-year data for the first trial, third-year data for second trial). Data will be analyzed using mixed model analysis, with blocks and years considered random and other treatments considered fixed.

References
McAdoo, J. K.  2012. Evaluating strategies for increasing plant diversity in crested wheatgrass seedings. Great Basin Native Plant Selection and Increase Project FY 2011 Progress Report. USDA Forest Service Rocky Mountain Research Station and U.S. Department of the Interior, Bureau of Land Management, Idaho State Office: 155-161.

## Presentations
McAdoo, J .K. 2012. Evaluating strategies for increasing plant diversity in crested wheatgrass seedings. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT.

## Management Applications and Seed Production Guidelines
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
- Field Tour: We conducted a field tour on 2012 July 7 to look at the results of applying crested wheatgrass reduction methodologies and seeding native species.

**Project Title** The Ecology of Native Forb Establishment in the Great Basin: A Holistic Approach

**Agreement No.** 11-IA-11221632-023

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**Project Description**

Objectives

Forbs are a critical functional component of sagebrush steppe systems and a central focus of the Great Basin Native Plant Selection and Increase Project (GBNPSIP). However, forb seed is expensive and forb establishment rates are very low, threatening our ability to use forbs widely in restoration. While environmental conditions and competition from non-native species may contribute to low forb establishment rates, underlying drivers of forb seeding failures appear to be more complex. For example, previous research in the GBNPSIP program has shown that although crested wheatgrass and cheatgrass control treatments can lower non-native plant abundance two-fold, this decrease did not improve native forb establishment (Hulet et al. 2010). The broad objective of this research is to identify the major demographic processes and environmental conditions that influence forb seedling recruitment in the Great Basin. We examine these patterns for three common forb species across five sites in eastern Oregon providing the first broad-scale evaluation of recruitment limitations. These results will directly link to native plant increase efforts and will guide increased efficiency of forb utilization in Great Basin restoration.

Methods

This project consists of two phases. The first phase was to assess general patterns of survival of native grass and forb seed. The second phase, 2012-2014, was manipulation and quantification of ecological processes and conditions limiting native forb establishment.

For the first phase, we followed seed and seedling fate of mixtures of native grasses and forbs that the USDI Bureau of Land Management (BLM) seeded across four fire sites in eastern Oregon and in experimental plots at the Eastern Oregon Experimental Range. At the fire sites we used germination bags to quantify the proportion of seeds that germinated and censused control and drill-seeded plots bi-weekly to quantify patterns of emergence, death, and survival over two growing seasons. At the experimental range we manipulated soil disturbance and snow cover during winter. In these treatments we measured bluebunch wheatgrass (*Pseudoroegneria spicata*) and cheatgrass (*Bromus tectorum*) seedling emergence and survival, seed pathogens, soil crusting and number of freeze-thaw events.

The second phase of this project examines the ecological processes and conditions limiting forb establishment. The core aspects of this study design include crested wheatgrass (*Agropyron desertorum*) competition (two levels), site (five sites spanning a long-term precipitation gradient of 100 to 300 mm) and three forb species: Western yarrow (*Achillea millefolium*), lomatium (*Lomatium* sp.), and globemallow (*Sphaeralcea munroana*). Seeds were sown in 2- x 2-m plots in fall 2012 with five replications per treatment combination. Germination bags will be pulled monthly in winter and spring of 2012-2013 and 2013-2014 to quantify germination rates and long-term seed viability. Plots will be monitored bi-weekly for demographic transitions key in seedling recruitment including emergence and survival during the first spring and then monthly through the second growing season. Forb and crested wheatgrass survival will be measured in spring 2012 and spring 2013. Final data will be summarized and published in the last year of the study.

<u>Results</u>

*First phase*

Grass and forb response across the four fire sites seeded by BLM have been reported in earlier reports and are now published (James et al., accepted). New results are centered on bluebunch wheatgrass and cheatgrass seed and seedling responses to soil disturbance and snow manipulations. Low winter snow pack on rangeland reduced seedling survival probability by 80% or more (Figure 1). Soil disturbance prior to seeding also significantly reduced seedling survival probability (Figure 1). Low snow increased fungal pathogen load on seed compared to both ambient snow and high snow conditions; this increase was larger for cheatgrass than for bluebunch wheatgrass (Figure 2).

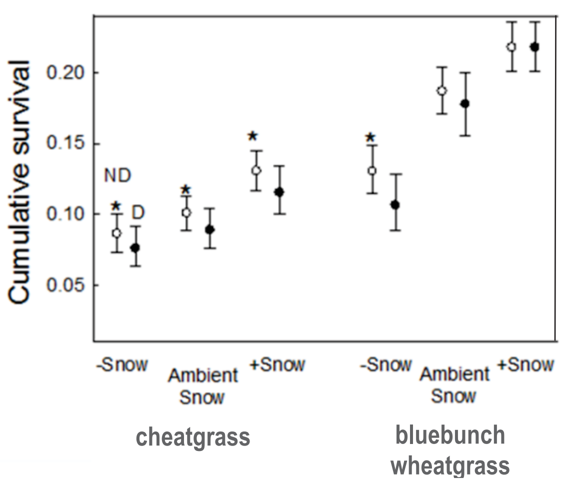


**Figure 1**. Influence of snow cover and soil disturbance (ND = no disturbance, D = tilled) on cheatgrass and bluebunch wheatgrass seedling survival. Asterisk above bars indicates significant difference between means (± SE).

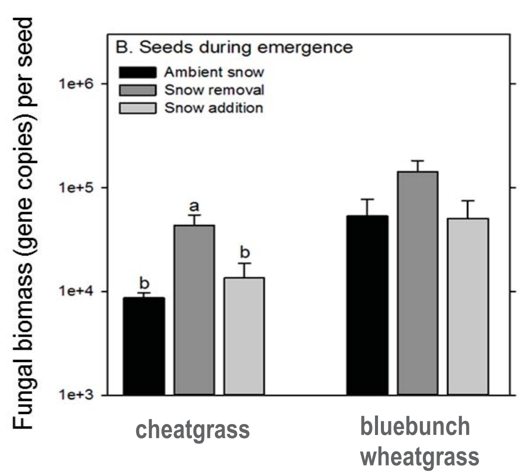


**Figure 2**. Influence of snow cover on fungal biomass on cheatgrass and bluebunch wheatgrass seed. Significant differences between means (± SE) are indicated by differing letters above bars.

*Second phase*

The second phase of the study was implemented in 2012 with the bulk of the work focused on controlling cheatgrass seed banks, obtaining clearance for plots on five BLM sites, fencing each site (2.02 ha or 5 acres per site) and installing an extensive network of soil and above-ground environmental sensor systems (Figures 3 and 4). Full sensor networks were installed at each site consisting of soil moisture and temperature at three depths and a suite of atmospheric variables (radiation, wind speed, temperature, precipitation), allowing us to use the SHAW model to model near-surface seedbed micro-environmental conditions.

**Figure 3**. Plots and sensor system installed at low precipitation site.

**Figure 4**. Seeded forb plots at the high precipitation site.

Future plans

2013 and 2014 will be major data collection years for this study, allowing us to fully parameterize the demographic models. If logistics and resources permit, we would like to add a second seeding year to give us 10 site x year combinations. This project is linked to and forms the basis of a four-year NIFA Rangeland Research Grant that examines seedling recruitment patterns at 15 sites in three states in the Great Basin. Ideally we would like to integrate the data collection approaches in both studies so we can compare across species and sites.

References

Hulet A.; Roundy, B. A.; Jessop, B. 2010. Crested wheatgrass control and native plant establishment in Utah. Rangeland Ecology & Management 63: 450-460.

James, J. J.; Rinella, M. J.; Svejcar, T. Grass seedling recruitment in Wyoming big sagebrush steppe: germination timing, seedling emergence and seedling death. Rangeland Ecology & Management. Accepted.

**Publications**

Hardegree, S. P.; Cho, J.; Moffet, C. A.; Roundy, B. A.; James, J. J. Hydrothermal indices for classification of seedbed microclimate. Rangeland Ecology & Management. Accepted.

James, J. J. 2012. Species performance: the relationship between nutrient availability, life history traits and stress. In: Monaco, T. M.; Sheley, R. L., eds. Invasive plant ecology and management: linking processes to practice. Oxfordshire, UK: CABI Publishing: 142-153.

James, J. J.; Rinella, M. J.; Svejcar, T. Grass seedling recruitment in Wyoming big sagebrush steppe: germination timing, seedling emergence and seedling death. Rangeland Ecology & Management. Accepted.

**Presentations**

James, J. J. 2012. Seedling establishment on disturbed landscapes: the relative importance of abiotic and biotic factors. 65th Annual Meeting of the Society for Range Management; 2012 January 29–February 3, Spokane, WA. Invited speaker.

James, J. J. 2012. Systems approaches to ecological restoration. University of California, 2012 September 20, Berkeley, CA.

**Management Applications and Seed Production Guidelines**

Results to date fundamentally shift how practitioners understand and manage native plant restoration efforts in the Great Basin. While this line of work is still relatively young, we have shown that for our study species, which include the most commonly seeded bunchgrasses in the Great Basin, most mortality occurs after germination, but before emergence. Thus, factors such as weed competition, grazing, and spring drought likely are not principle drivers of native plant recruitment failures. Instead, results are beginning to show that winter time processes, such freeze-thaw events, fungal pathogens, and formation of vesicular crust, pose the predominant barrier to recruitment. Targeting management of these specific processes can improve restoration outcomes greatly.

**Products**

- Grants:

  -James, J. J.; Sheley, R. L.; Hardegree, S. P.; Leger, E. A.; Brunson, M.; Adler, P. 2011. A systems approach for managing seedling establishment on rangeland. NIFA Rangeland Research Program (Award 2011-38415-31158) ($500,000).

  -James, J. J. 2012. Australia Botanic Gardens and Parks Authority, 2012 April 15-28, Visiting Distinguished Scholars Program.

**Project Title** Recruitment of Native Vegetation into Crested Wheatgrass Seedings and the Influence of Crested Wheatgrass on Native Vegetation

**Project Agreement No** 11-IA-11221632-003

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**Project Description**

Objectives

The objectives of our study were to determine 1) what factors (management, site/environmental characteristic, etc.) are associated with native plant recruitment in crested wheatgrass (*Agropyron cristatum*) plant communities and 2) if crested wheatgrass displaces native vegetation from plant communities.

Methods

We sampled 101 crested wheatgrass plant communities in southeastern Oregon between May and August 2012 to identify factors that promote native plant recruitment in these communities. Sites were selected with input from BLM Rangeland Management Specialists to represent a wide range of management practices such as timing (spring or fall) and intensity (distance to water/fencelines) of grazing, time since seeding and a variety of environmental factors (elevation, aspect and slope, proximity to untreated areas). Slope, aspect, elevation and UTM location were recorded at each site. Vegetation was sampled in 60- x 50-m plots at each site. In each plot, four 50-m transects were established at 20-m intervals along the 60-m sides. Along each transect, herbaceous vegetation basal cover and density were visually estimated by species inside 40- x 50-cm frames located at 3-m intervals on each transect line (starting at 3 m and ending at 45 m), resulting in 15 frames per transect and 75 frames per plot. Percentage ground cover (bare ground, rock, litter and crypto-biotic crust) were measured in the 40- x 50-cm frames. Shrub canopy cover by species was measured by line intercept (Canfield 1941). Canopy gaps less than 15 cm were included in the canopy cover measurements. Shrub density was determined by counting all rooted individuals in five 2- x 50-m belt transects in each plot. Soil samples were collected at three locations in each plot from 60-cm holes located at the center of the plot and at 15 m NW and SE of the center of the plot. Soil samples were taken from each of these holes at 0-15 cm, from 0-20 cm and from 20-60 cm. Depth to hardpan was recorded if it was less than 60 cm. The values for each of the samples per plot were averaged into a single plot value. Soil texture for the 0-20 cm and 20-60 cm samples was measured using the hydrometer method (Bouyoucos 1962). The 0-15 cm samples were used to obtain soil pH, nitrogen, carbon and total organic matter for each site. Collection of actual grazing use data for each of the sites is in progress. Disturbance and seeding history are collected for each site whenever possible. Data are still being collected and summarized. Future plans are to collect data from at least 25 more sample sites and continue to obtain management information for each of the sites.

References
Bouyoucos , G. J. 1962. Hydrometer method improved for making particle size analysis of soils. Agronomy Journal. 54: 464-465.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Journal of Forestry. 39: 388-394.

**Management Applications and Seed Production Guidelines**

Results are still preliminary and should not yet be applied to management applications.

**Project Title** Restoration of Native Understory Plants in Degraded Sagebrush Steppe Ecosystems

**Project** 12-IA-11221632-149

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**Project Description**

In the Great Basin, efforts to restore native sagebrush steppe plant communities typically begin after sagebrush shrubs have been killed (e.g., after wildfires) or mechanically removed to facilitate traditional revegetation approaches such as drill seeding. However, it may be feasible to begin restoration of native herbaceous plants while the sagebrush canopy is still intact. Our overall goal is to evaluate whether native bunchgrass and forb establishment from seeds and seedlings differs between sagebrush understories and interspaces in degraded sagebrush steppe ecosystems. We are addressing the following questions: 1) Does native bunchgrass and forb establishment differ in sagebrush understories vs. interspace gaps? 2) Do these patterns differ for seeds vs. seedlings? Two native bunchgrasses, Thurber's needlegrass (*Achnatherum thurberianum)* and squirreltail (*Elymus elymoides* [Raf.] Swezey), and two native forbs, largeflower hawksbeard (*Crepis occidentalis* Nutt.) and Munro's globemallow (*Sphaeralcea munroana* [Douglas] Spach), are the focal species for this study. At each of the three sites, we have established 50 different planting locations per microhabitat (sagebrush understory, interspace) per planting type (seeds, seedlings) per plant species (Table 1). Seeding occurred in fall 2012, while planting of seedlings will occur in spring 2013. In summer 2013, for seeded plants we will record establishment, average height, and number of tillers. For seedlings we will measure the initial number of tillers, survival (live, dead), average height, and basal circumference.

**Table 1.** Characteristics of planting locations.

| Factor | Number | Attributes |
|---|---|---|
| Sites | 3 | Loamy, 8-12 inch precipitation zone, Wyoming big sagebrush/bluebunch wheatgrass—Thurber's needlegrass (*Artemisia tridentata* ssp. *wyomingensis*/*Pseudoroegnaria spicata—Achnatherum thurberianum*) ecological sites |
| Focal species | 4 | Squirreltail, Thurber's needlegrass, Western hawksbeard, Munro's globemallow |
| Microhabitats | 2 | Sagebrush understory, Interspace |
| Plant type | 2 | Seed, Seedling |
| Planting locations | 50 | Per plant stage per microhabitat per species per site |
| **TOTAL** | **2400** | |

**Project Title** Revegetation Equipment Catalog Website Maintenance

**Project Agreement No.** 12-IA-11221632-149

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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 United States. With pages on topics ranging from "All-terrain Vehicles" and "Fertilizing and Mulching," to "Transport Trailers," the catalog is an important reference for information about revegetation equipment. During 2011, the website was updated with all links checked and corrected. During 2012, the process of fully redesigning the website was begun. Once this is finished, it will be fully hosted at Texas Tech University.

**Publications**

Website: http://reveg-catalog.tamu.edu/

**Management Applications and Seed Production Guidelines**

Land managers, seed producers or others can use the Revegetation Equipment Catalog to gain understanding about the types, capabilities, and requirements of various revegetation equipment items they might use to manage their projects.

**Products**

- The Revegetation Equipment Catalog is a stand-alone website designed to provide information about equipment that is used for revegetation efforts in the United States.

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

**Project Agreement No.** 09-JV-11221632-100

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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 cheatgrass (*Bromus tectorum*). The most common herbicide currently available for cheatgrass control is imazapic (Plateau®). Since restoration sites will likely be treated with imazapic for cheatgrass 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 cheatgrass. This project will also examine the effect of herbicide application timing and planting dates on successful species germination and growth.

Materials and Methods

No additional field research was initiated in 2012 due to doubt about successful establishment of test species. Efforts were focused on maintaining an established field of basalt milkvetch (*Astragalus filipies*) and Blue Mountain prairie clover (*Dalea ornata*) for future testing.

A comparison of plant response to herbicides performed in petri-dishes in the laboratory or in soil in pots in the greenhouse was conducted with cheatgrass as a test species due to its known sensitivity to imazapic. Cheatgrass seed was collected from the field, randomly selected, and divided into four replicates of 20 seeds each for imazapic treatments and an untreated control. Seeds were evaluated for germination in two trials: 1) in 9-cm petri dishes on filter paper and 2) in 0.6 l (0.16 gal) pots with field soil (Millville silt loam). Imazapic was applied at 105 g ai $ha^{-1}$ and 210 g ai $ha^{-1}$ pregermination to seeds in both the petri dish and field soil trials with a chamber sprayer calibrated to deliver 225 l $ha^{-1}$. Treatments were applied to the soil surface, or in the case of the petri dishes, directly to seeds placed on #3 Whatman filter paper. After spraying, 5 ml water was applied to each dish and lids were replaced and sealed with parafilm. Seeds in petri dishes were germinated in a controlled environment at constant 20 to 25 ºC and were evaluated 7 d and 14 d after treatment (DAT); seeds were counted as germinated when the radicle or shoot had emerged a minimum of 3 mm from the seed coat. At the end of the germination period, lengths of roots and shoots from germinated seedlings were measured and shoots were harvested for biomass. Harvested biomass was dried at 26 ºC for 36 to 48 h. Seeds grown in pots were placed in the greenhouse and were evaluated 7, 14, 21, and 28 DAT. Evaluations included emergence counts, height measurements and collection of above-ground biomass. Each trial was repeated. Data measurements were converted to a percent of the untreated. Data were analyzed using ANOVA. Run was not a significant factor, so data are combined for each method. Treatment means were separated using Fishers Protected LSD ($p < 0.05$).

Results

In the petri dish trials, imazapic significantly reduced shoot and root length, but did not reduce germination or shoot biomass (Table 1). In the greenhouse trials conducted in pots filled with a silt loam soil, imazapic reduced cheatgrass emergence, shoot length, and shoot biomass. The results of these trials suggest that petri dish trials have limited utility in determining species sensitivity as results do not compare directly with results from trial conducted using soil. Another concern for both petri dish and greenhouse trials is that plant response was not significantly influenced by imazapic rate even though the high rate was double the low rate. The inability to observe a rate response in these types of trials limits the utility of determining a how a tested species would respond to different imazapic rates in the field. It is possible that extending the duration of experiments would allow separation of different herbicide rates by allowing more time for imazapic symptoms to develop. It is also possible that both rates evaluated were high enough to overwhelm cheatgrass and that trials evaluating much lower rates would show a rate response.

**Table 1.** Comparison of species germination, shoot length, root length, and biomass response to imazapic exposure in petri dishes on filter paper or in 0.6 l pots of Milville silt loam field soil[a].

| | | **Cheatgrass – Petri-dish trials** | | | |
|---|---|---|---|---|---|
| **Treatment[b]** | **Rate** | **Germination** | **Shoot length** | **Root length** | **Biomass** |
| | g ai ha$^{-1}$ | ——— % of untreated[c] ——— | | | |
| Untreated | --- | 100 a | 100 a | 100 a | 100 a |
| Imazapic | 105 | 100 a | 74 b | 68 b | 97 a |
| Imazapic | 210 | 96 a | 79 b | 64 b | 92 a |
| | | **Cheatgrass – Pot trials** | | | |
| **Treatment** | **Rate** | **Emergence** | **Shoot length** | **--** | **Biomass** |
| | g ai ha$^{-1}$ | ——— % of untreated ——— | | | |
| Untreated | --- | 100 a | 100 a | -- | 100 a |
| Imazapic | 105 | 59 b | 21 b | -- | 5 b |
| Imazapic | 210 | 51 b | 18 b | -- | 3 b |

[a]Means in each column of each section of the table followed by the same letter are not significantly different according to Fisher's Protected LSD ($p \leq 0.05$).

[b]Treatments applied to seeds in 9 cm petri dishes on filter paper or to the soil surface of 0.6 l pots.

Plans for 2013

In 2013, a new research location will be established near Logan, Utah utilizing species with consistent germination. Further efforts will be made to evaluate plant native forb response in greenhouse trials utilizing a much broader rate range than tested in the preliminary trials. An additional trial will determine if evaluations of germination and growth in test tubes containing growth media infused with herbicides can be used to evaluate plant response to herbicides.

**Project Title** Drill Seeding with Minimum-till Drills

**Project Agreement No.** 09-JV-11221632-068

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**Project Description**

Introduction

The Snake River Birds of Prey National Conservation Area (BOP NCA) provides a unique opportunity to leverage on-going projects to diversify the structural and compositional vegetation attributes on sites that have been stabilized by past Emergency Rehabilitation efforts and now require diversification to meet the needs of raptor prey base species and pollinators. The U.S. Geological Survey (USGS) Joint Fire Science Project (JFSP) aims to integrate the seeding of natives with varying fuel treatments including mowing, herbicide applications and winter grazing. Tandem studies are also being conducted and include Boise State University investigations on the effects of fuel treatments on below-ground soil resources and a USGS pollinator response study. These studies will provide the experimental framework and necessary replication to generate information on the effectiveness of these fuel/restoration treatments.

The current JFSP study site also provides an opportunity to assess inter-seeding treatments in stabilized sites that exhibit response variables to three different disturbance legacies including agriculture, fire (past and recent), and seedings implemented with traditional rangeland drills. Our species selection for seeding includes a mix of early to mid-seral native shrub, grass and forb species (Table 1) that exhibit competitive attributes. These species may also provide other applied research opportunities to assess restoration plant materials under different disturbance legacy scenarios. This project provides the scientific framework to integrate the best available drill technology to increase native plant seeding success in a geographic area that currently has a dearth of applied research projects associated with diversification of altered, but stabilized Emergency Stabilization sites.

General Site Description

The project area is located 32 km (20 mi) south of Kuna, Idaho and extends southeast of Dedication Point (Figure 1). It is within Ada County at an elevation of 945 m (3,100 ft). Average annual precipitation is 20 cm (7.88 in) at Swan Falls Dam and 26.6 cm (10.06 in) at Kuna (Station: Kuna 2 NNE, Western Regional Climate Data 2012: http://www.wrcc.dri.edu/cgi-bin/cliGCStP.pl?id5038).

*Soils*

The majority of the project area soils are representative of a Loamy 8"-12" and Shallow Loamy 8"-12" ecological site (NRCS 2011). The predominantly loess soils, formed in alluvium and residuum derived from sedimentary materials and basalt, occur on nearly level to moderately sloping basalt plains and alluvial terraces in the Snake River Sediments and Volcanic Plateaus, Hills, and Plains ecoregions. They have moderate to high erosion potential without vegetative cover.

*Vegetation*

Frequent wildfires and other disturbances have converted over seventy percent of the NCA landscape from native sagebrush habitat to a non-native annual-dominated system. More than 59% of the NCA burned between 1980 and 2003, and ~32% has burned two or more times during that period. Only 37% of the NCA is still occupied by native shrublands leading to a loss of habitat for raptor prey-base species. The project area burned most recently in 1985 and was drill seeded and chained with generic rangeland seed mixes to provide site stabilization. These treatments can often incur unwanted impacts, including removal of biological soil crusts, loss of extant native bunchgrasses, and mixing of soil profiles, which alter biophysical and biological soil properties (USDI 2000).

The current vegetation composition consists of cheatgrass (*Bromus tectorum*) stands interspersed with annual mustards *(Brassica* spp.), Russian thistle (*Salsola tragus)* and sparse pockets of native Sandberg bluegrass (*Poa secunda*). In August 2011, the Big Foot Fire consumed part of the proposed project area (Figure 1). Prior to the fire, vegetation composition was similar to the other proposed project area blocks.

Seeding dates and weather conditions

Seeding occurred 7-16 November 2012. Weather conditions were dry and in the high 50's (ºF) for two days then the weather shifted to windy rain/snow conditions the remainder of the seeding. Between 20 October and 20 November, 109 mm (4.3 in) of precipitation was recorded from the Idaho National Guard RAWS station.

**Table 1.** Plant species and seeding rates (Joint Fire Science) – NCA BOP

| Plant Species | Common Name | TZ | Purity | PLS | PLS Seeds/ bulk lb. | PLS Seeds/ft.$^2$ | PLS lbs/acre | Total Acres |
|---|---|---|---|---|---|---|---|---|
| **Shrubs** | | | | | | | | |
| *Artemisia tridentata* ssp. *wyomingensis (*Oneida, ID 4,500 ft.) | Wyoming big sagebrush | 72 | 23.17 | 0.17 | 612,453 | 57 | 0.95 | 80 |
| *Ericameria nauseosa* | Rubber rabbitbrush | 82 | 42.00 | 0.34 | 350,611 | 16 | 0.39 | 80 |
| *Krascheninnikovia lanata* | Winterfat | 80 | 73.04 | 0.58 | 110,000 | 2.5 | 0.25 | 80 |
| **Perennial Grasses** | | | | | | | | |
| *Poa secunda* | Sandberg bluegrass (Mt. Home) | 85 | 99.22 | 0.84 | 852,879 | 21.8 | 0.39 | 80 |
| *Elymus elymoides* | Squirreltail | 91 | 97.09 | 0.88 | 138,858 | 4.4 | 0.39 | 80 |
| *Elymus wawawaiensis* | Snake River wheatgrass | 85 | 98.93 | 0.83 | 170,000 | 3.9 | 0.35 | 80 |
| **Forbs** | | | | | | | | |
| *Achillea millefolium* | Eagle western yarrow | 86 | 97.49 | 0.83 | 2,705,843 | 62 | 0.14 | 80 |
| *Astragalus filipes* | Basalt milkvetch | 95 | 95.35 | 0.90 | 114,350 | 1.31 | 0.12 | 80 |
| *Sphaeralcea munroana* | Munro's globemallow | 85 | 95.30 | 0.80 | 159,797 | 3.72 | 0.15 | 80 |
| *Lomatium dissectum* | Fernleaf biscuitroot | 69 | 98.28 | 0.67 | 45,000 | 1 | 0.10 | 80 |

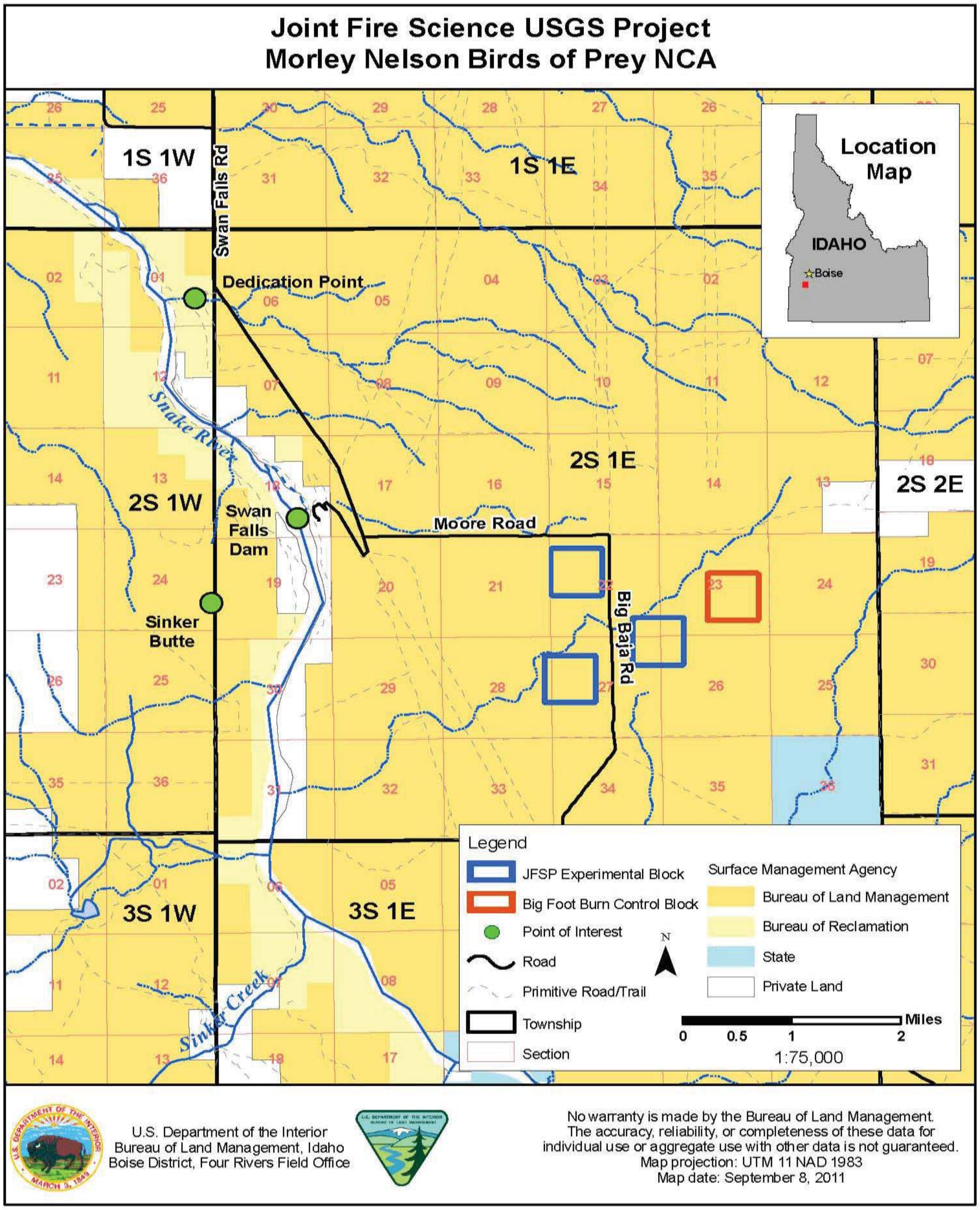


**Figure 1**. Project area map in southwestern Idaho showing locations of experimental and control study blocks.

Study Design and Seeding Methods

There are a total of 28 ha (69 ac) seeded plots throughout four 49-ha blocks (Figures 1 and 2; USGS 2011).

Each block is 700 m x 700 m (49 ha), with sixteen 100 m x 100 m (1-ha) treatment plots (treated and control), a 100-m untreated buffer between all plots, and a 50-m untreated buffer around the edge of the entire block (Figure 3). The total area treated in each of the three individual primary experimental blocks is shown in Figure 3. The seed mixes and distribution rates are shown in Table 2.

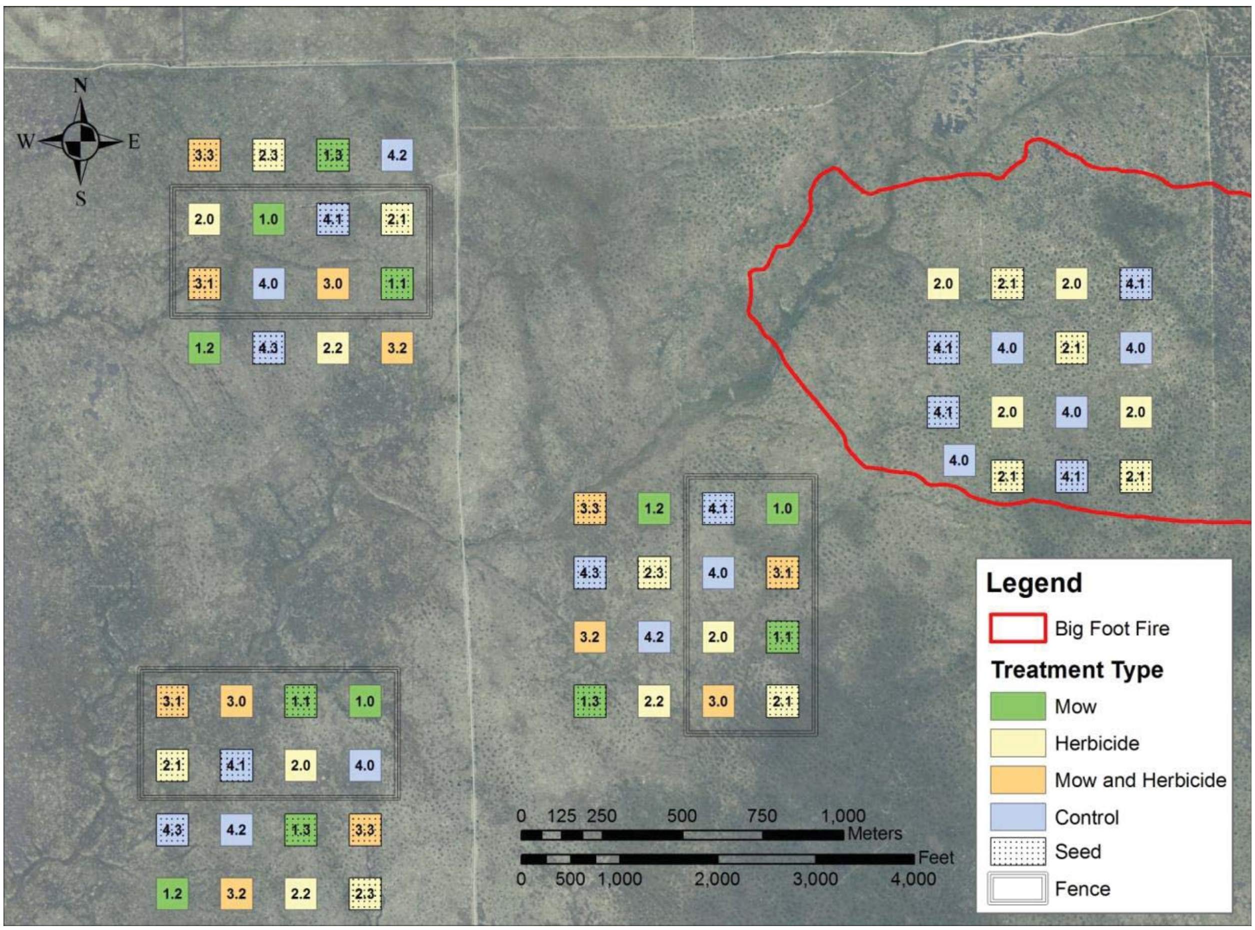


**Figure 2.** Treatment area within each block. Block 4, Big Foot burn, would have a total of 4 seeded ha (10 seeded acres). From USGS (2011).

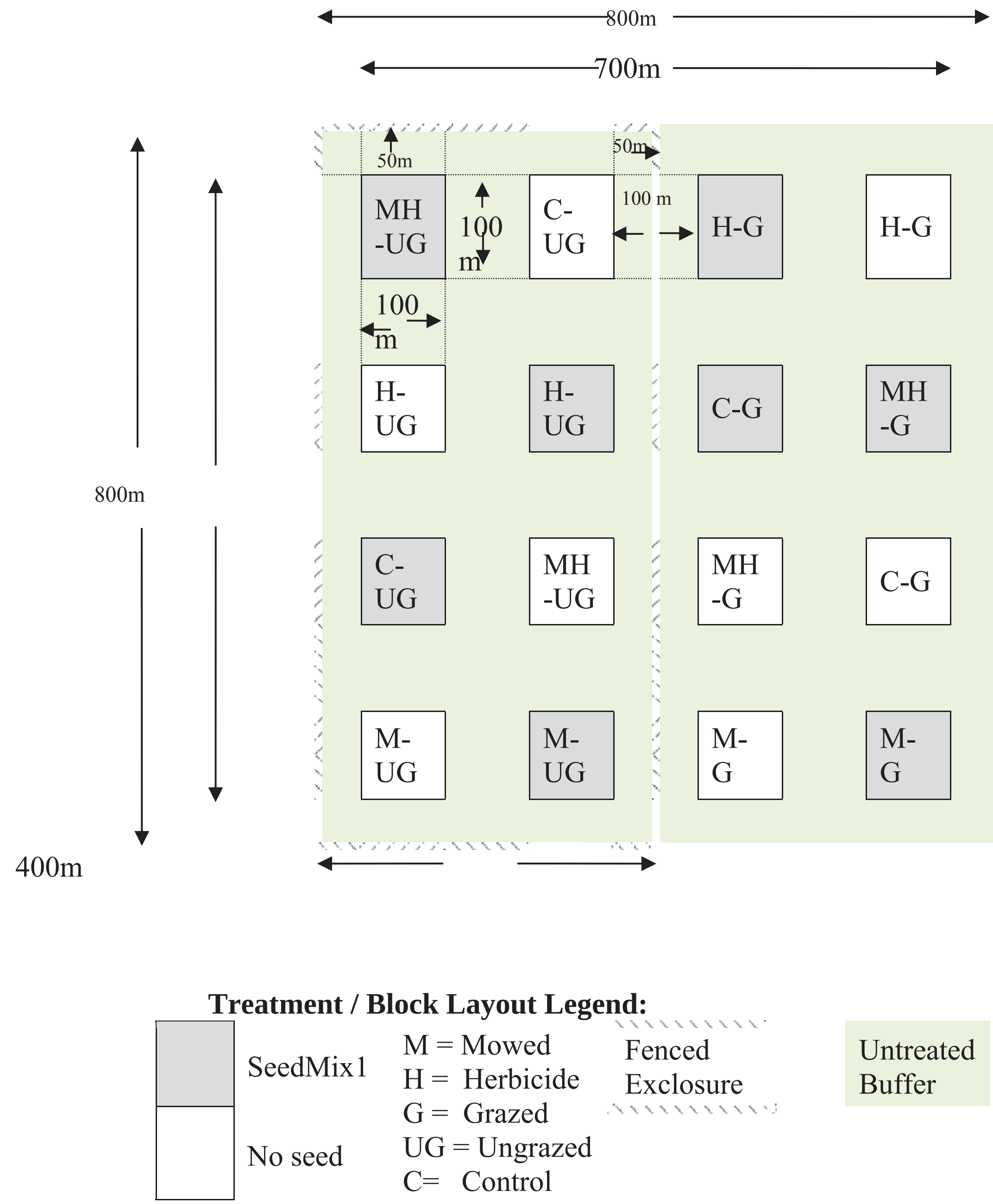


**Figure 3.** Treatment block design and dimensions (plot treatments for illustration only). From USGS (2011).

**Table 2.** Composition and distribution rate of drill and broadcast mixes. Drill calibrations performed by Loren St. John, Natural Resources Conservation Service Aberdeen Plant Material Center (Table 1).

| Drill Mix #1[1] | Bulk pounds/acre | Broadcast Mix #1[2] | Bulk pounds/acre |
|---|---|---|---|
| Snake River wheatgrass | 0.42 | Wyoming big sagebrush | 5.61 |
| Bottlebrush squirreltail | 0.45 | Rubber rabbitbrush | 1.15 |
| Basalt milkvetch | 0.12 | Winterfat | 0.43 |
| Fernleaf biscuitroot | 0.15 | Sandberg bluegrass | 0.47 |
| Gooseberryleaf globemallow | 0.19 | Eagle yarrow | 0.17 |
| Rice hulls | 2.58 | No rice hulls | -- |

[1]Drill setting 7.5 and gate open
Calibration 4.0 grams/spout

[2]Fluffy box setting sprocket 2/2 and no shields
Calibration 11.84 grams/spout

Drill Specifications, Performance and Modifications

The Truax On-The-Go (OTG) Minimum-till Drill (Figure 3) has an 8’ planting width with 12 planters. The OTG has double disc openers unlike the single disc openers on the Rough Rider (RR) Minimum-till Drill and the planters are mounted on two ranks about 1’ apart, unlike the RR which is 4’ spacing between ranks.

The primary benefit of the OTG drill is the feature that allows you to change from drilling with the no-till hydraulically down for inter-seeding or by simply moving a lever to hydraulically raise the no-till for planting in bare ground or prepared seed beds. Second, the redesigned planters utilize a much heavier duty disc bearing similar to those used on corn planters. Third, the output shifter controls for both the cool- season seed box and the small legume seed box have been redesigned to improve the adjustment of the seed output. Forth, imprinters are available, similar to the ones used on the RR, which will interchange with planter assemblies so you can plant the surface-sown species concurrently with drilling the grasses. The new OTGs weigh nearly as much as the RRs; for example the RR weighs 8,000 lb and the 10’ OTG-7516, which plants the same width, weighs 7,500 lb.

Other benefits of minimum till drill technology that drove its use for this project in the NCA are 1) reduced soil disturbance, 2) improved flexibility for planting different species combinations in separate rows, 3) improved hydraulic control of planting units, 4) increased control of seeding depth, 5) improved seed-to-soil contact with the addition of press wheels, and 5) enhanced seed slot opening and closure (Figures 4-6).

**Figure 4.** The Truax On-The-Go (OTG) Minimum-till Drill (left); broadcast seed box modification (right).

**Figure 5.** Example of typical terrain and Sandberg's bluegrass and cheatgrass matrix with drill rows more prominent in open sections.

**Figure 6.** A. Example of brillion imprint and successful broadcast seed application
B. Example of drill row in dense Sandberg's blue grass. Some seed was dispersed outside the drill row. C. Drill rows during rain/snow event.

The OTG performed well without any mechanical issues that interfered with operation or project efficiency. One disc arm became slightly bent due to a disc being torched by going over a slightly rocky section, but this did not hinder subsequent performance. The drill was set-up to accommodate both a broadcast and drill seed mix. Broadcast and drill seed boxes were filled alternately and empty boxes were sealed with duct tape to ensure broadcast and drill seed rows did not overlap. Pins in drill seed boxes had to be shortened by hammering away from the base to reduce puncturing of duct-taped sections. To maximize broadcast box fill, cardboard sections were added.

Seeding acreage per day averaged 11.4 which included pre-equipment check, seed box check and fill, and travel between blocks and nested plots. This was less acreage per hour than the projected 3-4 ac/h. The terrain was generally level with very few rocky sections and dominant vegetation consisted of moderately dense patches of Sandberg's bluegrass with larger sections of cheatgrass, tumble mustard (*Thelypodiopsis*), and Russian thistle. Some mowed plots contained a large release of Russian thistle, but the OTG did not accumulate these between the discs or brillion attachments.

Seed flow of both broadcast and seeded species was consistent, but the larger seeded fernleaf biscuitroot and squirreltail often did not fall into the drill furrows. Drill furrows were most distinct in more open areas and less so in dense bluegrass-dominated areas.

The overall impact to soils and biological soil crusts using the OTG was minimal, e.g., less than 10% of the soil surface was displaced outside individual drill rows within a drill swath and no churning, or removal of biological soil crusts was observed.

Boise District operations staff noted several design features that they foresaw as beneficial as well as potentially problematic with the OTG model;

- The positive: seed stops feeding when implement is raised and it is easier to mount than the Rough Rider minimum till drill.
- The negative: the front cutting discs swing too freely, potentially damaging each other and the frame parts of the machine. Also, because the planting arms are made of two pieces of heavy flat bar that flex and twist this could cause damage to the arms when planting on uneven surfaces.

<u>Current status of OTG</u>
The drill is currently being stored at the Bureau of Land Management (BLM) Horse Corrals and has been winterized and covered with a tarp. Although the drill has been offered for use to fuels and other operations staff on the Boise District for such projects as fuel breaks, no one has requested its use. The OTG is planned for use in FY13 by BOP NCA staff, which will be the last year to "test" this specific drill.

Currently, there are up to eight Rough Rider minimum till drills on the Vale District, however none currently meet the up-to-date specifications on the Rough Rider being used on many Great Basin Native Plant Selection and Increase Projects. Specifically, no broadcast seed (brillion imprinter) attachments are available, seed tubes and discs are bent on some drills, and seed box number and design vary widely. Operators are reluctant to use minimum till drills due to the commensurate maintenance issues associated with this subpar-standard equipment. It is unlikely that minimum till technology will be used on the Boise BLM district without a more universal availability of up-to-date, functional minimum till drills.

<u>Acknowledgements</u>
The implementation of this phase of the JFSP project would not have been possible without the support of Mike Pellant, BLM; Nancy Shaw, USFS Rocky Mountain Research Station; and Jim Truax who generously provided the BLM with the opportunity to experiment with the new "On-the-Go" model drill. Special thanks to Jared Fluckiger from BOP NCA staff who drove the

tractor and to Dale Nichols from Boise District Ops. staff who provided fuel and logistical support.

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**Products**

- A workshop *Preparing and seeding multi-species mixtures, and drill calibration and operation* was held at Initial Point, Boise, ID, 18 July 2012 (Appendix IV).

**Project Title** Influence of Post-fire Treatments on Exotic, Native Residual and Seeded Species Production at the Scooby Wildfire Site in Northern Utah

**Project Agreement No.** 11-JV-11221632-090

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**Project Description**

Introduction and Objectives

In Western states, exotic annuals such as cheatgrass (*Bromus tectorum)*, halogeton (*Halogeton glomeratus)* and prickly Russian thistle (*Salsoa tragus)* often gain dominance following wildfire. Post-fire entry of exotics influences establishment of seeded native species and diminishes habitat quality and forage availability for wildlife and domestic livestock. This study, conducted in 2010 and 2011, documents the productivity of annual exotics relative to wildfire rehabilitation seeding treatments to understand trade-offs between the productivity of seeded grasses and forbs and their exotic competitors. We compare seeding treatments applied in 2008 for their impact on the biomass production of the three exotic annuals: cheatgrass, halogeton, and prickly Russian thistle. In 2011 we also examined seeding treatments relative to soil biota associated with cheatgrass, prickly Russian thistle and bluebunch wheatgrass.

Methods

The study was conducted on the site of the August 2008 Scooby Fire, which burned in a Wyoming big sagebrush community in northern Utah. Treatments evaluated strategies and equipment for reestablishing the native community and included application of seed mixes of native shrubs, grasses, and forbs (Table 1) planted in the area using drill seeding and hand broadcasting methods in a randomized complete block design to evaluate strategies and equipment for reestablishing the native community.

**Table 1.** Seed mixes for post-fire seedings in the burn area of the Scooby Fire (August 2008) near the Great Salt Lake, UT. Drill seed mix does not vary among treatments; broadcast mix varies only by big sagebrush seeding rate (see Table 2 for rates).

| Mix | Common name | Species | Collection site or Germplasm | Pure Live Seed/m$^2$ % | 1X | 5X | 10X |
|---|---|---|---|---|---|---|---|
| Broadcast mix | | | | | | | |
| | Wyoming big sagebrush | *Artemisia tridentata* spp. *wyomingensis* | Sanpete Co., UT (1460 m) | 17.5 | 52 | 234 | 495 |
| | rubber rabbitbrush | *Ericameria nauseosa* | Sanpete Co., UT (1460 m) | 14.8 | 86 | 86 | 86 |
| | Sandberg bluegrass | *Poa secunda* | Mountain Home Germplasm | 81.6 | 91 | 91 | 91 |
| | Western yarrow | *Achillea millefolium* | Eagle Germplasm | 88.2 | 100 | 100 | 100 |
| | blue penstemon | *Penstemon cyaneus* | Lincoln Co., ID (1370 m) | 69.2 | 76 | 76 | 76 |
| | | | | Total Broadcast | 405 | 587 | 848 |
| Drill mix | | | | | | | |
| | bluebunch wheatgrass | *Pseudoroegneria spicata* | Anatone Germplasm | 88.9 | 67 | 67 | 67 |
| | Indian ricegrass | *Achnatherum hymenoides* | 'Rimrock' | 98.0 | 51 | 51 | 51 |
| | bottlebrush squirreltail | *Elymus elymoides* | Toe Jam Creek Germplasm | 94.3 | 47 | 47 | 47 |
| | Munro's globemallow | *Sphaeralcea munroana* | Uintah Co., UT (1550 m) | 65.8 | 93 | 93 | 93 |
| | sulfur-flower buckwheat | *Eriogonum umbellatum* | Northern Great Basin - pooled | 50.4 | 11 | 11 | 11 |
| | | | | Total Drill | 269 | 269 | 269 |
| | | | | **Total Drill + Broadcast** | 674 | 856 | 1117 |

*Biomass Sampling, Summer 2010 and 2011*
Biomass samples were harvested by species or species' group from two 0.25 $m^2$ quadrats, placed 2 m away from each of two transects in each of the 13 seeding treatments (Table 2) for a total of four quadrats in each treatment plot (see Taylor et al. 2011 for details). Biomass of samples from the four quadrats in each plot was summed to estimate production ($g/m^2$) in each treatment plot in four replicate blocks for analysis of variance (ANOVA).

**Table 2.** Rehabilitation treatments seeded at the Scooby Fire site in 2008.

| Drill | Drill Seed Mix Application | Broadcast Seed Mix Application (Sagebrush Rate)* | Treatment Symbol |
|---|---|---|---|
| No Drill | No Seed | No Seed | C |
| Rangeland** | No Seed | No Seed | R0 |
| | Drill | Drill (1x)* | R1x |
| | Drill | Drill (5x)* | R5x |
| | Drill | Drill (10x)* | R10x |
| | Drill | Hand broadcast, fall (5x) | RBC5x |
| | Drill | Hand broadcast, winter (5x) | RwBC5x |
| Minimum-till*** (Broadcast seed covered with brillion packer) | No Seed | No Seed | M0 |
| | Drill | Drill (1x) | M1x |
| | Drill | Drill (5x) | M5x |
| | Drill | Drill (10x) | M10x |
| | Drill | Hand broadcast, fall (5x) | MBC5x |
| | Drill | Hand broadcast, winter (5x) | MwBC5x |

*1x, 5x, and 10x are rates of Wyoming big sagebrush rate, 1x = 52 Pure Live Seed/$m^2$.
**Broadcast seed planted through the drill was covered by dragging a chain behind the drill. Hand broadcast seed was not covered.
***Broadcast seed was pressed into the soil surface with imprinter wheels. Hand broadcast seed was not covered.

Three exotics, cheatgrass, halogeton and prickly Russian thistle, were clipped and bagged separately by species. Seeded forbs (western yarrow [*Achillea millefolium*], sulphur-flower buckwheat [*Eriogonum umbellatum*], blue penstemon [*Penstemon cyaneus*], and Munro's globemallow [*Sphaeralcea munroana*]) were collected separately by species. All native grasses, volunteer (primarily Sandberg bluegrass [*Poa secunda*]) and seeded (Indian ricegrass [*Achnatherum hymenoides*], squirreltail [*Elymus elymoides*], Sandberg bluegrass and bluebunch wheatgrass [*Pseudoroegneria spicata*]) were clipped as a group. Residual forbs (primarily mustards [*Brassica* sp.*, Sisymbrium altissimum, and Descurainia* spp.], lambsquarters [*Chenopodium album*], yellow salsify [*Tragopogon dubius*] and desert princesplume [*Stanleya pinnata*]) were also clipped as a group.

*Soil Biota Sampling, Summer 2011*
In addition to biomass harvests, we collected soil samples for soil biota analyses from microsites under the seeded grasses bluebunch wheatgrass, Sandberg bluegrass, and two exotic annuals

(halogeton and cheatgrass). Samples were collected in a subset of the 13 seeding treatments: the three controls [C, M0 and R0], R5x and M5x (Table 2). We collected cheatgrass and seeded bunchgrass samples in early June and returned in July to collect halogeton and repeat seeded bunchgrass sampling.

Soil biota presence (Gram negative bacteria, Gram positive bacteria, general fungi, arbuscular mycorrhizal (AM) fungi, and protozoans) was documented in soils under seeded grasses and exotic annuals using phospholipid fatty acid (PLFA) extraction assays. Analyses also included comparison of soil biota collected beneath bluebunch wheatgrass in June and July.

## Results

### *Biomass*

Seeded species established well in all seeded plots, perhaps in part, because of favorable moisture in June 2009, the first spring following the seeding (Figure1). Total plant biomass was comparable in all treatments in 2010 ($p = 0.0957$). In contrast, in 2011 there were several differences in total plant biomass among treatments ($p = 0.0054$), primarily with controls producing less biomass than other treatments (Figure 2).

Total exotic production (sum of cheatgrass, halogeton, and prickly Russian thistle) was at least five times as great in the unseeded controls as in the seeded treatments in 2010 and 2011 (Figure 2). In particular, prickly Russian thistle and cheatgrass weights were much lower in seeded treatments than in the three controls. Seeded forbs were absent from the controls and did not differ among the seeded treatments (Figures 2 and 3; $p = 0.1670$). Residual forbs (primarily native and exotic annual mustards) were twice as productive in the unseeded controls as in any of the seeded treatments (Figure 2).

Because total biomass production did not differ among treatments in 2010, greater native production reduced the relative and absolute amount of residual forbs and exotics relative to controls (Figure 2). Soil disturbance caused by empty drills (R0, M0) appeared to enhance recruitment of prickly Russian thistle relative to undisturbed controls in 2010 ($p < 0.0001$); however, by 2011 that difference had disappeared ($p = 0.1159$; Figure 3a).

In general, seeding increased desired species which provided greater competition with exotic and residual annuals (Figures 2 and 3) relative to unseeded controls. These differences are less apparent in 2010 ($p = 0.0957$) than in 2011 when seeded species are more fully established ($p = 0.0054$; Figure 2). Otherwise, few differences are apparent within the seeded treatments and reasons for the somewhat lower total production in 2011 within the rangeland 5x and minimum till 10x treatments are not readily apparent (Figure 2).

### *Soil Biota*

The total abundance (i.e., volume) of soil biota beneath cheatgrass increased with greater soil moisture ($p < 0.0001$; Figure 4a). There was no apparent relationship between soil moisture and soil biota under the perennials bluebunch wheatgrass ($p = 0.0636$; Figure 4b) or Sandberg bluegrass ($p = 0.2282$; Figure 4c).

Soil fungi were in greater abundance in M0 than in M5x treatments within Sandberg bluegrass microsites (Figure 5) suggesting that seeding reduced soil fungi abundance. Fungi in cheatgrass microsites were reduced in the minimum till treatments (M0 versus M5x) relative to other control and rangeland drill treatments. Within bluebunch microsites, general fungi, arbuscular mycorrhizal fungi, and protozoans increased from June to July 2011 (Figure 6) although soil moisture declined during the same period.

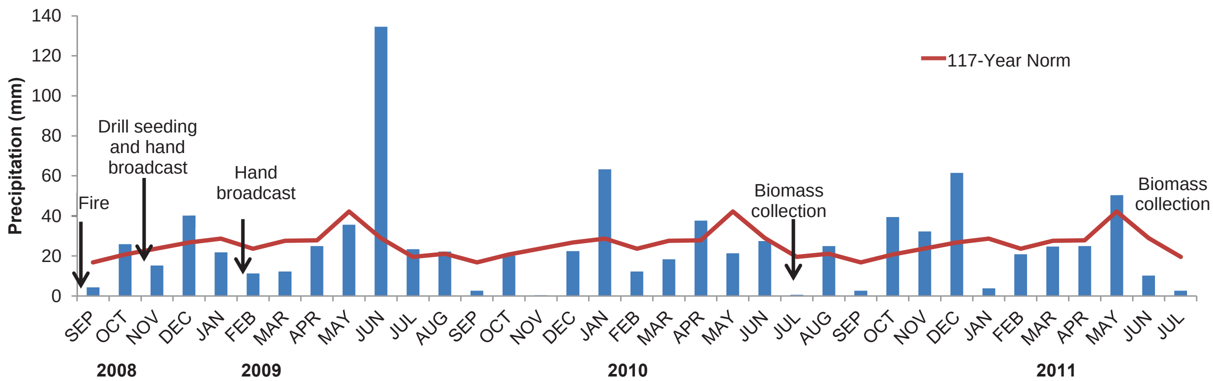


**Figure 1.** Monthly (blue bars) and long-term precipitation (red line) for the Scooby Fire site (WRCC 2012). Monthly data were collected at Rosette, UT, approximately 32 km (20 mi) W of the study site. The 117-year norm is average precipitation data from Rosette and Snowville, UT, located approximately 30 km (19 mi) NE of the study site.

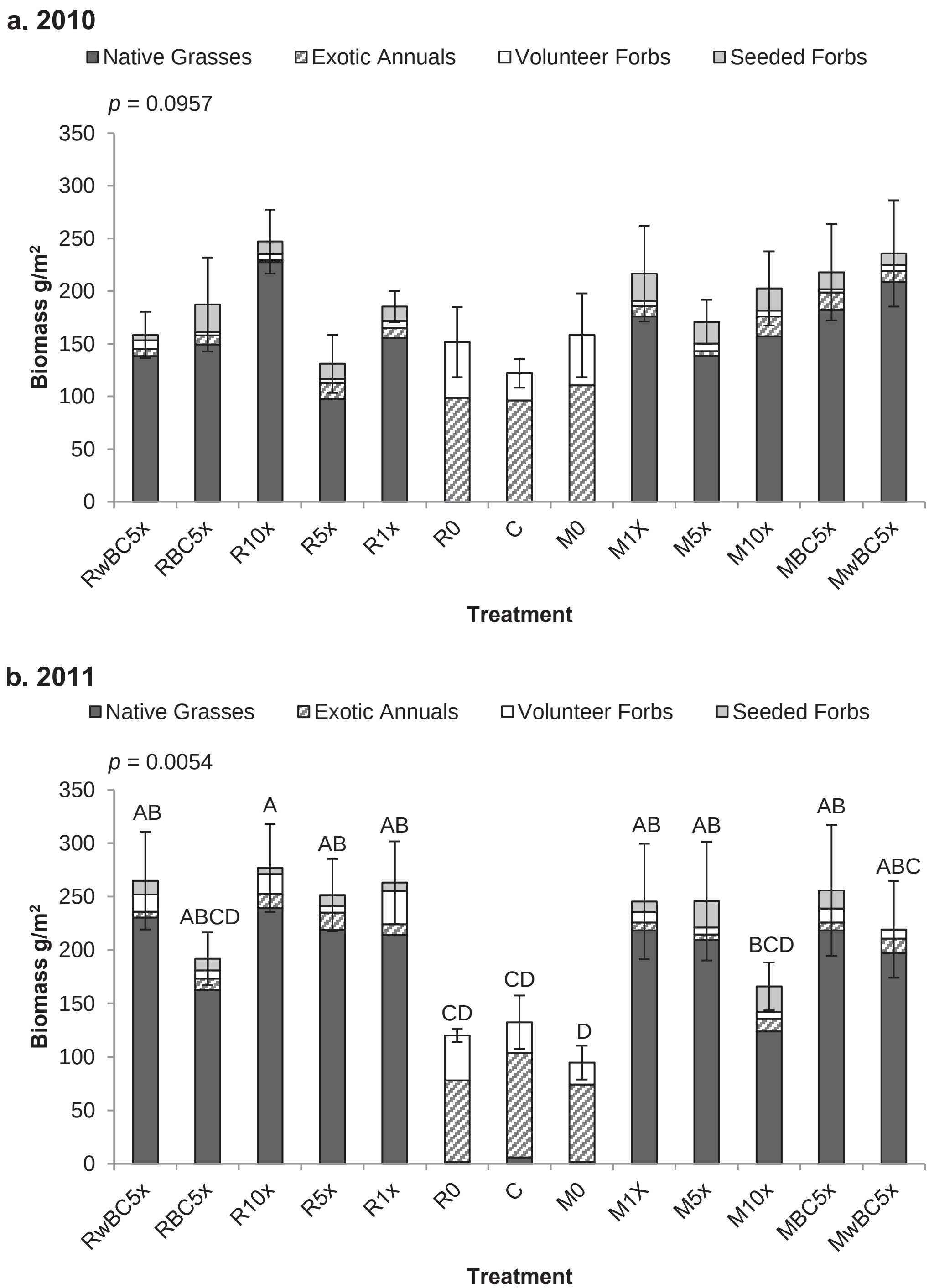


**Figure 2.** Biomass production (± SE) by plant group within all 13 treatments in July 2010 (a) and July 2011 (b). Means with the same letter do not differ ($p > 0.05$, LSD).

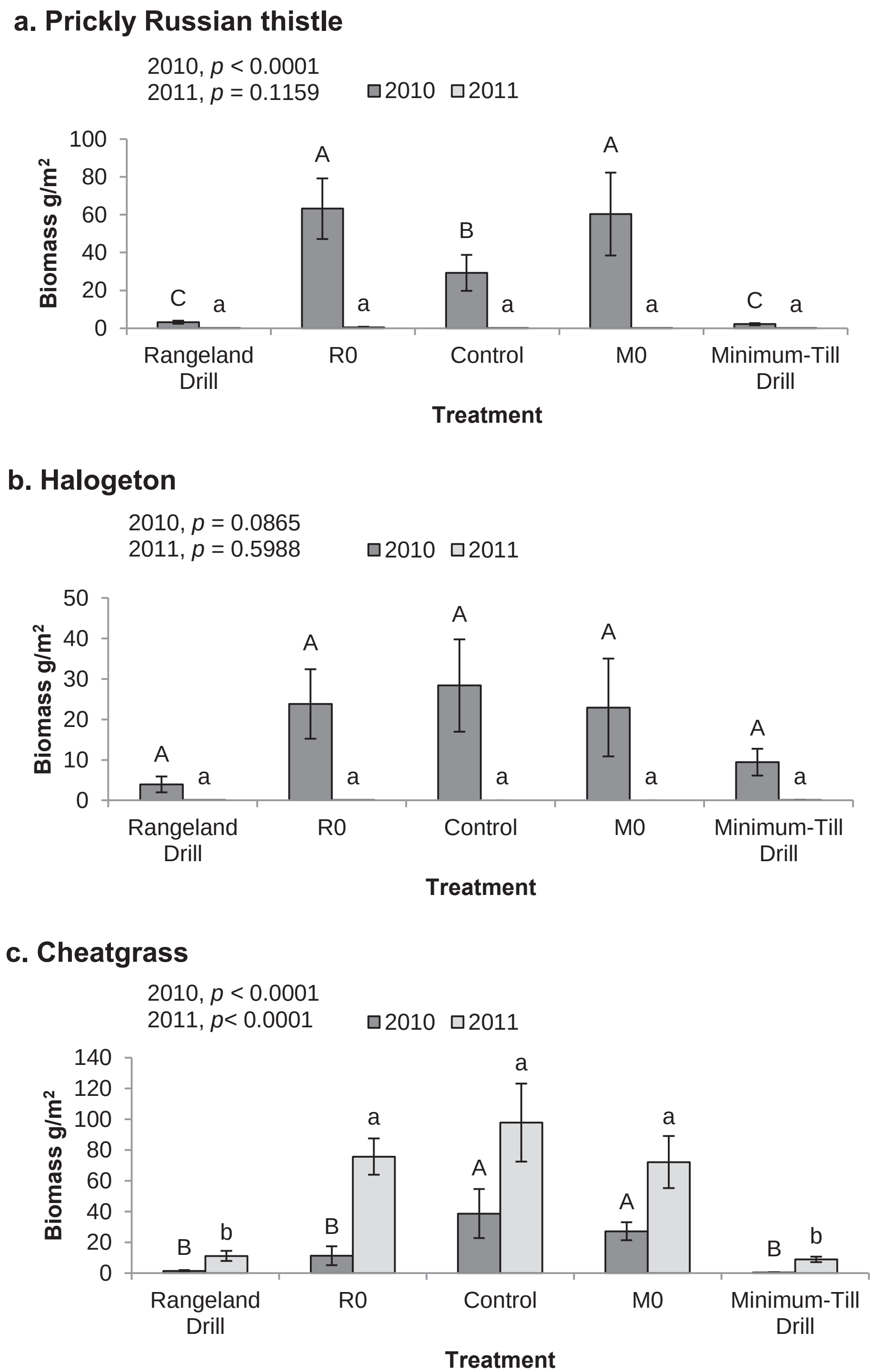


**Figure 3.** Prickly Russian thistle, halogeton, and cheatgrass biomass in seeded and control treatments (± SE) in July 2010 and July 2011. Mean separation, LSMeans contrast, was calculated within year; capital letters separate 2010 means and lowercase letters separate 2011 means.

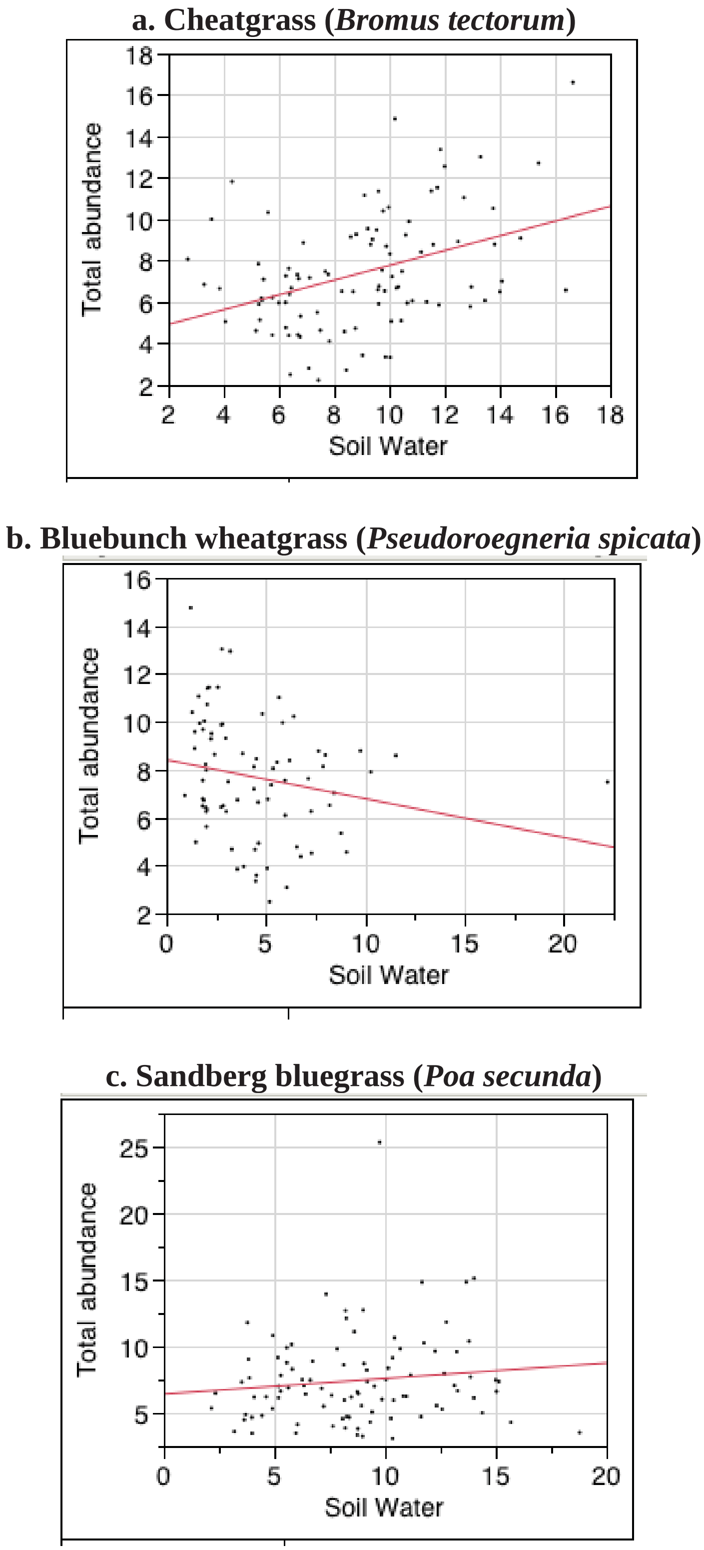


**Figure 4.** Soil biota abundance (i.e., volume) increased as a function of gravimetric soil water content in cheatgrass microsites, (a), $p < 0.0001$, linear fit. The relationship was not significant with increasing soil moisture under bluebunch wheatgrass, (b), $p = 0.0636$, linear fit, or under Sandberg bluegrass, (c), $p = 0.2282$.

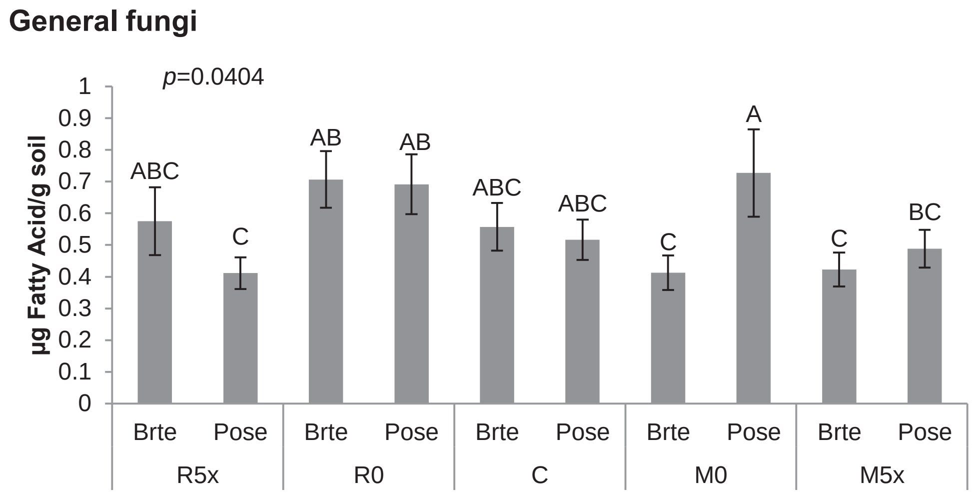


**Figure 5.** Soil fungi (± SE) present beneath cheatgrass (Brte) and Sandbergs bluegrass (Pose) in three control treatments (C, R0 and M0) and two seeded treatments (R5x and M5x) seeded with the rangeland (R) or minimum-till (M) drills. Means sharing the same capital letter do not differ ($p > 0.05$).

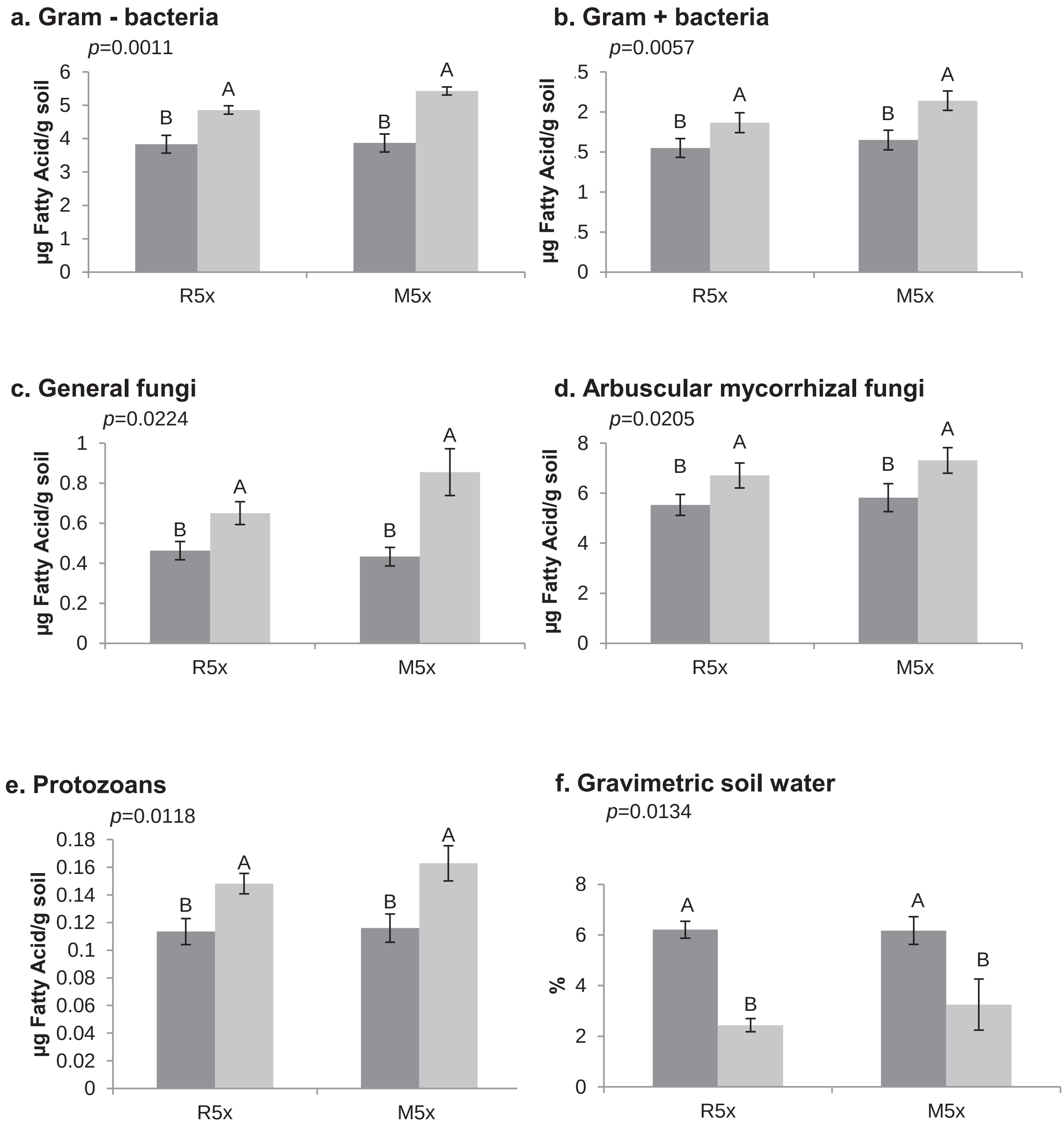


**Figure 6.** Soil biotic community traits (± SE) in June (dark gray) and July (light gray) 2011 in bluebunch wheatgrass microsites within the R5X and M5X treatments. *P*-values are reported for tests of inter-month differences. Letters above mean bars compare seeding treatments by month; means sharing the same letter do not differ ($p > 0.05$).

Discussion

Native seedings can effectively reduce the production of annual forbs (this group was mostly exotic) and exotic species following wildfire. Soil biotic communities beneath annual exotic species appear to be more abundant than those beneath perennial grasses. However, perennial grasses have great flexibility in soil biotic abundance and community makeup, as demonstrated by the shift of the soil biotic community between June and July 2011. It is reasonable to expect that soil communities are tied to soil moisture, however, soil moisture diminished beneath the bluebunch microsites in this short time period (likely because of the robust drill row of grasses, which extracted greater amounts of soil moisture than did the inter-row spaces which contained few perennials).

Future studies that undertake characterization of soil biota within reclamation seedings are needed. Such studies should be careful to sample in microsites under plant species and to sample repeatedly during the growing season to understand the community shifts that seem to occur quickly (June to July in this study) under identical plant species (microsites). Single samples within a growing season may be misleading for characterizing soil biota even within the same microsite and seeding treatment.

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**Management Applications and Seed Production Guidelines**

Managers may be tempted to seed non-native species to dominate sites subjected to wildfire because historically, introduced grasses were used in restoring degraded rangelands (Hafenrichter 1958; Hull 1974) in belief that introduced perennial species may more effectively compete with exotic invasive annuals than native species. However, this study provides evidence reported by others (Jessop and Anderson 2007) that native seedings are a viable option for restoration and can limit exotic annual production following wildfire.

**Publications**

Taylor, M. [In preparation]. Exotic, native and seeded species, and soil biology response to post-fire seedings in northern Utah. University of Wyoming, Laramie, WY. Thesis.

**Presentations**

Taylor, M. M.; Hild, A. L.; Shaw, N. L.; Denney, E. K.; Fisk, M.. 2012. Response of natives to exotic presence in post-fire seedings. Society for Range Management, 2012 January 29 – February 3, Spokane, WA. Abstract.

**Project Title** Use of Native Annual Forbs and Early Seral Species in Seeding Mixtures for Improved Success in Great Basin Restoration

**Project No. & Location** 11-IA-11221632-001

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**Project Description**

Background/Objectives/Hypotheses

Use of native annual and early seral species in Great Basin rangeland reseeding efforts may increase invasion resistance and facilitate succession to desired vegetation, thus improving restoration/rehabilitation success. Early serals may be similar to exotic annual grasses in growth and resource acquisition strategies. Because they occupy a similar ecological niche, due to functional trait similarities such as growth rates and resource acquisition strategies, theory predicts that early serals would compete more strongly against invasives like cheatgrass (*Bromus tectorum*) and medusahead (*Taeniatherum caput-medusae*). As invasion and success of exotic grasses appears to be associated with soil type, competitive interactions may also depend on soil type.

In this study, we used a common garden approach to evaluate the performance of two exotic annual grasses (either cheatgrass or medusahead) and mixtures of native species growing in two soil types of contrasting texture. We assessed seedling emergence and early survival, because early life stages are critical to restoration success. Our first objective was to assess the relative performance of two native seed mixes, a novel seed mix composed of early seral species versus a representative traditional seed mix composed of late seral species, when seeded in the presence of an exotic annual grass. We hypothesized that the early seral seed mix would be more successful in early seedling life stages in comparison to the late seral seed mix, when growing in the presence of an exotic annual grass. Our second objective was to test the potential suppressive effect of the early versus late seral seed mix on the early life stages of exotic annual grasses. Here we hypothesized that the early seral seed mix would have a greater suppressive effect on the exotic annual grasses in comparison to the late seral seed mix, and that this effect would be strongest in the soil type to which the exotic is presumed to be least well adapted. Our third objective was to examine the performance of exotics and natives in two different soil types contrasting in texture (i.e., a clay loam vs. a sandy loam). We hypothesized that the exotics would be more successful when growing in the soil type to which the exotic is presumed to be most well adapted. Specifically, we predicted that medusahead would be most successful on the clay loam, while cheatgrass would be most successful on the sandy loam. For the natives, we hypothesized that performance would differ by soil type when growing with exotics due to soil preference by the exotics.

## Methods

We used a common garden approach to assess exotic and native plant performance in two soil types under the same climatic conditions. Three experiments were performed, using completely randomized designs. Two parallel 2x3 factorial experiments, one with each exotic annual grass (either cheatgrass or medusahead), were designed to assess the performance of the early seral native seed mix versus the late seral seed mix when growing in the presence of an exotic annual grass, as well as the relative performance of these two exotic annuals when growing with and without natives. In these experiments, two levels of soil type (clay loam and sandy loam) were crossed with three levels of seed mix (early seral mix, late seral mix, and no mix). A third experiment was designed to evaluate the performance of natives when growing in the absence of exotics. In this 'No Exotic' experiment, levels of soil type (clay loam and sandy loam) were crossed with two levels of seed mix (early seral mix and late seral mix).

Each seed mix consisted of two forbs, two perennial grasses, and one shrub. A novel early seral mix was composed of the following species: bristly fiddleneck (*Amsinckia tessellata*), Veatch's blazingstar (*Mentzelia veatchiana*), squirreltail (*Elymus elymoides*), Sandberg bluegrass (*Poa secunda*) and rubber rabbitbrush (*Ericameria nauseosa*), and these seeds were collected from multiple wild populations. A late seral mix, representative of traditional seeding mixes used in past restoration efforts, was composed of the following species: Palmer's penstemon (*Penstemon palmer*), goosberryleaf globemallow (*Sphaeralcea grossulariifolia*), Snake River wheatgrass (*Elymus wawawaiensis),* Indian ricegrass (*Achnatherum hymenoides*), and Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis)*. These seeds were commercially purchased from Comstock Seeds (Gardnerville, NV). A representative clay loam soil (clayey, smectitic, mesic, Lithic Argixeroll) and a representative sandy loam soil (fine-loamy, mixed, superactive, mesic Durinodic Xeric Haplargid) were collected from multiple field locations, homogenized by soil type, and filled into 41-cm deep treepots. The pots were then sunk into the ground at the University of Nevada Agricultural Experiment Station in Reno, NV. In each pot, seeds were sown by hand into randomized locations within each pot (15x15 $cm^2$ surface area) using a 20-location fixed grid (Oct. 2010). In the 'No Exotic' experiment, we used two species combinations: (1) early seral native species only (10 seeds, consisting of two of each species) and (2) late seral native species only (10 seeds, consisting of two of each species). In the two parallel experiments with exotic grasses, we used three species combinations: (1) exotic species only (10 seeds), (2) exotic and early seral native species together (10 + 10 seeds), and (3) exotic and late seral native species together (10 + 10 seeds).

Emergence and seedling survival were monitored biweekly from first emergence (November 2010) through spring of the following year (May 2011) (Fig. 1). We also measured aboveground biomass production, seed output, and final establishment though fall 2011, which will be summarized in planned manuscripts. Logistic regression analysis was performed on the emergence and survival of exotics and natives in each experiment. Models included seed mix and soil type as factors. For the natives models, functional group (grass, forb, shrub) was also included as a factor. Additionally, ANOVA was used to assess treatment differences in timing of emergence, both for exotics and for natives, using the same model structure described above. Analyses were performed using SAS 9.3 or JMP 9.0 statistical analysis software (SAS Institute, Inc., Cary, NC).


Results

We found that early seral species generally outperformed late seral species when growing with exotic annual grasses, for emergence probabilities ($p < 0.0001$), survival probabilities ($p < 0.05$, with medusahead), and earlier emergence timing ($p < 0.0001$), though results differed among functional groups and soil types. When growing with cheatgrass, early and late seral native survival differed in sandy loam but not clay loam ($P<0.01$). Within each seed mix, native grasses exhibited the highest emergence probabilities of the functional groups ($p < 0.0001$). In both the cheatgrass and medusahead experiments, we found that the presence of native species did not have a suppressive effect on the exotics. In contrast, cheatgrass had a higher probability of survival when it was growing with either of the native seed mixes ($p < 0.05$). A suppressive effect of the natives on the exotics is more likely to be expressed in later life stages. In terms of soil preference, we found that cheatgrass performed better in sandy loam, as predicted, both for emergence and survival ($p < 0.0001$). Contrary to our prediction, medusahead did not have a preference for the clay loam; rather it demonstrated superior performance in both soils. Emergence of all native functional groups was generally higher on sandy loam when growing with exotics ($p < 0.01$). We also found that native grasses had higher survival in sandy loam while forbs and shrubs had higher survival in clay loam when growing with exotics ($p < 0.0001$).

Conclusions

Given their generally higher performance, the early seral natives may have a greater chance of persisting in the presence of cheatgrass or medusahead in comparison to the late seral natives. Success of seeded natives at the seedling stage is likely critical in determining the eventual success of native reseeding efforts. Our findings suggest that use of native annuals and early serals in reseeding efforts may result in greater density of natives in communities where exotics are present, though additional studies will be needed to assess whether these species are able to persist in the long-term. Differences in native performance on the two different soil types when growing with exotics suggest that use of early serals in restoration seedings may result in greater success in more coarse-textured soils, particularly when native grasses comprise a large proportion of the native seed mix. We also found that performance of medusahead is comparable in the two soil types. To date, medusahead invasion has been most closely associated with fine-textured soils, but it has been observed on certain sites with more coarse-textured soils (Dahl and Tisdale 1975). Our results support these observations and suggest that medusahead is capable of expanding its current range in the Intermountain West.

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Collaborator

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**Publications**

Uselman, S. M.; Snyder, K. A.; Leger, E. A.; Duke, S. E. [In preparation]. Use of native annual forbs and early seral species in seeding mixtures for improved success in Great Basin restoration: seedling emergence and early survival.

**Presentations**

Uselman, S. M.; Snyder, K. A.; Leger, E. A.; Duke, S. E. 2012. Use of native annual forbs and early seral species in seeding mixtures for improved success in Great Basin restoration. Ecological Society of America Annual Meeting, 2012 August 5-10, Portland, OR.

**Management Applications and Seed Production Guidelines**

This research lends support to the use of early seral natives to improve success rates of rangeland restoration/rehabilitation reseedings in the Great Basin. Given their greater performance when growing with exotics during early life stages, early seral species may have a greater chance of persisting in communities where exotic annual grasses are present. If they persist, and possibly suppress exotics once they mature, their establishment may facilitate succession to a more native dominant community of desired later seral vegetation. Our research findings also suggest that it would be advisable to rely more on native grasses in Great Basin restoration seedings, based on the relative performance of the different native functional groups in this study. Although the forbs in this study did not perform as well as the native grasses, certain species may show promise for use in rangeland reseedings and additional research is warranted. Differences in native performance in the two soil types suggest that restoration seedings, particularly those using native grasses, may be more successful in more coarse-textured soils when native seeds are added to an existing exotic seedbank. The strong performance of medusahead in both soil types indicate that it is able to expand its range beyond fine-textured soils, and these findings bolster the call for greater efforts to prevent its further spread in the Great Basin.

**Products**

- Outreach: Brochures for the public at the Nevada Agricultural Experiment Station Field Day, College of Agriculture, Biotechnology, and Natural Resources, University of Nevada-Reno, September 2012, Reno, Nevada.

**Project Title** Effects of N-sulate® Fabric on Germination and Establishment of Native Seeded Species

**Project Agreement No.** 09-JV-11221632-193, 11-JV-11221632-009, 12-JV-11221632-050

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**Project Description**

Forb Island Study

In previous work using N-Sulate® fabric on our research farms we saw a significant increase in germination. After seeing this increase in germination we wanted to test the use of this fabric in a wildland setting. This study was implemented in 2009 and 2010. Four sites were selected in Utah, two in Tooele County, one in Sanpete County, and one in Carbon County. This study examines the effect of N-Sulate® fabric on the germination and establishment of seeded species.

Each study site consists of five randomized complete blocks, treatments are two seed mixes (Table 1) and two mulch treatments covered with N-sulate® fabric and an uncovered control. The study sites were prepared by mechanically removing sagebrush and other vegetation with two passes of a pipe harrow. The seed mixes were sown with rice hulls using a hand-operated seed broadcaster to a rate of 20-25 seeds $ft^2$, depending on the species. The plots were then compacted with a Brillion packer wheel (Brillion Farm Equipment, Brillion, WI) to ensure good seed to soil contact.

*2009 Plots*

Germination and establishment data were recorded in 2010 and 2011. The N-sulate® fabric increased spring germination and second-year survival. The most dramatic increases in germination and establishment were on the two sites in Tooele County that receive less annual precipitation than the other two sites.

*2010 Plots*

We recorded initial emergence in 2011, and second-year survival in 2012. In 2011, while recording emergence at the Lookout Pass site in Toole County, we observed that common or winter wheat (*Triticum aestivum*) was inadvertently seeded in all plots and the long- term effects were noticed the following year. There was extremely low establishment of the seeded forbs in 2012 and reduced densities of annual weedy species like cheatgrass (*Bromus tectorum*). The wheat appeared to be more competitive and used water resources faster than the seeded species which resulted in minimal establishment.

Data from all plots and years are currently being compiled and analyzed to compare germination and establishment between and among all four sites and both planting years. We will also look at the correlation between the presence of annual weeds and the establishment of the seeded species on all treatments. Initial observations suggest that the presence of cheatgrass or other weedy annuals may suppress the germination and establishment of the seeded species. Further monitoring of these plots will take place to record the long term effect of using N-sulate® fabric to increase initial germination of seeded species.

**Table 1.** Forb Island study seed mixes.

**Seed Mix 1**

| USDA Plant Code | Common Name | Scientific Name | Accession No. | Seeded Rate (g) |
|---|---|---|---|---|
| BASA3 | Arrowleaf balsamroot | *Balsamorhiza sagittata* | Basa-I-UT-R2 | 17.0 |
| CLSE | Rocky Mountain beeplant | *Cleome serrulata* | CSE-107 | 2.8 |
| HEBO | Utah sweetvetch | *Hedysarum boreale* | 2008.0366 | 21.3 |
| LILE3 | Blue flax | *Linum perenne* Appar | NBS-RR8-APP-2 | 3.12 |
| LUAR3 | Silvery lupine | *Lupinus argenteus* | 122 | 63.8 |
| PEPA6 | Thickleaf beardtongue | *Penstemon pachyphyllus* | PEPA6-B5-2009 | 4.3 |
| POFE | Muttongrass | *Poa fendleriana* | 2006.04.08 | 1.1 |
| SPGR2 | Gooseberryleaf globemallow | *Sphaeralcea grossulariifolia* | 287 | 2.3 |

**Seed Mix 2**

| USDA Plant Code | Common Name | Scientific Name | Accession No. | Seeded Rate (g) |
|---|---|---|---|---|
| AGGR2 | Bigflower agoseris | *Agoseris grandiflora* | AGGLG 28080 LPN | 4.5 |
| AGHE2 | Annual agoseris | *Agoseris heterophylla* | SI-1 | 1.9 |
| ARMU | Flatbud pricklypoppy | *Argemone munita* | ARMU-U1-2009 | 8.7 |
| HEMUN | Nevada goldeneye | *Heliomeris multiflora* var. *nevadensis* | HEMUN-B4-2009 | 1.9 |
| LONU2 | Barestem biscuitroot | *Lomatium nudicaule* | Big Butte source | 28.4 |
| NIAT | Coyote tobacco | *Nicotiana attenuata* | Mud Springs source | 0.4 |
| THMI5 | Manyflower thelypodium | *Thelypodium milleflorum* | THMI5-P2-2009 | 0.4 |

**Project Title** Reducing Cheatgrass: Research into *Bromus tectorum* and *Sordaria* Symbiosis

**Project Agreement No.** 10-CR-11221632-182

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**Project Description**

*Experiments to Assess Animal-Plant Lifecycle of Sordaria Strain CID 323*

Dung fungi are being examined in the biocontrol of cheatgrass (*Bromus tectorum*). These fungi, which occur symbiotically with cheatgrass, are consumed by herbivores and then spread through the herbivore's feces. After passage through the GI tract, these fungi then produce spores on the animal's dung that should multiply and reduce fecundity in new generations of cheatgrass. Current work tests the assumptions that CID 323 can be freely passed from animal to plant host, and from plant to animal host. A field experiment confirmed that CID-infected cheatgrass did pass through the digestive tracts of sheep. A greenhouse experiment is underway to see if spores present on the dung will re-infect cheatgrass plants.

The early part of the year was spent in efforts to determine vectors of introduction of the fungus *Sordaria* CID 323 into both field plots of cheatgrass and animal hosts (sheep, Ovis aries). Foliar inoculation by spraying a mixture of mycelia and spores was previously shown by Baynes (2011) to be successful in introducing CID 323 into stands of cheatgrass in the field. In order to confirm a complete lifecycle of CID 323 with animal and plant hosts, several experiments were conducted to test whether CID 323 can be freely passed from animal to plant hosts, and from plant to animal hosts.

CID 323-infected foliage of cheatgrass was fed to sheep, and dung was collected to test for the presence of CID 323. The first experiment was unsuccessful because of two confounding factors: a) the test subjects (sheep) had been exposed to CID 323 or a similar strain through feed (i.e., CID 323 was present in control subjects); b) efforts to use alfalfa pellets to 'cleanse' the sheep digestive system were too successful (i.e., all dung fungi were absent from alfalfa-treated subjects). This led to a refined experiment, where sheep treated with alfalfa for several days to clear their system were fed a mixture of cooked feed free of CID 323 for several days, then randomly assigned to control and treatment groups. CID 323 was introduced to the sheep in a bolus of mycelia and spores, and the presence of CID 323 was confirmed in the treatment group through incubation of dung in a moist chamber with sterile filter paper acting as a selective medium for cellulolytic fungi.

Several more experiments were conducted in fall 2011 and spring 2012 to refine the process of introducing CID 323 to sheep and to control for various confounding effects of feed, interference from other dung fungi (e.g., zygomycetes), and related concerns. The design of custom moist chambers to the detect presence of CID 323 in dung was also refined during this period.

In April 2012, a field plot at Parker Farm on the University of Idaho campus was prepared for use in a sheep-cheatgrass-CID 323 experiment. Approximately 0.5 acre of cheatgrass-dominated grassland was sprayed with CID 323 inoculum. After the CID 323 was given time to successfully infect and establish itself in the inoculated field plots, an area was fenced and divided into four subplots, where sheep were pastured for a week after being 'cleared out' with the alfalfa-clean feed process. Dung was collected throughout the pasturing time. Incubation of dung samples confirmed that all sheep were free of CID 323 at time of pasturing. Dung samples collected after 72 h of feeding on CID 323-infected cheatgrass were incubated, and the presence of CID 323 was confirmed in the dung of all test subjects.

Currently, two experiments are in progress to conclusively describe the complete lifecycle of CID 323 as an endophytic dung fungus (i.e., having distinct but related animal host and plant host phases). CID 323-infected dung is being used in a greenhouse experiment to show that fruiting bodies growing on the dung can directly infect cheatgrass foliage in close proximity. Additionally, a laboratory experiment aims to show that spores ejected from CID 323 perithecia can germinate on the surface of cheatgrass leaves and infect the plants directly. This is an effort to address a long standing assumption in the dung-fungi literature that spores germinate primarily in the digestive tracts of herbivores and that plants act primarily as a passive medium for spores on the surface to regain entrance to the digestive tracts of herbivores. By demonstrating that spores can germinate on the leaves of cheatgrass and infect the plant, the hypothesis that CID 323 is an endophytic dung fungus (should be fungus?) , with both animal and plant hosts, will be supported.

*Experiments to Assess the Effects of CID 323 on Native Grasses and on Competition between Cheatgrass and Native Grasses*

Starting in late spring 2012, a series of experiments were initiated to assess the effects of CID 323 infection on various native grasses. Following from Baynes (2011) which showed that CID 323 reduces fecundity and biomass of cheatgrass, these experiments will assess what, if any, effect CID 323 has on natural competitors of cheatgrass in the Great Basin and Intermountain West regions of the United States.

It was determined in the laboratory that surface sterilization of native perennial grass seeds (bluebunch wheatgrass [*Pseudoroegneria spicata*],; squirreltail [*Elymus elymoides*], Sandberg bluegrass [*Poa secunda*], and needle and thread [*Hesperostipa comata*]) is best accomplished by soaking the seeds in a 0.6% NaClO solution for 5 min followed by a sterile deionized water rinse. Control of surface contaminant fungi and bacteria was more effective and germination greater using the 0.6% NaClO soak than a 5 min soak in 70% ethanol.

Cohorts of the four native perennial grasses are currently being raised in the greenhouse on UI campus for treatment with CID 323 to determine if there is an effect on biomass after an arbitrary length of time (~100 d). Cheatgrass seedlings are being vernalized at 4°C for 90 d, and will be grown in 3.8 l (1 gal) pots with size-matched seedlings of native grasses to assess competition coefficients in the presence and absence of CID 323 infection.

*Effects of Endophytic Fusaria Isolated from North Africa grass* (Ventenata dubia) *on Cheatgrass and Native Grasses*
A recent development as of summer 2012 was the isolation of distinctive communities of fungi in the genus *Fusarium* from North Africa grass (*Ventenata dubia*) and cheatgrass root tissue. Preliminary experiments are being prepared to determine whether the *Fusarium* isolates (~28 distinct strains in two groups, one associated with *Ventenata* and one with cheatgrass) have pathogenic effects on cheatgrass and native grasses. Initial tests are being conducted with bluebunch wheatgrass and squirreltail. These are based on the observation that *Ventenata* plants from which half of the *Fusaria* were isolated did *not* show signs of disease or reduced growth, while cheatgrass plants from which *Fusaria* were isolated were not as healthy as *Fusaria*-free plants. This could support a novel weapons hypothesis (Callaway and Ridenour 2004) related to observed cheatgrass die-offs in the last decade or so, namely, that North Africa grass may have an endophytic association with strains of *Fusarium* which are pathogenic to cheatgrass and native grasses, thus enabling invasion. Alternately,North Africa grass may be resistant to *Fusarium*-related disease in a manner different from cheatgrass and native grasses, thus facilitating invasion.

Cheatgrass and native grasses grown in the greenhouse on the University of Idaho campus will be treated with inoculum from cheatgrass-derived and North Africa grass-derived *Fusarium* strains and assessed for signs of disease or reduced growth after an arbitrary amount of time has elapsed (~100 d).

<u>References</u>
Baynes, M. 2011. Endophytic fungal communities of *Bromus tectorum*: mutualisms, community assemblages and implications for invasion. University of Idaho, Moscow, ID. Thesis. 103 p.

Callaway, R. M.; Ridenour, W. M. 2004. Novel weapons: invasive success and the evolution of increased competitive ability. Frontiers in Ecology and the Environment 2: 436–443.

**Publications**
Baynes, M. A.; Newcombe, G.; Dixon, L.; Castlebury, L.; O'Donnell, K. 2012. A novel plant-fungal mutualism associated with fire. Fungal Biology 116: 133-144.

Baynes, M. A.; Russell, D. M.; Newcombe, G.; Carta, L. K.; Rossman, A. Y.; Ismail, A. 2012. A mutualistic interaction between a fungivorous nematode and a fungus within the endophytic community of *Bromus tectorum*. Fungal Ecology 5: 610-623.

**Presentations**
Presentation made on *Sordaria-Bromus* symbiosis and implications for rangeland restoration to staff scientists and visitors at MPG Ranch in Missoula, Montana in June, 2012.

A presentation on the effects of CID 323 on cheatgrass was made to staff scientists and visitors at MPG Ranch in Missoula, MT on June 19, 2012.

**Management Applications**

Although exploration of the *Sordaria*-cheatgrass-native grass system is in the preliminary stages, work will likely lead to useful information for land managers in the future. The work on fungal endophytes (and *Fusarium* endophytes and rhizosphere pathogens) will broaden the knowledge base on why some native grass plantings fail, how cheatgrass and North African grass are successfully invading native perennial grasslands and sagebrush steppe, and potential ways to reduce cheatgrass and North African grass infestations.

**Outreach and Field Work Collaborations**

The presentation and meetings with staff scientists at MPG who research cheatgrass and native grasses (see Presentations, above) has laid the groundwork for collaborative field-work starting in November 2012. MPG Ranch is a privately owned venture conducting research in conservation and restoration ecology. Field sites are being prepared in the Bitterroot Valley of Montana on MPG managed lands to test the effectiveness of CID 323 inoculation in reducing cheatgrass infestations and/or facilitating re-introduction of native grasses. The current experiment will assess the relative effectiveness in reduction of cheatgrass fecundity and biomass of fall inoculation (post emergence) versus spring inoculation (post vernalization).
In addition to developing a relationship with MPG Ranch and associated scientists, working relationships are being formed with several ranchers and farmers in Washington and Idaho. Verbal agreements to secure access to field sites have been reached with two landowners with cattle ranching interests in the area.

A potential field site is located on semi-arid benchland on the north shore of the Snake River west of Pullman, Washington. This site has a mix of native bunchgrasses, cheatgrass, North African grass, and several other invasives, and is used as low-intensity grazing land. The owner is very interested in how CID 323 might affect the invasive grasses and their relationship to native plants, and has offered land for that purpose.

A verbal agreement has been reached with a landowner of property north of the Salmon River on the Nez Perce Reservation in North-Central Idaho. This is semi-arid grassland characterized by native grasses mixed with cheatgrass and North African grass. This large ranch, used for seasonal cattle grazing, has large monocultures of cheatgrass, and is in the first stages of significant North African grass invasion. The owner, a retired extension agent for the state of Idaho, has offered use of his land for experimental purposes, and is also very interested in communicating future findings of these studies to his extensive contacts in ranching, farming, and forestry.

**Project Title** Native Plant Selection and Restoration Strategies

**Project Agreement No.** 11-IA-11221632-077

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**A. Seeding Native Species following Wildfire in Wyoming Big Sagebrush (*Artemisia tridentata* ssp. *wyomingensis*)***

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*Partial funding provided by the Joint Fire Sciences Program and the National Fire Plan

**Project Description**
The cycle of annual weed invasion and wildfire has altered western shrublands, disrupted ecosystem functioning, and increased wildfire size, intensity and frequency. These impacts are costly in terms of losses to native species and ecosystems. Post-fire rehabilitation provides an opportunity to stabilize and revegetate at-risk shrublands. USDI Bureau of Land Management policies and regulations encourage the use of native species, but improved seeding equipment and strategies are required to increase the success of multi-species native seedings. We examined the effectiveness of two drills, a standard rangeland drill and a minimum-till drill; techniques for seeding small-seeded species; and sagebrush seeding rates as approaches for re-establishing native species in Wyoming big sagebrush (*Artemisia tridentata* var. *wyomingensis*) shrublands following wildfire.

Methods

Post-fire seeding treatments were established at four locations in the northern Great Basin following wildfires in 2007-2010 (Figure 1; Table 1). A total of 13 treatments differing by drill type (standard rangeland drill or minimum-till drill), seeding method, and sagebrush seeding rate (Table 2) were applied to 30-m x 70-m plots in fall or winter following each fire. A randomized complete block design with five blocks was replicated at each site. A drill seed mix (large seeds) (Table 3) was seeded in alternate rows. The seed passed from the large seed box through the drill assembly of each drill. The broadcast mix (small seeds) (Table 3) was allowed to fall to the soil surface of the intervening rows from the broadcast seed box and was covered by chains (rangeland drill) or imprinter units (minimum-till drill). Aerial seeding was simulated by hand-seeding the broadcast mix in fall or winter on plots that had been drill- seeded in alternate rows with the broadcast seed boxes empty. All plots were fenced to exclude livestock.


**Figure 1.** Great Basin post-fire seeding locations.

**Table 1.** Northern Great Basin seeding locations, wildfire and seeding dates, and site descriptions.

| | Mountain Home | Glass Butte | Scooby | Saylor Creek |
|---|---|---|---|---|
| Location | 42°58'42" N, 115°37'57" W | 43°31'44" N, 119°54'4" W | 41°51"16" N, 113°2'46" W | 42°39'43" N, 115°28'18" W |
| County, State | Elmore, ID | Lake, OR | Box Elder, UT | Elmore, ID |
| Wildfire (date) | 6 Jul 2007 | 5 Jul 2007 | 22 Sep 2008 | 29 Jun 2010 |
| Fall seeding | 29-30 Oct 2007 | 31 Oct-1 Nov 2007 | 18-19 Nov 2008 | 27-28 Oct 2010 |
| Winter broadcast (date) | 18 Jan 2008 | 16 Jan 2008 | 29 Jan 2009 | 15 Feb 2011 |
| Elevation (m) | 911 | 1,430 | 1,422-1,475 | 1,204 |
| Annual precipitation (mm)[1] | 178-305 | 203-305 | 203-356 | 203-330 |
| Frost-free days[1] | 100-170 | 50-90 | 100-150 | 90-170 |
| Soil[1] | Coarse-silty, mixed, superactive mesic Xereptic and Xeric Haplocalcids | Ashy, glassy, frigid Vitriorrandic Haploxerolls | Loamy- skeletal, mixed, mesic Xeric Haplocalcids; Sandy-skeletal, mixed, mesic Xeric Torriorthents | Fine-silty, mixed, superactive, mesic Haploxeralfic Argidurids, Durinodic Xeric Haplargids, and Xeric Natridurids |

[1]Soil Survey Staff (2011).

**Table 2.** Seeding treatments applied post-fire at Scooby and Saylor Creek.

| Treatment | Drill | Drill mix[1] | Broadcast mix[2] | Wyoming big sagebrush seeding rate[2] |
|---|---|---|---|---|
| C | Control (no drill, no seed) | | | |
| R0 | Rangeland drill | No seed | | |
| R1X | | Drilled in alternate rows in fall | Broadcast through drill in alternate rows - fall | 1X |
| R5X | | | | 5X |
| R10X | | | | 10X |
| Rf+BC5X | | | Hand broadcast in fall | 5X |
| Rw+BC5X | | | Hand broadcast in winter | 5X |
| M0 | Minimum-till drill | No seed | | |
| M1X | | Drilled in alternate rows in fall | Broadcast through drill in alternate rows in fall | 1X |
| M5X | | | | 5X |
| M10X | | | | 10X |
| Mf+BC5X | | | Hand broadcast in fall | 5X |
| Mw+BC5X | | | Hand broadcast in winter | 5X |

[1]One drill mix was used for all seeding treatments.
[2]The broadcast mix varies among treatments only by the Wyoming big sagebrush seeding rate.

**Table 3.** Seed mixes for post-fire seedings in the Northern Great Basin.

| Site | Mix / Species | Source | PLS (%) | PLS*/m² 1X** | 5X | 10X |
|---|---|---|---|---|---|---|
| **MT. HOME** | Broadcast mix | | | | | |
| | *Artemisia tridentata* spp. *wyomingensis* | Lincoln/Blaine/Jerome Co., ID (1230 m) | 20.9 | 52 | 262 | 525 |
| | *Ericameria nauseosa* | Uinta Co., WY (2060m) | 27.0 | 86 | 86 | 86 |
| | *Poa secunda* | Mountain Home Germplasm | 83.9 | 91 | 91 | 91 |
| | *Penstemon deustus* | Northern Great Basin - pooled | 56.2 | 76 | 76 | 76 |
| | | Total Broadcast | | 305 | 515 | 778 |
| | Drill mix | | | | | |
| | *Pseudoroegneria spicata* | Anatone Germplasm | 86.3 | 67 | 67 | 67 |
| | *Achnatherum hymenoides* | 'Rimrock' | 85.7 | 51 | 51 | 51 |
| | *Elymus elymoides* | Toe Jam Creek Germplasm | 91.6 | 47 | 47 | 47 |
| | *Sphaeralcea munroana* | Utah Co., UT (1470 m) | 53.2 | 93 | 93 | 93 |
| | *Eriogonum umbellatum* | Northern Great Basin - pooled | 61.0 | 8 | 8 | 8 |
| | | Total Drill | | 266 | 266 | 266 |
| | | **Total Drill + Broadcast** | | 571 | 781 | 1044 |
| **GLASS BUTTE** | Broadcast mix | | | | | |
| | *A. tridentata* ssp. *wyomingensis* | Elko/Humboldt Co., NV (1220-1830 m) | 29.3 | 52 | 234 | 495 |
| | *Ericameria nauseosa* | Uinta Co., WY (2060 m) | 27.0 | 86 | 86 | 86 |
| | *Poa secunda* | Mountain Home Germplasm | 83.9 | 91 | 91 | 91 |
| | *Penstemon deustus* | Northern Great Basin - pooled | 56.2 | 76 | 76 | 76 |
| | | Total Broadcast | | 305 | 487 | 748 |
| | Drill mix | | | | | |
| | *Pseudoroegneria spicata* | Anatone Germplasm | 86.3 | 67 | 67 | 67 |
| | *Achnatherum hymenoides* | 'Rimrock' | 85.7 | 51 | 51 | 51 |
| | *Elymus elymoides* | Toe Jam Creek Germplasm | 91.6 | 47 | 47 | 47 |
| | *Sphaeralcea munroana* | Utah Co., UT (1470 m) | 53.2 | 93 | 93 | 93 |
| | *Eriogonum umbellatum* | Northern Great Basin - pooled | 61.0 | 11 | 11 | 11 |
| | | Total Drill | | 269 | 269 | 269 |
| | | **Total Drill + Broadcast** | | 574 | 756 | 1017 |
| **SCOOBY** | Broadcast mix | | | | | |
| | *A. tridentata* spp. *wyomingensis* | Sanpete Co., UT (1460 m) | 17.5 | 52 | 234 | 495 |
| | *Ericameria nauseosa* | Sanpete Co., UT (1460 m) | 14.8 | 86 | 86 | 86 |
| | *Poa secunda* | Mountain Home Germplasm | 81.6 | 91 | 91 | 91 |
| | *Achillea millefolium* | Eagle Germplasm | 88.2 | 100 | 100 | 100 |
| | *Penstemon cyaneus* | Lincoln Co., ID (1370 m) | 69.2 | 76 | 76 | 76 |
| | | Total Broadcast | | 405 | 587 | 848 |
| | Drill mix | | | | | |
| | *Pseudoroegneria spicata* | Anatone Germplasm | 88.9 | 67 | 67 | 67 |
| | *Achnatherum hymenoides* | 'Rimrock' | 98.0 | 51 | 51 | 51 |
| | *Elymus elymoides* | Toe Jam Creek Germplasm | 94.3 | 47 | 47 | 47 |
| | *Sphaeralcea munroana* | Uintah Co., UT (1550 m) | 65.8 | 93 | 93 | 93 |
| | *Eriogonum umbellatum* | Northern Great Basin - pooled | 50.4 | 11 | 11 | 11 |
| | | Total Drill | | 269 | 269 | 269 |
| | | **Total Drill + Broadcast** | | 674 | 856 | 1117 |
| **SAYLOR CREEK** | Broadcast mix | | | | | |
| | *A. tridentata* spp. *wyomingensis* | Power Co., ID (1390 m) | 28.4 | 50 | 250 | 500 |
| | *Ericameria nauseosa* | Utah Co., UT (1650 m) | 40.5 | 85 | 85 | 85 |
| | *Poa secunda* | Mountain Home Germplasm | 82.0 | 100 | 100 | 100 |
| | *Achillea millefolium* | Eagle Germplasm | 94.3 | 100 | 100 | 100 |
| | *Penstemon speciosus* | Northern Great Basin - pooled | 57.8 | 15 | 15 | 15 |
| | | Total Broadcast | | 350 | 550 | 800 |
| | Drill mix | | | | | |
| | *Pseudoroegneria spicata* | Anatone Germplasm | 80.0 | 60 | 60 | 60 |
| | *Achnatherum hymenoides* | 'Rimrock' | 96.6 | 50 | 50 | 50 |
| | *Elymus elymoides* | Emigrant Germplasm | 97.0 | 35 | 35 | 35 |
| | *Achnatherum thuberianum* | Snake River Plain - pooled | 55.4 | 30 | 30 | 30 |
| | *Hesperostipa comata* | Millard Co., UT | 77.6 | 20 | 20 | 20 |
| | *Sphaeralcea munroana* | Uintah Co., UT (1550 m) | 61.0 | 40 | 40 | 40 |
| | *Astragalus filipes* | Dry River, Deschutes Co., OR (1330 m) | 90.0 | 14 | 14 | 14 |
| | | Total Drill | | 249 | 249 | 249 |
| | | **Total Drill + Broadcast** | | 599 | 799 | 1049 |

*Pure live seed.

**Drill seed mix does not vary among treatments. Broadcast mix varies only by big sagebrush seeding rate, see Table 2.

## Data Analysis

Density (first year only) and cover of broadcast species, drilled species and cheatgrass (*Bromus tectorum*) were analyzed in SAS 9.3 (SAS Institute Inc. 2011) as general linear mixed effects models with the Poisson distribution. Tukey's HSD was used for mean comparisons. Effects of sagebrush seeding rate and drill/broadcast seeding method were analyzed separately by parsing out relevant treatment levels. The effect of drill impact—independent of seeding—on cheatgrass and non-seeded residual species was analyzed by parsing out treatments with no seed. Site and block were nested random effects in these analyses which included all four sites. We also compared sites but without formal statistical tests.

## Results

### *Effects of Drill Type and Seeding Method/Timing*

When the broadcast species mix was broadcast through the drills, first-year density (Figure 2) was higher and cover within years (Figure 3) was similar for the minimum-till compared to the rangeland drill. When hand seeded, the fall (as opposed to winter) broadcast yielded higher density and cover of broadcast species in the rangeland drill, but not in the minimum-till (Figures 2 and 3). When seed was broadcast through the minimum-till drill, first year density was greater and cover within years was similar compared to hand-seeded broadcast treatments (Figures 2 and 3).

Density, but not cover, of the drilled species mix was higher with the rangeland drill than the minimum-till drill (Figures 2 and 3). Rangeland drill treatments had significantly lower cheatgrass density than equivalent minimum-drill treatments (Figure 2); however cheatgrass cover did not differ except among non-seeded treatments (Figure 3). Mean cheatgrass densities during the first year were all less than 40 $m^{-2}$ (Figure 2). Cover of all species categories (cheatgrass, broadcast species and drilled species) increased substantially between the first and second years (Figure 3).

### *Sagebrush Seeding Rate Effects*

First-year sagebrush seedling density increased linearly to geometrically with each increase in seeding rate (Figure 4). Higher densities were achieved with the minimum-till drill (Figure 4). Densities declined in all treatments by the second year but treatment differences remained (Figure 4).

### *Drill Impact Independent of Seeding*

Drilling with empty seed boxes was used to simulate failed seedings and allowed drill impacts to be examined independent of seeding effects. Cover of residual non-seeded plants was higher in minimum-till than rangeland drill treatments (Figure 5), but cheatgrass cover was also higher in minimum till (Figure 6). On the other hand, neither minimum-till nor rangeland drill treatments differed significantly from the control treatment (no drilling or seeding) in cover of residual non-seeded plants and cheatgrass (Figures 5 and 6).

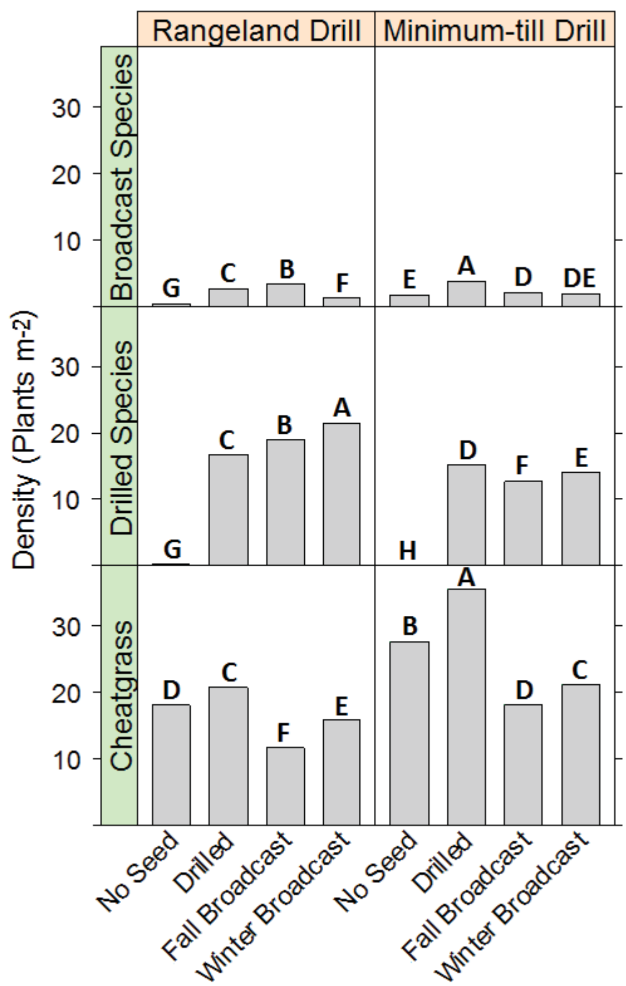
### *Variation by Site*

Sites differed noticeably in seeded species establishment and cheatgrass dominance, as illustrated by graphs of 2$^{nd}$ year mean cover by site and treatment (Figure 7). These site differences can be interpreted in terms of site potential, which is largely a function of elevation, and precipitation patterns during the post-treatment period. Glass Butte and Scooby are higher elevation sites (relative to Mountain Home and Saylor Creek) and thus appear to have greater potential for seeding success, but because of differences in post-treatment precipitation and the greater presence of residual perennial grasses and forbs at Glass Butte, drilled species establishment was higher at Scooby than Glass Butte (Figure 7). Even so, Glass Butte had relatively high establishment of broadcast species (Figure 7). Saylor Creek and Mountain Home also differed in post-treatment precipitation and seeding establishment; Saylor Creek seedings were moderately successful and had only moderate amounts of cheatgrass, while Mountain Home had poor seedling establishment and high cheatgrass dominance (Figure 7) in conjunction with low precipitation during the first two years post-treatment.

Conclusions

The minimum-till drill performs similarly to the rangeland drill for drilled species and better for broadcast species including sagebrush. Seeding broadcast species through the minimum-till drill provided greater or equal cover than any treatments that simulated aerial seeding. The rangeland drill reduces cheatgrass density during the first year following treatment but also reduces residual plant recovery compared to the minimum-till drill. Appropriate seeding techniques, timing and rates can improve native plant seeding success, but adverse site conditions, such as low precipitation, weed seed banks, etc. remain an issue.

**Figure 2**. First-year density by drill type and seeding method/ broadcast timing. Within each species category, means with the same letter are not significantly different ($p \geq 0.5$).



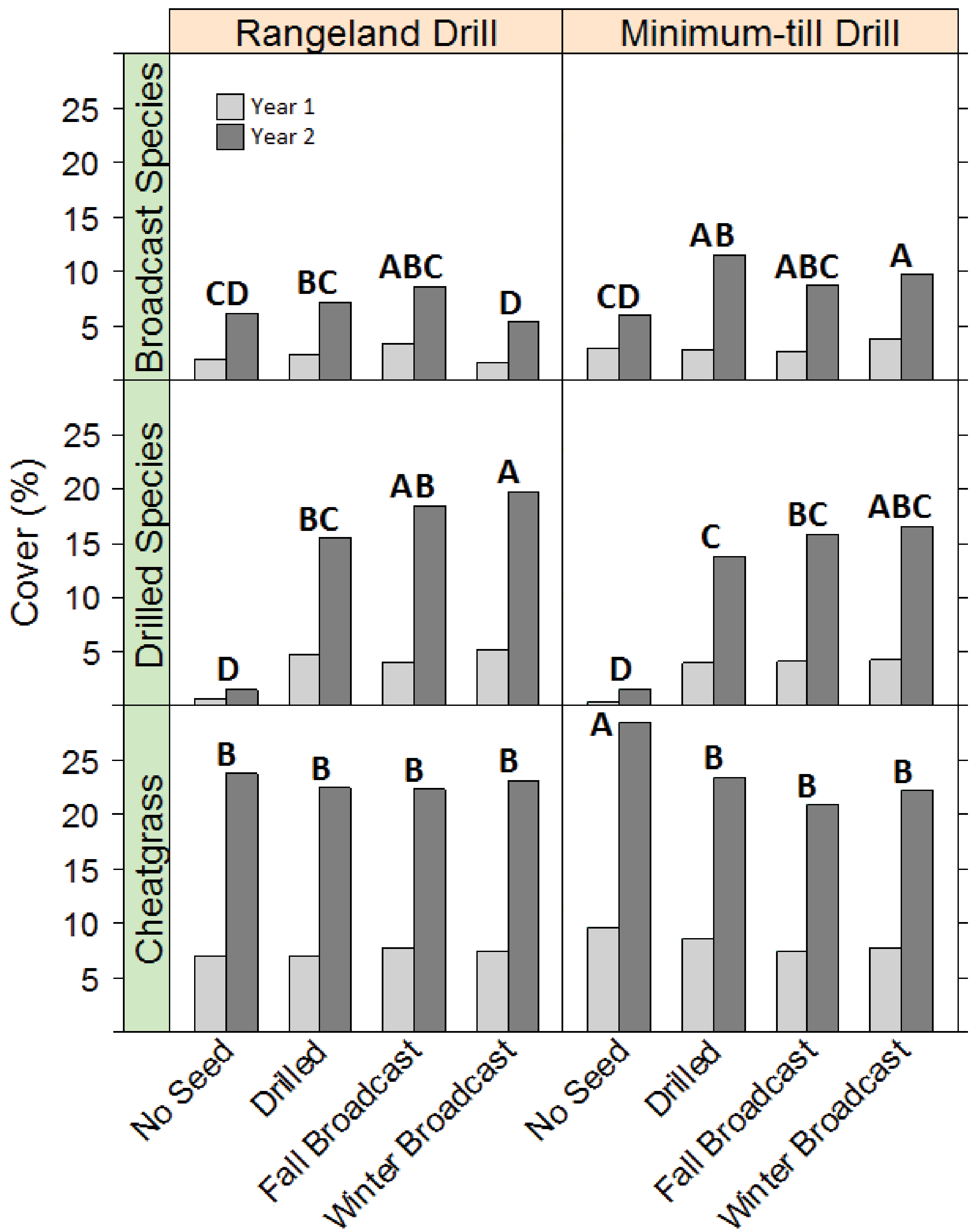



**Figure 3**. Cover by drill type and seeding method/broadcast timing. For each species category, within-year means with the same letter are not significantly different ($p \geq 0.5$). Year 2 means were significantly higher than Year 1 within treatments.

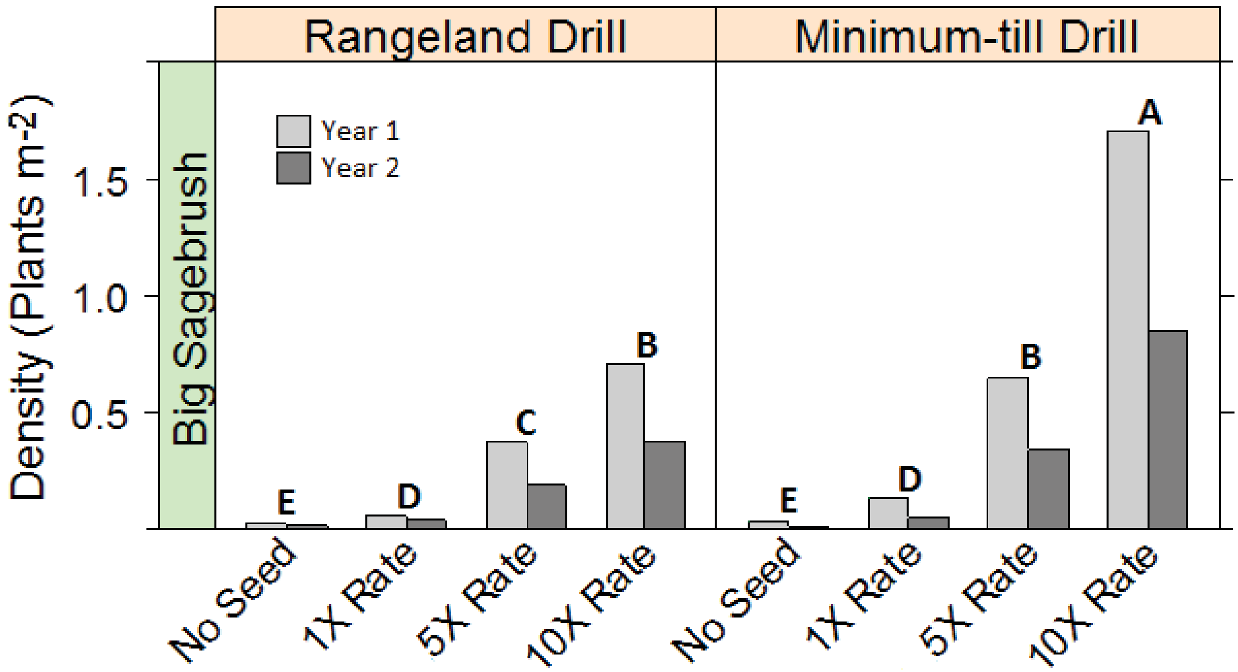



**Figure 4.** Density of Wyoming big sagebrush by drill type and seeding rate. Within-year means with the same letter are not significantly different ($p \geq 0.5$). Year 2 means were significantly lower than Year 1 means within treatments.

**Figure 5.** Cover of non-seeded plants in non-seeded treatments. Within-year means with the same letter are not significantly different ($p \geq 0.5$). Year 2 means were significantly higher than Year 1 means within treatments.

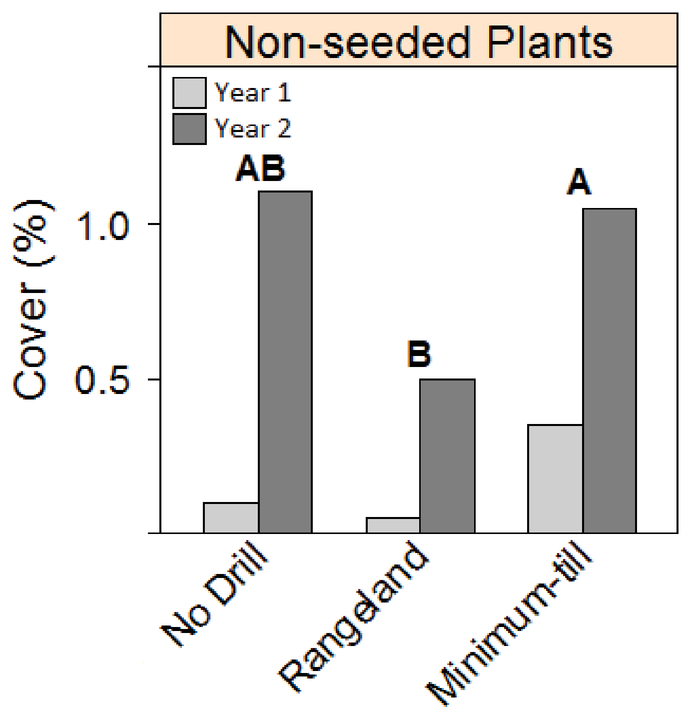
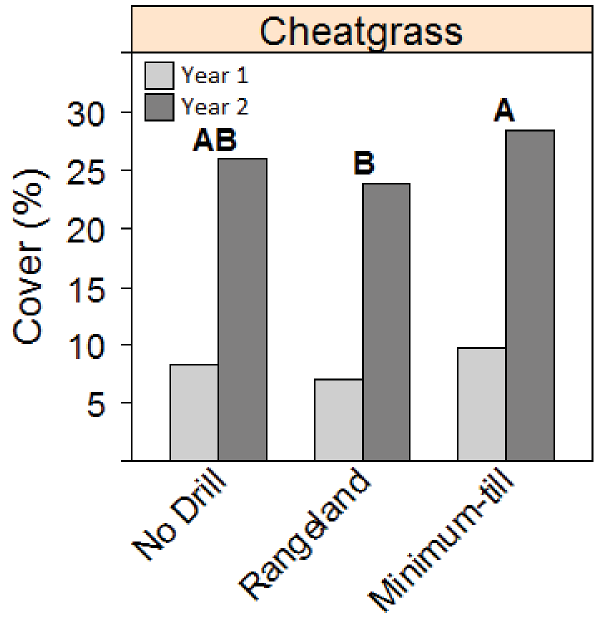


Figure 6. Cover of cheatgrass in non-seeded treatments. Within-year means with the same letter are not significantly different (p>=0.5). Year 2 means were significantly higher than Year 1 means within treatments.



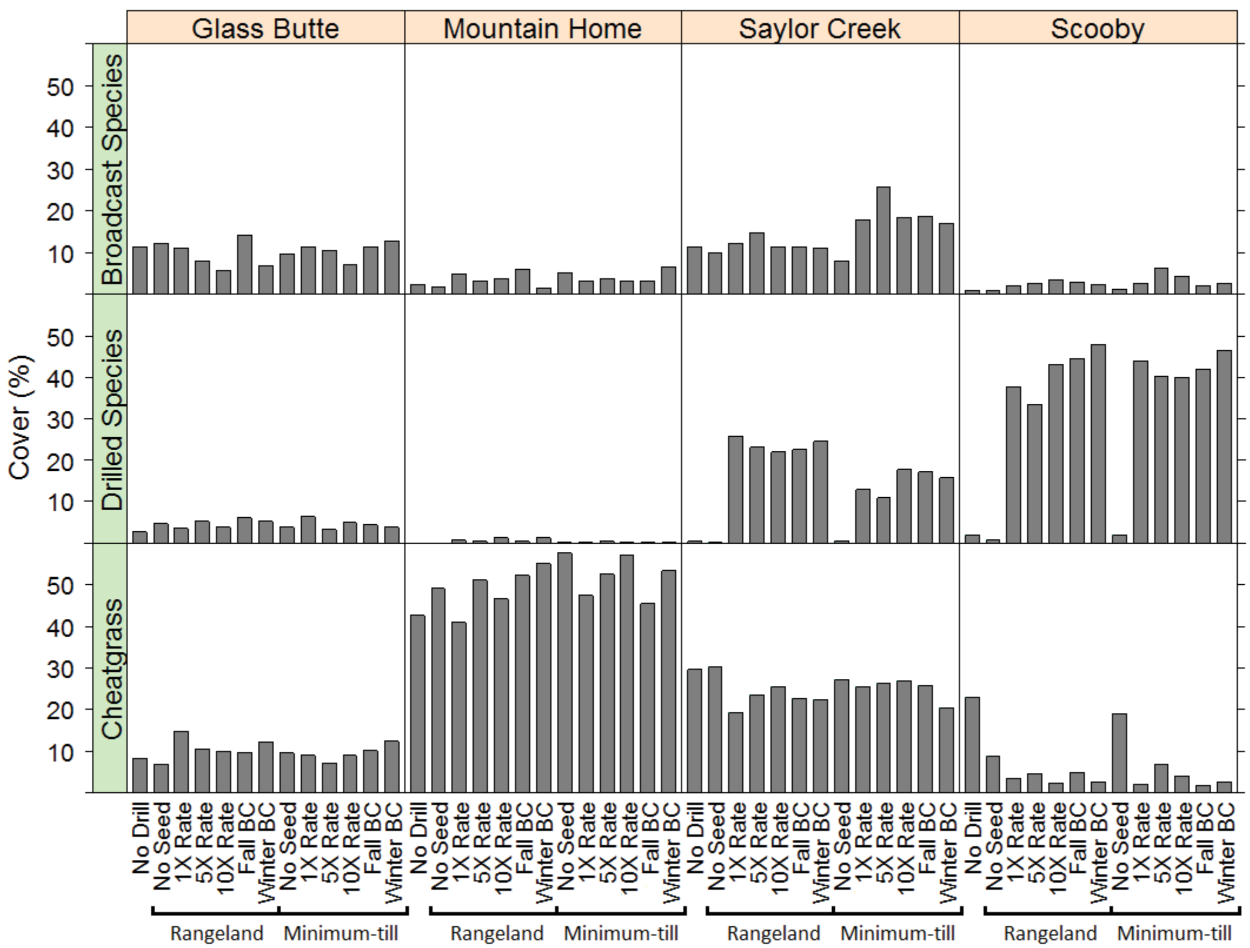




Figure 7. Second-year cover by site and treatment for three species categories.

## B. Plant Materials Development and Distribution

Seed Collection
Fifty-five collections of 25 species were made in 2012.

Distribution of Seed to Growers
Seed of two species was distributed to one private sector seed grower for seed increase and commercial sales. Seed of two species was provided to the USDA NRCS Aberdeen Plant Materials Center and Utah Division of Wildlife Resources for seed stock increase (Table 1).

Seed Distribution
1. Forty-two total collections consisting of 19 species were distributed to the USDA Agriculture Research Service Western Regional Plant Introduction Station/Seeds of Success Program for addition to the Germplasm Resources Information Network (GRIN) system: http://www.ars-grin.gov/ system (Appendix V).
2. Seventy-eight collections and seed mixes were distributed to cooperators and other users, totaling 33.7 kg (Appendix VI).

**Table 1.** Seed lots distributed to private growers, seed increase, and stock seed provided to Utah Crop Improvement Association in 2012.

| Species | Distribution | Seed Origin (county, state or ecoregion) | Source Type | Kg | Number of growers |
|---|---|---|---|---|---|
| *Achillea millefolium* var. *occidentalis* Western yarrow Eagle germplasm | private grower | Snake River Plain | Singe | 4.237 | 1 |
| *Balsamorhiza sagittata* Hooker's balsamroot | seed increase | Snake River Plain | Single | 0.454 | 1 |
| *Pseudoroegneria spicata* Bluebunch wheatgrass | seed increase | Columbia Plateau | Single | 0.39 | 1 |
| *Penstemon acuminatus* Sharpleaf penstemon | private grower | Snake River Plain | Pooled | 3.175 | 1 |
| | | **TOTAL SEED DISTRIBUTED (kg)** | | **8.256** | |

**Publications**

Friggens, M. M.; Pinto, J. R.; Dumroese, R. K.; Shaw, N. L. 2012. Chapter 8. Decision support: vulnerability, conservation, and restoration. In: Finch, D. M., ed. Climate change in grasslands, shrublands, and deserts of the interior American West: a review and needs assessment. Gen. Tech. Rep. RMRS-GTR-285. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 116-139.

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**Presentations**

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Fisk, M.; Denney, E.; Cox, R.; Shaw, N. 2012. Post-fire native seeding strategies: results from a Wyoming big sagebrush site in northern Nevada. Society for Range Management 65th Annual Meeting, 2012 January 28 – February 3, Spokane, WA. (poster). Also presented at the Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT.

Fisk, M. R.; Malcomb, A. 2012. Grassland, Shrubland and Desert Ecosystem Research Program: Collaboration and research challenges, College of Western Idaho, 2012 October 31, Boise, ID.

McAdoo, K.; Swanson, J.; Shaw, N. 2012. Evaluating strategies for increasing plant diversity in crested wheatgrass seedings. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT.

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Taylor, M.; Hild, A.; Shaw, N.; Denney, E.; Fisk, M. 2012. Rehabilitation seeding and soil dynamics associated with invasive species in a semi-desert sagebrush shrubland. Society for Range Management 65th Annual Meeting, 2012 January 28-February 3, Spokane, WA (received best M.S. presentation award). Also presented at Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT.

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*Workshops*

Great Basin Native Plant Selection and Increase Project 2012 Annual Meeting, 2012 February 21-22, Salt Lake City, UT.

Native plant material programs and arid land issues and restoration strategies – field tour for Kuwaiti Scientists, 2012 October 8-9, Boise, ID. Field tour sponsored by USDI BLM.

Preparing and seeding multi-species mixtures, drill calibration and operation, 2012 July 18, Boise, ID. Workshop co-sponsored by USDI BLM, Morley Nelson Birds of Prey National Conservation Area.

Co-organized a session on native plant materials for the 8th European Conference on Ecological Restoration, 2012 September 9-14, České Budějovice, Czech Republic.

*Great Basin Native Plant Selection and Increase Project Exhibit*
*Presented at:*
Great Basin Native Plant Selection and Increase Project Annual Meeting, 2012 February 21-22, Salt Lake City, UT.

Native Plant Field Day at the Oregon State University Malheur Experiment Station, 2012 May 16, Ontario, OR.

**Management Applications and Seed Production Guidelines**
Emergence of broadcast-seeded species, but not drilled species is enhanced by use of the minimum-till drill. Seeding broadcast species through the minimum-till drill provided greater or equal cover than any treatments that simulated aerial seeding, thus a one-pass seeding of large- and small-seeded species through the minimum-till drill could be as effective as and more economical than drilling large-seeded species followed by aerial seeding. Use of the minimum-till drill can also reduce loss of residual species compared to the rangeland drill, but the rangeland drill does bury some cheatgrass seed, reducing its density. Operationally, use of one drop for the generally more expensive small-seeded species might be adequate to provide added diversity to native seedings.

**Products**

- A workshop held at the USDI BLM Morley Nelson Birds of Prey National Conservation Area provided users with instruction on seeding multi-species mixtures and drill calibration and operation.
- Collaboration with the USDA NRCS Aberdeen Plant Material Center and the Oregon State University Malheur Experiment Station resulted in publication of six Extension Bulletins and Reports, five Plant Guides, and three Plant Propagation Protocols. These publications summarize information on seed technology and seed production for use by seed growers.
- Seed lots of eight species were added to the stock seed inventory available to growers.

**Appendix I.** Research species and their occurrence in Great Basin states.

| Family<br>Species | | Idaho | Nevada | Oregon | Utah |
|---|---|---|---|---|---|
| **Apiaceae** | **Carrot Family** | | | | |
| *Lomatium dissectum* | Fernleaf biscuitroot | √ | √ | √ | √ |
| *Lomatium grayi* | Gray's biscuitroot | √ | √ | √ | √ |
| *Lomatium nudicaule* | Barestem biscuitroot | √ | √ | √ | √ |
| *Lomatium triternatum* | Nineleaf biscuitroot | √ | √ | √ | √ |
| *Perideridia bolanderi* | Bolander's yampah | √ | √ | √ | √ |
| **Asteraceae** | **Sunflower or Aster Family** | | | | |
| *Achillea millefolium occidentalis* | Western yarrow | √ | √ | √ | √ |
| *Agoseris grandiflora* | Bigflower agoseris | √ | √ | √ | √ |
| *Agoseris heterophylla* | Annual agoseris | √ | √ | √ | √ |
| *Artemisia tridentata tridentata* | Basin big sagebrush | √ | √ | √ | √ |
| *Artemisia tridentata vaseyana* | Mountain big sagebrush | √ | √ | √ | √ |
| *Artemisia tridentata wyomingensis* | Wyoming big sagebrush | √ | √ | √ | √ |
| *Balsamorhiza hookeri* | Hooker balsamroot | √ | √ | √ | √ |
| *Balsamorhiza sagittata* | Arrowleaf balsamroot | √ | √ | √ | √ |
| *Blepharipappus scaber* | Rough eyelashweed | √ | √ | √ | |
| *Chaenactis douglasii* | Douglas' dustymaiden | √ | √ | √ | √ |
| *Crepis acuminata* | Tapertip hawksbeard | √ | √ | √ | √ |
| *Crepis intermedia* | Gray hawksbeard | √ | √ | √ | √ |
| *Crepis occidentalis* | Western hawksbeard | √ | √ | √ | √ |
| *Enceliopsis nudicaulis* | Nakedstem sunray | √ | √ | | √ |
| *Erigeron speciosus* | Aspen fleabane | √ | √ | √ | √ |
| *Eriophyllum lanatum* | Common woolly sunflower, Oregon sunshine | √ | √ | √ | √ |
| *Gaillardia aristata* | Blanketflower | √ | | √ | √ |

| Family<br>Species | | Idaho | Nevada | Oregon | Utah |
|---|---|---|---|---|---|
| *Heliomeris multiflora multiflora* | Showy goldeneye | √ | √ | | √ |
| *Heliomeris multiflora nevadensis* | Nevada goldeneye | | √ | | √ |
| *Heterotheca villosa* | Hairy false goldenaster | √ | √ | √ | √ |
| *Machaeranthera canescens* | Hoary tansyaster | √ | √ | √ | √ |
| *Wyethia amplexicaulis* | Mule-ears | √ | √ | √ | √ |
| **Boraginaceae** | **Borage Family** | | | | |
| *Amsinckia menziesii intermedia* | Common fiddleneck | √ | √ | √ | √ |
| *Amsinckia tessellata* | Bristly fiddleneck | √ | √ | √ | √ |
| *Cryptantha pterocarya* | Wingnut cryptantha | √ | √ | √ | √ |
| *Lappula occidentalis* | Flatspine stickseed | √ | √ | √ | √ |
| *Phacelia crenulata* | Cutleaf wildheliotrope | | √ | | √ |
| *Plagiobothrys tenellus* | Pacific popcornflower | √ | √ | √ | √ |
| **Brassicaceae** | **Mustard Family** | | | | |
| *Descurainia pinnata* | Western tansymustard | √ | √ | √ | √ |
| *Thelypodium milleflorum* | Manyflower thelypodium | √ | √ | √ | √ |
| **Capparaceae** | **Caper Family** | | | | |
| *Cleome lutea* | Yellow beeplant | √ | √ | √ | √ |
| *Cleome serrulata* | Rocky Mountain beeplant | √ | √ | √ | √ |
| **Fabaceae** | **Legume Family** | | | | |
| *Astragalus eremiticus* | Hermit milkvetch | √ | √ | √ | √ |
| *Astragalus filipes (A. stenophyllus)* | Basalt milkvetch, threadstalk milkvetch | √ | √ | √ | √ |
| *Dalea ornata* | Blue Mountain prairie clover, prairie clover | √ | √ | √ | |
| *Dalea searlsiae* | Searls' prairie clover | | √ | | √ |
| *Lupinus arbustus* | Longspur lupine | √ | √ | √ | √ |
| *Lupinus argenteus* | Silvery lupine | √ | √ | √ | √ |
| *Lupinus caudatus* | Tailcup lupine | √ | √ | √ | √ |
| *Lupinus malacophyllus* | Jawleaf lupine | | √ | | |

| Family<br>Species | | Idaho | Nevada | Oregon | Utah |
|---|---|---|---|---|---|
| *Lupinus polyphyllus* | Bigleaf lupine | √ | √ | √ | |
| *Lupinus prunophilus* | Hairy bigleaf lupine | √ | √ | √ | √ |
| *Lupinus sericeus* | Silky lupine | √ | √ | √ | √ |
| **Gentianaceae** | **Gentian Family** | | | | |
| *Frasera albomarginata* | Desert frasera | | √ | | √ |
| **Hydrophyllaceae** | **Waterleaf Family** | | | | |
| *Phacelia hastata* | Silverleaf phacelia | √ | √ | √ | √ |
| *Phacelia linearis* | Threadleaf phacelia | √ | √ | √ | √ |
| **Lamiaceae** | **Mint Family** | | | | |
| *Agastache urticifolia* | Nettleleaf giant hyssop | √ | √ | √ | √ |
| **Liliaceae** | **Lily Family** | | | | |
| *Allium acuminatum* | Tapertip onion | √ | √ | √ | √ |
| **Linaceae** | **Flax Family** | | | | |
| *Linum lewisii* | Lewis flax | √ | √ | √ | √ |
| *Linum subteres* | Sprucemont flax | | √ | | √ |
| **Loasaceae** | **Loasa Family** | | | | |
| *Mentzelia albicaulis* | Whitestem blazingstar | √ | √ | √ | √ |
| *Mentzelia laevicaulis* | Smoothstem blazingstar | √ | √ | √ | √ |
| *Mentzelia veatchiana* | Veatch's blazingstar | | √ | √ | |
| **Malvaceae** | **Mallow Family** | | | | |
| *Sphaeralcea ambigua* | Globemallow | | √ | | √ |
| *Sphaeralcea coccinea* | Scarlet globemallow | √ | √ | √ | √ |
| *Sphaeralcea grossulariifolia* | Gooseberryleaf globemallow | √ | √ | √ | √ |
| *Sphaeralcea munroana* | Munro's globemallow | √ | √ | √ | √ |
| *Sphaeralcea parvifolia* | Small-flower globemallow | | √ | | √ |
| **Onagraceae** | **Evening Primrose Family** | | | | |
| *Epilobium brachycarpum* | Tall annual willowherb | √ | √ | √ | √ |
| *Oenothera caespitosa* | Tufted evening primrose | √ | √ | √ | √ |

| Family<br>Species | | Idaho | Nevada | Oregon | Utah |
|---|---|---|---|---|---|
| **Papaveraceae** | **Poppy Family** | | | | |
| *Argemone munita* | Flatbud pricklypoppy | √ | √ | √ | √ |
| **Poaceae** | **Grass Family** | | | | |
| *Achnatherum hymenoides* | Indian ricegrass | √ | √ | √ | √ |
| *Achnatherum thurberianum* | Thurber's needlegrass | √ | √ | √ | √ |
| *Elymus elymoides* | Squirreltail | √ | √ | √ | √ |
| *Elymus multisetus* | Big squirreltail | √ | √ | √ | √ |
| *Hesperostipa comata* | Needle and thread | √ | √ | √ | √ |
| *Leymus cinereus* | Great Basin wildrye | √ | √ | √ | √ |
| *Poa secunda* | Sandberg bluegrass | √ | √ | √ | √ |
| *Vulpia octoflora* | Six weeks fescue | √ | √ | √ | √ |
| *Pseudoroegneria spicata* | Bluebunch wheatgrass | √ | √ | √ | √ |
| **Polemoniaceae** | **Phlox Family** | | | | |
| *Eriastrum sparsiflorum* | Great Basin woollystar | √ | √ | √ | √ |
| *Ipomopsis aggregata* | Scarlet gilia | √ | √ | √ | √ |
| *Phlox longifolia* | Longleaf phlox | √ | √ | √ | √ |
| **Polygonaceae** | **Buckwheat Family** | | | | |
| *Eriogonum heracleoides* | Parsnipflower buckwheat, Wyeth buckwheat | √ | √ | √ | √ |
| *Eriogonum microthecum* | Slender buckwheat | √ | √ | √ | √ |
| *Eriogonum ovalifolium* | Cushion buckwheat | √ | √ | √ | √ |
| *Eriogonum sphaerocephalum* | Rock buckwheat | √ | √ | √ | |
| *Eriogonum sphaerocephalum sphaerocephalum* | Rock buckwheat | √ | √ | √ | |
| *Eriogonum umbellatum* | Sulfur-flower buckwheat | √ | √ | √ | √ |
| **Scrophulariaceae** | **Snapdragon Family** | | | | |
| *Penstemon acuminatus* | Sharpleaf penstemon | √ | √ | √ | |
| *Penstemon cyaneus* | Blue penstemon | √ | | | |
| *Penstemon deustus* | Scabland penstemon | √ | √ | √ | √ |

| **Family**<br>**Species** | | **Idaho** | **Nevada** | **Oregon** | **Utah** |
|---|---|---|---|---|---|
| *Penstemon eatonii* | Firecracker penstemon | | √ | | √ |
| *Penstemon pachyphyllus* | Thickleaf penstemon | | √ | | √ |
| *Penstemon speciosus* | Royal penstemon | √ | √ | √ | √ |
| **Solanaceae** | **Nightshade Family** | | | | |
| *Nicotiana attenuata* | Coyote tobacco | √ | √ | √ | √ |

## Appendix II. UCIA STOCK MATERIALS TAGGING INFORMATION FORM (1/23/2012)

**Utah Crop Improvement Assn. 4855 Old Main Hill Logan, UT 84322-4855 Ph (435) 797-2082 Fax (435) 797-0642**

Please complete this form in detail when requesting certification tags for plant materials sent to growers for stock increase.

Propagative type (seeds, plants, cuttings, etc.) ______________ Amount sent ______________ Date sent ____________

Tag Request Date ___________

| | |
|---|---|
| Breeder/Developer | |
| Agency/Company | |
| Address | |
| Phone/Cell | Email |

| | |
|---|---|
| Stock Material Recipient | |
| Address | |
| Phone/Cell | Email |

| | |
|---|---|
| Species | Common Name |

DEVELOPMENT STAGE:

| | |
|---|---|
| ☐ A. | **Pre-Variety Germplasm** (SI, S, or T germplasm not intended for variety release) |
| ☐ B. | **Experimental Variety** (germplasm being developed for variety release) |
| ☐ C. | **Released Variety** |

DEVELOPMENTAL STAGE DETAILS:

A. **Pre-Variety Germplasm** Source Identified (SI) ☐ Selected (S)[1] ☐ Tested (T)[1] ☐

1. PVG Official Release: Completed ☐ Intended ☐ Not Intended ☐
2. Germplasm Identification Term (Germplasm ID): ____________________________________________________________[2]
3. Material Transfer Agreement required?[3] Yes ☐ No ☐
4. Stock material lot #:______________________________[4] Seed certification #:________________________ (if assigned)
5. Generation of this lot #, and Generation limitation (if specified): G__ / G__
6. (a) G0 Source location if stock material is Natural-Track:
   County:[5] ___________________________________ State:[5] __________ Elevation: __________
   (b) G0 indigenous? Yes ☐ No ☐ Unknown ☐
   (c) G1 origin location if Manipulated-Track:[6]
   County: ___________________________________ State: ___________ Elevation: __________
7. If applicable, field production location where this lot # was produced:
   County: ___________________________________ State: ___________ Elevation: __________

B. **Experimental Variety**

1. Experimental number of designation: ___________________________________________________________
2. Material Transfer Agreement required? Yes ☐ No ☐
3. Certification status equivalent of this stock material:
   Breeder ☐ Experimental-F ☐ Experimental-R ☐ Other: ______________________
4. Stock material lot #: ______________________________[4] Seed Certification #: _______________________ (if assigned)

C. **Released Variety**

1. Variety name: _____________________________________________________________________________
2. PVP applied for? Yes ☐ No ☐
3. Certification status of this stock material:
   Breeder ☐ Foundation ☐ Registered ☐
4. Stock material lot #: ______________________________[4] Seed Certification #: _______________________ (if assigned)

**Appendix III.** Great Basin Native Plant Selection and Increase Project (GBNPSIP) seed increase, stock seed, an
availability. Funding provided by: USDI Bureau of Land Management, GBNPSIP, USDA Forest Service Rocky
Station, and Utah Division of Wildlife Resources.

| Plant Code | Scientific Name | Common Name | Lab[1] | Source[2] | # of pop |
|---|---|---|---|---|---|
| **GRASSES** | | | | | |
| ACTH7 | *Achnatherum thurberianum* | Thurber needlegrass | BOI | SRP | |
| ELEL5 | *Elymus elymoides* | Squirreltail Little Sahara germplasm | UCIA | CBR (Little Sahara, near Jericho, UT) | |
| ELELC2 | *Elymus elymoides* ssp. *californicus* | Squirreltail Toe Jam Creek Selected Germplasm | FRRL | NBR (northern Nevada source) | |
| ELELE | *Elymus elymoides* ssp. *elymoides* | Squirreltail Fish Creek Selected Germplasm | FRRL | NBR (southern Idaho source) | |
| HECO26 | *Hesperostipa comata* | Needle-and-thread | SSL/ DWR | < 10 in precip/< $80^{o}$ | |
| LECI4Y | *Leymus cinereus* | Basin wildrye | UCIA | CBR/NBR (Intermountain Tetra - multiple Great Basin sources) | |
| POSE | *Poa secunda* | Sandberg bluegrass Mountain Home Selected Germplasr | BOI | SRP | |
| PSSP6 | *Pseudoroegneria spicata* | Bluebunch wheatgrass Anatone Selected Germplasm | BOI/S SL/AB D | CP | |
| **FORBS** | | | | | |
| ACMIO | *Achillea millefolium* ssp. *occidentalis* | Western yarrow Eagle Selected Germplasm | BOI | SRP | |
| AGHE2 | *Agoseris heterophylla* | Annual goat chicory | SSL/ DWR | 14-24 in. precip. / 70-$80^{o}$ | |
| ARMU | *Argemone munita* | Flat-bud prickley-poppy | SSL/ DWR | 14-24 in. precip. / 70-$80^{o}$ | |
| ASFI | *Astragalus filipes* | Basalt milkvetch NBR1 Selected Germplasm | FRRL | NBR | |
| BAHO | *Balsamorhiza hookeri* | Hooker's balsamroot | BOI | CBR | |

| Plant Code | Scientific Name | Common Name | Lab[1] | Source[2] | # of pop |
|---|---|---|---|---|---|
| CHDO | *Chaenactis douglasii* | Douglas' dustymaiden | BOI | NBR | |
| CLLU2 | *Cleome lutea* | Yellow spider flower | SSL/ DWR | 10-14 in. precip. / 80-90$^o$ | |
| CLSE | *Cleome serrulata* | Rocky Mountain beeplant | SSL/ DWR | <10 in. precip. / >80$^o$ | |
| CRIN4 | *Crepis intermedia* | Limestone hawk's-beard | SSL/ DWR | 10-14 in. precip. / 70-80$^o$ | |
| DAOR2 | *Dalea ornata* | Western prairie clover | DBSC | BM | |
| DAOR2 | *Dalea ornata* | Western prairie clover Spectrum Selected Germplasm | FRRL | NBR | |
| DAOR2 | *Dalea ornata* | Western prairie clover Majestic Selected Germplasm | FRRL | ECSF | |
| DASE2 | *Dalea searlsiae* | Searl's prairie clover | FRRL | CBR | |
| ENNU | *Enceliopsis nudicaulis* | Naked stem sunray | SSL/ DWR | 1) < 10 in precip/< 80$^o$<br>2) 10-14 in. precip. / 70-80$^o$ | |
| ERIGE2 | *Erigeron speciosus* | Aspen fleabane | SSL/ DWR | 14-24 in. precip. / <70$^o$ | |
| ERHE2 | *Eriogonum heracleiodes* | Wyeth's buckwheat (pooled source) | BOI | NBR/SRP | |
| ERUM | *Eriogonum umbellatum* | Sulphur-flower buckwheat | BOI | NBR | |
| ERUM | *Eriogonum umbellatum* | Sulphur-flower buckwheat (pooled source) | BOI | SRP/IB | |
| HEBO | *Hedysarum boreale* | Utah sweetvetch | SSL | CBR/WUM boundary: Orem bench ( TIMP ) | |
| HEMUN | *Heliomeris multiflora* var. *nevadensis* | Nevada showy false goldeneye | SSL/ DWR | 1) 14-24 in. precip. / 70-80$^o$<br>2)10-14 in. precip. / 80-90$^o$ | |
| IPAG | *Ipomopsis aggregata* | Scarlet skyrocket | SSL/ DWR | 14-24 in. precip. / 70-80$^o$ | |
| LILE3 | *Linum lewisii* | Lewis flax Maple Grove Selected Germplasm | SSL | CBR/WUM boundary | |
| LILE3 | *Linum lewisii* | Lewis flax | DBSC | BM (Pendleton area) | |
| LILE3 | *Linum lewisii* | Prairie flax | SSL/ DWR | 10-14 in. precip. / 70-80$^o$ | |
| LODI | *Lomatium dissectum* | Fernleaf biscuitroot (pooled source) | BOI | NBR | |
| LODI | *Lomatium dissectum* | Fernleaf biscuitroot (pooled source) | BOI | SRP | |

| Plant Code | Scientific Name | Common Name | Lab[1] | Source[2] | # of pop |
|---|---|---|---|---|---|
| LOGR | *Lomatium grayi* | Gray's biscuitroot (pooled source) | BOI/ SSL | SRP | |
| LONU2 | *Lomatium nudicaule* | Barestem biscuitroot | SSL/ DWR | 14-24 in. precip. / 70-80$^{o}$ | |
| LONU2 | *Lomatium nudicaule* | Barestem biscuitroot | BOI | NBR | |
| LOTR2 | *Lomatium triternatum* | Nineleaf biscuitroot | BOI | NBR | |
| LOTR2 | *Lomatium triternatum* | Nineleaf biscuitroot (pooled source) | BOI | ECSF | |
| LUAR6 | *Lupinus arbustus* | Long-spur lupine | SSL/ DWR | 1) 14-24 in. precip. / <70$^{o}$<br>2) 14-24 in. precip. / 70-80$^{o}$<br>3) >24 in. precip. | |
| LUAR3 | *Lupinus argenteus* | Silver-stem lupine | SSL/ DWR | 10-14 in. precip. / 70-80$^{o}$ | |
| LUPR2 | *Lupinus prunophilus* | Hairy big leaf lupine | SSL/ DWR | 14-24 in. precip. / 70-80$^{o}$ | |
| LUSE4 | *Lupinus sericeus* | Pursh's silky lupine | SSL/ DWR | CBR | |
| MACA2 | *Machaeranthera canescens* | Hoary tansyaster | BOI | NBR/SRP | |
| MEAL6 | *Mentzelia albicaulis* | White-stem blazing star | SSL/ DWR | 10-14 in. precip. / 70-80$^{o}$ | |
| MELA2 | *Mentzelia laevicaulis* | Giant blazing star | SSL/ DWR | 1)10-14 in. precip. / 70-80o<br>2)14-24 in. precip. / 70-80$^{o}$ | |
| NIAT | *Nicotiana attenuata* | Coyote tobacco | SSL/ DWR | 14-24 in. precip. / <70$^{o}$ | |
| PHCRC | *Phacelia crenulata* var. *corrugata* | Cleftleaf wildheliotrope | SSL/ DWR | 10-14 in. precip. / 70-80$^{o}$ | |
| PEAC | *Penstemon acuminatus* | Sharpleaf penstemon (pooled source) | BOI | SRP | |
| PECY3 | *Penstemon cyaneus* | Blue penstemon | BOI | SRP (Richfield, ID) | |

| Plant Code | Scientific Name | Common Name | Lab[1] | Source[2] | # of pop |
|---|---|---|---|---|---|
| PEDE4 | *Penstemon deustus* | Hotrock penstemon | BOI | SRP (foothills N of Boise) | |
| PEPA6 | *Penstemon pachyphyllus* | Thickleaf beardtongue | SSL/ DWR | 1) 10-14 in. precip. / 70-80°<br>2) 14-24 in. precip. / 70-80° | |
| PESP | *Penstemon speciosus* | Royal penstemon | BOI | NBR | |
| SPCO | *Sphaeralcea coccinea* | Scarlet globe-mallow | SSL/ DWR | 14-24 in. precip. / 70-80° | |
| SPGR2 | *Sphaeralcea grossulariifolia* | Currant-leaf globe-mallow | SSL/ DWR | 10-14 in. precip. / 80-90° | |
| SPMU2 | *Sphaeralcea munroana* | Munro's globemallow | BOI | NBR | |
| THMI5 | *Thelypodium milleflorum* | Many-flowered thelypody | SSL/ DWR | < 10 in precip/< 80° | |

## Additional plant materials under evaluation and/or early seed increase.

### GRASSES

| Plant Code | Scientific Name | Common Name | Lab[1] | Source[2] | # of pop |
|---|---|---|---|---|---|
| MUAS | *Muhlenbergia asperifolia* | Scratchgrass | SSL/ DWR | <10 in. precip. / >80° | |
| SPCR | *Sporobolus cryptandrus* | sand dropseed | BOI | NGB | |

### FORBS

| Plant Code | Scientific Name | Common Name | Lab[1] | Source[2] | # of pop |
|---|---|---|---|---|---|
| ARMAF | *Arenaria macradenia* ssp. *ferrisiae* | Ferris' sandwort | SSL/ DWR | Eco Region 13W | |
| BAHO | *Balsamorhiza hookeri* | Hooker's balsamroot | SSL/D WR | 10-14 in. precip. / 70-80°<br>14-24 in. precip./ 70-80° | |
| BASA3 | *Balsamorhiza sagittata* | Arrow-leaf balsamroot | SSL/ DWR | 1) 10-14 in. precip. / 70-80°<br>2) 14-24 in. precip. / 70-80° | |
| CHDO | *Chaenactis douglasii* | Douglas' dustymaiden | BOI | SRP | |
| CLLU2 | *Cleome lutea* | yellow spiderflower | BOI | NGB | |
| CRAC2 | *Crepis acuminata* | Long-leaf hawk's-beard | SSL/ DWR | 10-14 in. precip. / 70-80° | |
| DENU2 | *Delphinium nuttallianum* | Two-lobe larkspur | SSL/ DWR | 14-24 in. precip. / <70° | |
| ERLA6 | *Eriophyllum lanatum* | common woolly sunflower | BOI | NGB | |

| Plant Code | Scientific Name | Common Name | Lab[1] | Source[2] | # of pop |
|---|---|---|---|---|---|
| FRAL5 | *Frasera ablomarginata* | Desert frasera | SSL/ DWR | 1) 10-14 in. precip. / 70-80$^{o}$ 2) 14-24 in. precip. / 70-80$^{o}$ | |
| IPMA4 | *Ipomopsis macrosiphon* | Mountain skyrocket | SSL/ DWR | 14-24 in. precip. / 70-80$^{o}$ | |
| LIKI2 | *Linum kingii* | King's flax | SSL/ DWR | <10 in. precip. / >80$^{o}$ | |
| LISU5 | *Linum subteres* | Sprucemont flax | SSL/ DWR | <10 in. precip. / >80$^{o}$ | |
| MELA2 | *Mentzelia laevicaulis* | smoothstem blazingstar | BOI | NGB | |
| PEBO2 | *Perideridia bolanderi* | Bolander's yampa | SSL/ DWR | 10-14 in. precip. / 70-80$^{o}$ | |
| PEEA | *Penstemon eatonii* | Eaton's firecracker | SSL/ DWR | 1) 14-24 in. precip. /70-80$^{o}$; 2) 10-14 in. precip./70-80$^{o}$ | |
| PEPR2 | *Penstemon procerus* | Little flower pentemon | SSL/ DWR | 10-14 in. precip. / 70-80$^{o}$ | |
| PERY | *Penstemon rydbergii* | Rydberg's beardtongue | SSL/ DWR | 14-24 in. precip. / <70$^{o}$ | |
| PESP | *Penstemon speciosus* | Royal penstemon | BOI | SRP | |
| PEST2 | *Penstemon strictus* | Rocky Mountain penstemon | SSL/ DWR | 10-14 in. precip. / 70-80$^{o}$ | |
| PHHA | *Phacelia hastata* | silverleaf phacelia | BOI | NGB | |
| PHHE2 | *Phacelia heterophylla* | varileaf phacelia | BOI | NGB | |
| PHLI | *Phacelia linearis* | threadleaf phacelia | BOI | NGB | |
| SPPA2 | *Sphaeralcea parvifolia* | Small leaf globemallow | SSL/ DWR | 10-14 in. precip. / 70-80$^{o}$ | |
| STPI | *Stanleya pinnata* | Golden prince's-plume | SSL/ DWR | <10 in. precip. / >80$^{o}$ | |

[1] **Lab**

ABD = NRCS Plant Materials Center, Aberdeen, ID (208) 397-4133
BOI = USFS RMRS, Boise, ID (208) 373 4360
DBSC = Deschutes Basin Seed Cooperative, OR (541) 447-8166
DWR = Utah Division of Wildlife Resources, Ephraim, UT (435) 283 4441
FRRL = ARS, Logan, UT (435) 797-2249
SSL = USFS RMRS Shrub Sciences Lab, Provo, UT (801) 356 5100
UCIA = Utah Crop Improvement Association, Logan, UT (435) 797-2082

[2] **Provisional Seed Zone Map: Omernik Level III ecoregions (http://www.nps.gov/plants/sos/pdf/SOS%20Omernik%20Level%20III.pdfEcore**

**Level III Ecoregion**

BM = Blue Mountains
CBR = Central Basin and Range
NBR = Northern Basin and Range
SRP = Snake River Plain
WUM = Wasatch and Uinta Mountains
ECSF = Eastern Cascade Slopes and Foothills
CP=Columbia Plateau

[3] **Stock Seed Availability for Growers**

Materials are source identified unless otherwise indicated. Stock seed can be requested through State Foundation Seed Organizations.
Limited = < 10lbs
Available = > 10lbs

**Appendix IV.** The workshop entitled: *Preparing and seeding multi-species mixtures, and drill calibration and operation* was held at Initial Point, Boise, ID, 2012 July 18.

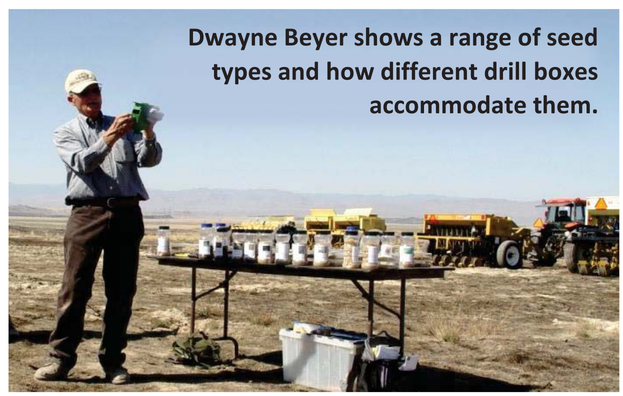
Workshop organizers: Jim Truax, Truax Co., New Hope, MN; Anne Halford, Snake River Birds of Prey National Conservation Area, Boise, ID; Nancy Shaw and Matt Fisk, USFS RMRS, Boise, ID.

**Workshop participants view demonstration of the Truax RoughRider minimum-till drill.**

On July 18, twenty-five restoration practitioners' from six different federal and state resource agencies participated in a drill calibration workshop at the BLM Morley Nelson Snake River Birds of Prey National Conservation Area (BLM-NCA). The workshop was sponsored by the BLM Great Basin Native Plant Selection and Increase Project (GBNPSIP), US Forest Service Rocky Mountain Research Station, Natural Resource Conservation Service, Aberdeen Plants Material Center, USDA, Agricultural Research Service, Northwest Watershed Research Center, and the SER Great Basin Chapter.

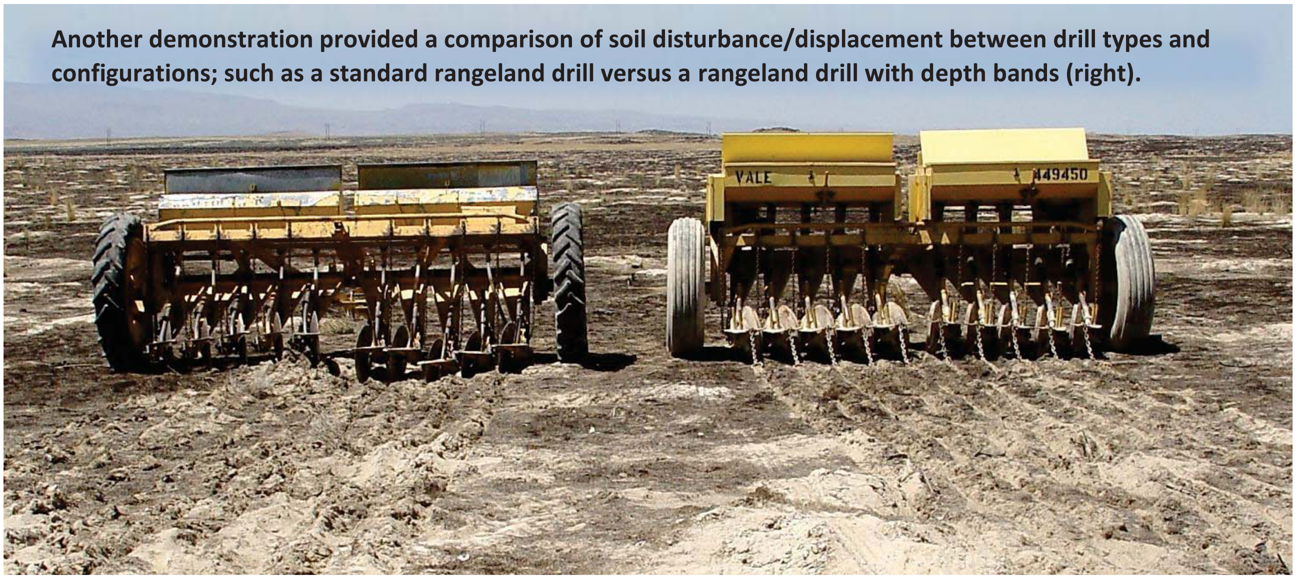
Participants were given an opportunity to become familiar with different drill types, seed boxes and drill calibration methods. Four drills were used in the workshop; a standard rangeland drill with a single seed box, 3 seed box rangeland drill with depth bands, a Truax Rough Rider minimum till drill and a Truax On-the-Go minimum till drill.

Topics discussed included; seed boxes and metering, seed delivery and placement, calibration, seed type, seed test interpretation, seeding rate determination, seeding mix calculations, and use of diluents. Three options were highlighted for participants to consider in the selection of appropriate seed boxes: cool season/grain seed box; small seed/legume seed box, and; fluffy seed box.



**Dwayne Beyer shows a range of seed types and how different drill boxes accommodate them.**

The advantages and disadvantages of the drills were discussed to increase participant's awareness and familiarity with different restoration tools like minimum drill technology. These drills can minimize soil disturbance and increase the capacity to plant more diverse seed mixes, especially broadcast species, such as sagebrush and smaller seeded native forbs that are important for sagebrush obligate species including sage grouse. The workshop was timely given this year's numerous fires in the Great Basin and BLM's focus on improving and restoring sage grouse habitat.




**Another demonstration provided a comparison of soil disturbance/displacement between drill types and configurations; such as a standard rangeland drill versus a rangeland drill with depth bands (right).**

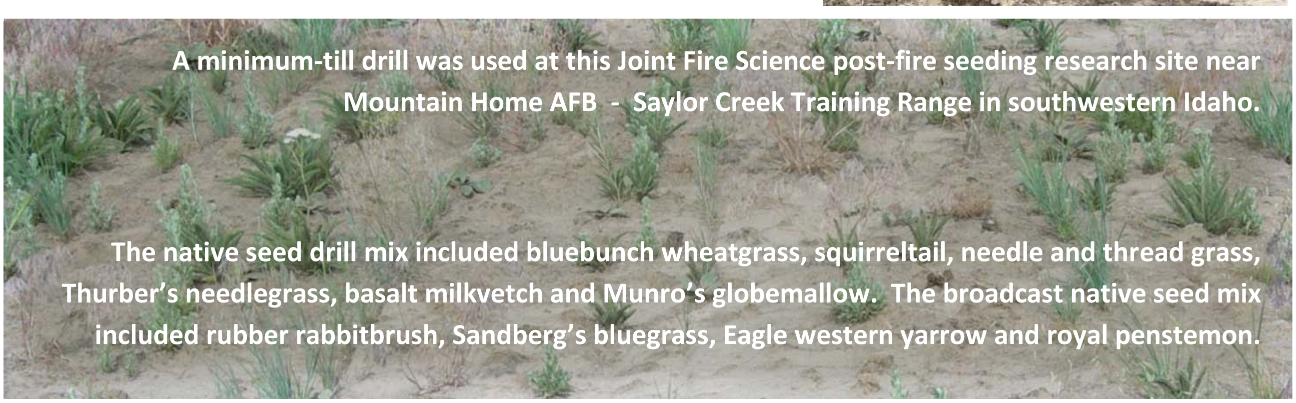
With its partner's, the BLM-NCA is expanding the use of these tools and on-the-ground techniques developed by GBNPSIP, to restore native shrub structure necessary for raptor prey base habitat and increase forb diversity for pollinator habitat important for the federally threatened slickspot peppergrass (*Lepidium papilliferum*). Additional information about annual GBNPSIP reports and products, as well as Joint Fire Science Projects, can be found at the following websites:


**Workshop participants inspect seed boxes and drops**

http://www.fs.fed.us/rm/boise/research/shrub/greatbasin.shtml

http://www.firescience.gov/projects/07-1-3-12/project/07-1-3-12_final_report.pdf

**Truax On-The-Go minimum-till demo**



**A minimum-till drill was used at this Joint Fire Science post-fire seeding research site near Mountain Home AFB - Saylor Creek Training Range in southwestern Idaho.**

**The native seed drill mix included bluebunch wheatgrass, squirreltail, needle and thread grass, Thurber's needlegrass, basalt milkvetch and Munro's globemallow. The broadcast native seed mix included rubber rabbitbrush, Sandberg's bluegrass, Eagle western yarrow and royal penstemon.**

**Appendix V.** Germplasm conservation samples contributed by USDA Forest Service, Rocky Mountain Researc
to the USDI Bureau of Land Management Seeds of Success Program and USDA Agricultural Research Service,
Plant Introduction Station in 2012 for addition to the Germplasm Resources Information Network (GRIN) syste

| Symbol | Scientific Name | Common Name | Ecoregion | Ecoregion Name | C |
|---|---|---|---|---|---|
| ACMI 01 | *Achillea millefolium* | Common yarrow | 12j | Unwooded Alkaline foothills | A |
| ACTH 01 | *Achnatherum thurberianum* | Thurber's needlegrass | 12h | Mountain Home Uplands | A |
| UKAM 01 | *Amsinckia* sp. | Fiddleneck | 12j | Unwooded Alkaline foothills | F |
| ASER 07 | *Astragalus eremiticus* | Hermit milkvetch | 12a | Treasure Valley | A |
| BAHO 19 | *Balsamorhiza hookeri* | Hooker's balsamroot | 12c | Camas Prairie | C |
| BAHO 04 | *Balsamorhiza hookeri* | Hooker's balsamroot | 12h | Mountain Home Uplands | A |
| BAHO 08 | *Balsamorhiza hookeri* | Hooker's balsamroot | 12h | Mountain Home Uplands | A |
| BAHO 19 | *Balsamorhiza hookeri* | Hooker's balsamroot | 12c | Camas Prairie | C |
| CHDO 16 | *Chaenactis douglasii* | Doulglas' dustymaiden | 80a | Dissected High Lava Plateau | C |
| CHDO 12 | *Chaenactis douglasii* | Doulglas' dustymaiden | 11i | Continental Zones Foothills | M |
| CRAC 101 | *Crepis acuminata* | Tapertip hawksbeard | 12h | Mountain Home Uplands | F |
| DAOR 09 | *Dalea ornata* | Blue Mountain prairie clover | 12a | Treasure Valley | M |
| ERHE 20 | *Eriogonum heracleoides* | Parsnipflower buckwheat | 12f | Semiarid Foothills | F |
| ERUM 01 | *Eriogonum umbellatum* | Sulphur-flower buckwheat | 16k | Southern Forested Mountains | F |
| ERUM 15 | *Eriogonum umbellatum* | Sulphur-flower buckwheat | 16f | Foothill Shrublands-Grasslands | F |

| Symbol | Scientific Name | Common Name | Ecoregion | Ecoregion Name |
|---|---|---|---|---|
| ERUM 67 | *Eriogonum umbellatum* | Sulphur-flower buckwheat | 12f | Semiarid Foothills |
| ERUM 62 | *Eriogonum umbellatum* | Sulphur-flower buckwheat | 12f | Semiarid Foothills |
| ERUM 33 | *Eriogonum umbellatum* | Sulphur-flower buckwheat | 16f | Foothill Shrublands-Grasslands |
| ERUM 66 | *Eriogonum umbellatum* | Sulphur-flower buckwheat | 16k | Southern Forested Mountains |
| ERUM 68 | *Eriogonum umbellatum* | Sulphur-flower buckwheat | 16k | Southern Forested Mountains |
| MACA 09 | *Machaeranthera canescens* | Hoary tansyaster | 12a | Treasure Valley |
| MACA 01 | *Machaeranthera canescens* | Hoary tansyaster | 12h | Mountain Home Uplands |
| MACA 12 | *Machaeranthera canescens* | Hoary tansyaster | 11i | Continental Zone Foothills |
| MACA 11 | *Machaeranthera canescens* | Hoary tansyaster | 80f | Owyhee Uplands and Canyons |
| MELA 02 | *Mentzelia laevicaulis* | Smoothstem blazingstar | 11i | Continental Zone Foothills |
| MELA 03 | *Mentzelia laevicaulis* | Smoothstem blazingstar | 80f | Owyhee Uplands and Canyons |
| PEAC 35 | *Penstemon acuminatus* | Sharpleaf penstemon | 16k | Southern Forested Mountains |
| PEAC 57 | *Penstemon acuminatus* | Sharpleaf penstemon | 12j | Unwooded Alkaline Foothills |
| PEDE 35 | *Penstemon deustus* | Scabland penstemon | 11i | Continental Zone Foothills |
| PEDE 05 | *Penstemon deustus* | Scabland penstemon | 12f | Semiarid Foothills |
| PEDE 29 | *Penstemon deustus* | Scabland penstemon | 16f | Foothill Shrublands-Grasslands |
| PEDE 50 | *Penstemon deustus* | Scabland penstemon | 16k | Southern Forested Mountains |

| Symbol | Scientific Name | Common Name | Ecoregion | Ecoregion Name |
|---|---|---|---|---|
| PESP 55 | *Penstemon speciosus* | Royal penstemon | 80f | Owyhee Uplands and Canyons |
| PESP 35 | *Penstemon speciosus* | Royal penstemon | 12j | Unwooded Alkaline foothills |
| PHHA 06 | *Phacelia hastata* | Silverleaf phacelia | 12j | Unwooded Alkaline foothills |
| PHHA 02 | *Phacelia hastata* | Silverleaf phacelia | 80f | Owyhee Uplands and Canyons |
| PHHA 07 | *Phacelia hastata* | Silverleaf phacelia | 16f | Foothill Shrublands-Grasslands |
| PHHE 01 | *Phacelia heterophylla* | Varileaf phacelia | 80f | Owyhee Uplands and Canyons |
| PHHE 03 | *Phacelia heterophylla* | Varileaf phacelia | 11i | Continental Zone Foothills |
| PHHE 02 | *Phacelia heterophylla* | Varileaf phacelia | 16f | Foothill Shrublands-Grasslands |
| PHLI 01 | *Phacelia linearis* | Threadleaf phacelia | 80f | Owyhee Uplands and Canyons |
| SPMU 09 | *Sphaeralcea munroana* | Munro’s globemallow | 12j | Unwooded Alkaline foothills |

**Appendix VI.** Seed lots distributed to cooperators in 2012 by USDA Forest Service, Rocky Mountain Research S

| Species | Common Name | Seed Origin (county, state) | Affiliation |
|---|---|---|---|
| *Achillea millefolium* | Western yarrow | Ada, ID | Texas Tech University |
| *Achillea millefolium* | Western yarrow | Ada, ID | Healthy Hills Initiative |
| *Achnatherum hymenoides* | Indian ricegrass | Yellowstone, MT | Texas Tech University |
| *Achnatherum hymenoides* | Indian ricegrass | Yellowstone, MT | University of Idaho |
| *Achnatherum thurberianum* | Thurber’s needlegrass | Elmore, ID | Healthy Hills Initiative |
| *Agoseris glauca* | Pale agoseris | Harney, OR | OSU Malheur Experiment Station |
| *Agoseris grandiflora* | Bigflower agoseris | Lake, OR | Healthy Hills Initiative nursery see |
| *Astragalus filipes* | Basalt milkvetch | Deschutes, OR | Healthy Hills Initiative |
| *Balsamorhiza hookeri* | Hooker’s balsamroot | Ada, ID | OSU Malheur Experiment Station |
| *Balsamorhiza hookeri* | Hooker’s balsamroot | Ada, ID | OSU Malheur Experiment Station |
| *Balsamorhiza hookeri* | Hooker’s balsamroot | Malheur, OR | OSU Malheur Experiment Station |
| *Balsamorhiza hookeri* | Hooker’s balsamroot | Ada, ID | USDA FS National Seed Laborato |
| *Balsamorhiza hookeri* | Hookers' balsamroot | Ada, ID | Healthy Hills Initiative |
| *Balsamorhiza sagittata* | Arrowleaf balsamroot | Camas, ID | Healthy Hills Initiative nursery see |
| *Chaenactis douglasii* | Douglas’ dustymaiden | Malheur, OR | OSU Malheur Experiment Station |
| *Chaenactis douglasii* | Douglas’ dustymaiden | Owyhee, ID | OSU Malheur Experiment Station |

| Species | Common Name | Seed Origin (county, state) | Affiliation |
|---|---|---|---|
| *Chaenactis douglasii* | Douglas' dustymaiden | Malheur, OR | OSU Malheur Experiment Station |
| *Chaenactis douglasii* | Douglas' dustymaiden | Elmore, ID | OSU Malheur Experiment Station |
| *Chaenactis douglasii* | Douglas' dustymaiden | Gooding, ID | USDA FS National Seed Laborato |
| *Chaenactis douglasii* | Douglas' dustymaiden | Owyhee, ID | Healthy Hills Initiative nursery see |
| *Cleome serrulata* | Rocky Mountain beeplant | Ada, ID | Healthy Hills Initiative |
| *Crepis acuminate* | Tapertip hawksbeard | Elmore, Idaho | USDI BLM/USDI USGS |
| *Crepis occidentalis* | Largeflower hawksbeard | Mono, CA | Healthy Hills Initiative nursery see |
| *Dalea ornate* | Blue Mountain prairie clover | Malheur, OR | Healthy Hills Initiative nursery see |
| *Elymus elymoides* | Bottlebrush squirreltail | Elko, NV | University of Idaho |
| *Elymus elymoides* | Bottlebrush squirreltail | Harney, OR | University of Idaho |
| *Eriogonum heracleoides* | Parsnipflower buckwheat | Boise, ID | HEALTHY HILLS INITIATIVE nursery stock seed |
| *Eriogonum umbellatum* | Sulphur-flower buchwheat | Elmore, ID | Texas Tech University |
| *Eriogonum umbellatum* | Sulphur-flower buckwheat | Adams, ID | USDA ARS Western Regional Pla Introduction Station |
| *Eriogonum umbellatum* | Sulphur-flower buckwheat | Boise, ID | USDA ARS Western Regional Pla Introduction Station |
| *Eriogonum umbellatum* | Sulphur-flower buckwheat | Boise, ID | USDA ARS Western Regional Pla Introduction Station |
| *Eriogonum umbellatum* | Sulphur-flower buckwheat | Owyhee, ID | USDA ARS Western Regional Pla Introduction Station |
| *Eriogonum umbellatum* | Sulphur-flower buckwheat | Elmore, ID | USDA ARS Western Regional Pla Introduction Station |

| Species | Common Name | Seed Origin (county, state) | Affiliation |
|---|---|---|---|
| *Eriogonum umbellatum* | Sulphur-flower buckwheat | Boise, ID | USDA ARS Western Regional Pla Introduction Station |
| *Eriogonum umbellatum* | Sulphur-flower buckwheat | Elmore, ID | USDA ARS Western Regional Pla Introduction Station |
| *Eriogonum umbellatum* | Sulphur-flower buckwheat | Boise, ID | USDA ARS Western Regional Pla Introduction Station |
| *Eriogonum umbellatum* | Sulphur-flower buckwheat | Elmore, ID | USDA ARS Western Regional Pla Introduction Station |
| *Eriogonum umbellatum* | Sulphur-flower buckwheat | Elmore, ID | USDA ARS Western Regional Pla Introduction Station |
| *Eriogonum umbellatum* | Sulphur-flower buckwheat | Elmore, ID | USDA ARS Western Regional Pla Introduction Station |
| *Eriogonum umbellatum* | Sulphurflower buckwheat | JFSP mix | Healthy Hills Initiative |
| *Eriogonum umbellatum* | Sulphurflower buckwheat | Baker, OR | Healthy Hills Initiative nursery see |
| *Eriophyllum lanatum* | Common woolly sunflower | Malheur, OR | OSU Malheur Experiment Station |
| *Eriophyllum lanatum* | Common woolly sunflower | Malheur, OR | OSU Malheur Experiment Station |
| *Eriophyllum lanatum* | Common woolly sunflower | Malheur, OR | OSU Malheur Experiment Station |
| *Eriophyllum lanatum* | Common woolly sunflower | Malheur, OR | OSU Malheur Experiment Station |
| *Hesperostipa comata* | Needle and thread grass | Millard, UT | University of Idaho |
| *Hesperostipa comata* | Needle and thread grass | Millard, UT | Healthy Hills Initiative |
| JFSP seed mix | Cover crop | N/A | Healthy Hills Initiative |
| JFSP seed mix | Broadcast mix | N/A | Utah Transit Authority |
| JFSP seed mix | Drill mix | N/A | Utah Transit Authority |

| Species | Common Name | Seed Origin (county, state) | Affiliation |
|---|---|---|---|
| *Leymus cinereus* | Basin wildrye | Owyhee, ID | NRCS Bridger Plant Materials Cer |
| *Linum lewisii* | Lewis flax | Millard, UT | USDI BLM Healthy Hills Initiativ |
| *Lomatium dissectum* | Fernleaf biscuitroot | Malheur, OR | Texas Tech University |
| *Lomatium dissectum* | Fernleaf biscuitroot | Harney, OR | Truax Co., Inc. |
| *Lomatium dissectum* | Fernleaf biscuitroot | Elmore, ID | USDA FS National Seed Laborato |
| *Lomatium dissectum* | Fernleaf biscuitroot | Ada, ID | USDA FS National Seed Laborato |
| *Lomatium dissectum* | Fernleaf biscuitroot | Ada, ID | Healthy Hills Initiative |
| *Lomatium grayi* | Gray's biscuitroot | Ada, ID | Healthy Hills Initiative nursery see |
| *Lomatium grayi* | Gray's biscuitroot | Ada, ID | Texas Tech University |
| *Lomatium triternatum* | Nineleaf biscuitroot | Ada, ID | Healthy Hills Initiative nursery see |
| *Machaeranthera canescens* | Hoary tansyaster | Elmore, ID | OSU Malheur Experiment Station |
| *Machaeranthera canescens* | Hoary tansyaster | Elmore, ID | Healthy Hills Initiative nursery see |
| *Penstemon acuminatus* | Sharpleaf penstemon | Snake River Plain pool | USDI BLM Birds of Prey |
| *Penstemon deustus* | Scabland penstemon | Baker, OR | Healthy Hills Initiative nursery see |
| *Penstemon speciosus* | Royal penstemon | Malheur, OR | Texas Tech University |
| *Penstemon speciosus* | Sagebrush penstemon | JFSP Saylor Creek mix | Healthy Hills Initiative |
| *Penstemon speciosus* | Sagebrush penstemon | Payette, ID | Healthy Hills Initiative nursery see |

| Species | Common Name | Seed Origin (county, state) | Affiliation |
|---|---|---|---|
| *Phacelia hastate* | Silverleaf phacelia | Malheur, OR | OSU Malheur Experiment Station |
| *Phacelia hastate* | Silverleaf phacelia | Malheur, OR | Healthy Hills Initiative nursery see |
| *Phacelia linearis* | Threadleaf phacelia | Harney, OR | OSU Malheur Experiment Station |
| *Poa secunda* | Sandberg bluegrass | San Pete, UT | NRCS Bridger Plant Materials Cer |
| *Poa secunda* | Sandberg bluegrass | Owyhee, ID | University of Idaho |
| *Pseudoroegneria spicata* | Bluebunch wheatgrass | Asotin, WA | University of Idaho |
| *Pseudoroegneria spicata* | Bluebunch wheatgrass | Asotin, WA | Healthy Hills Initiative |
| *Pseudoroegneria spicata* | Bluebunch wheatgrass | Asotin, WA | USDI National Biological Service |
| *Sphaeralcea grossularifolia* | Gooseberryleaf globemallow | Owyhee, ID | Healthy Hills Initiative nursery see |
| *Sphaeralcea munroana* | Munro's globemallow | Uintah, UT | Healthy Hills Initiative |
| *Sphaeralcea munroana* | Munro's globemallow | Payette, ID | Healthy Hills Initiative nursery see |
| **TOTAL SEED DISTRIBUTED (kg)** | | | |