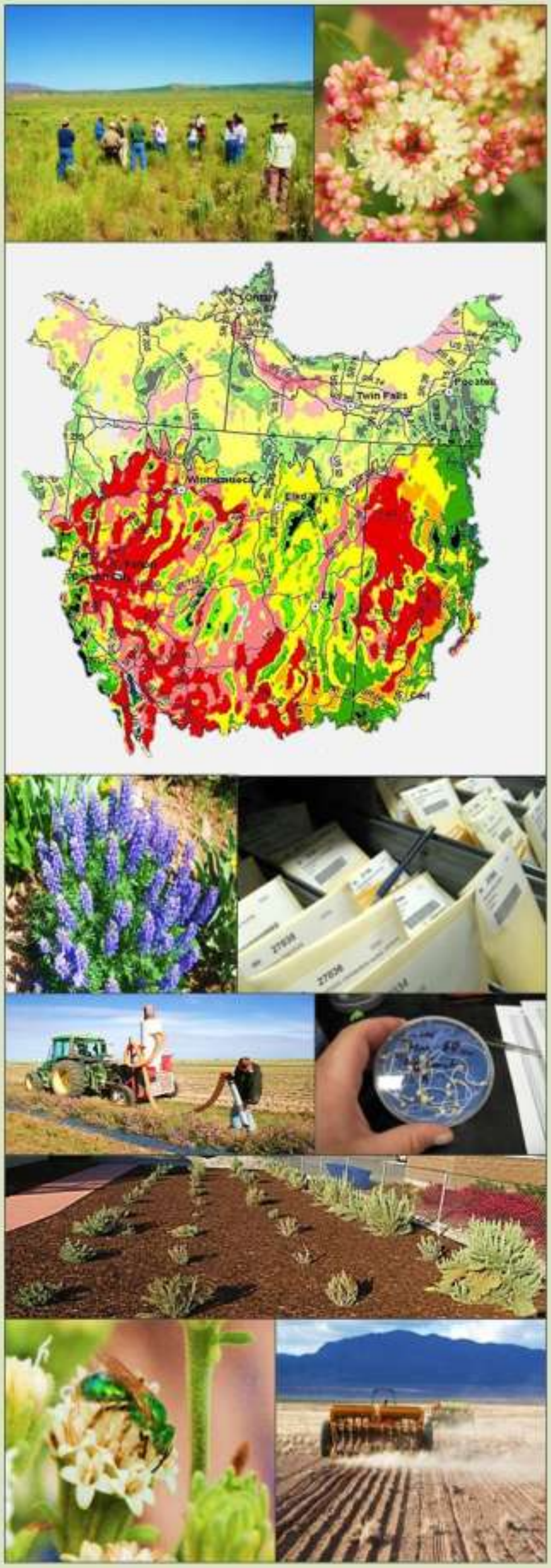

Great Basin Native Plant Selection and Increase Project

2011 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

2011 Progress Report

USDA Forest Service, Rocky Mountain Research Station
and USDI Bureau of Land Management, Boise, ID
April 2012

Cooperators

USDI Bureau of Land Management, Great Basin Restoration Initiative, Boise, ID
USDI Bureau of Land Management, Plant Conservation Program, Washington, DC
USDA Forest Service, Rocky Mountain Research Station,
Grassland, Shrubland and Desert Ecosystem Research Program, Boise, ID and Provo, UT
Boise State University, Boise, ID
Brigham Young University, Provo, UT
Colorado State University Cooperative Extension, Tri-River Area, Grand Junction, CO
Eastern Oregon Stewardship Services, Prineville, OR
Oregon State University, Malheur Experiment Station, Ontario, OR
Private Seed Industry
Texas Tech University, Lubbock, TX
Truax Company, Inc., New Hope, MN
University of Idaho, Moscow, ID
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, Western Regional Plant Introduction Station, Pullman, WA
USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center, Aberdeen, ID
USDA Forest Service, National Seed Laboratory, Dry Branch, GA
USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR
US Geological Survey, Forest and Rangeland Ecosystem Science Center, Boise, ID
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
2011 Progress Report

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

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

We thank our collaborators for their expertise and the in-kind contributions of their agencies that have made it possible to address many of the issues involved in native plant materials development and use. We especially thank Erin Denney for her patience in formatting and compiling the report. We also thank Jan Gurr and Matt Fisk for assisting with completion of the report.

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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:
http://www.blm.gov/id/st/en/prog/gbri.html

NATIONAL AWARD RECIPIENT

The Great Basin Native Plant Selection and Increase Project received the Joint USDI Bureau of Land Management/USDA Forest Service Conservation Partner Award, which was presented at the North American Wildlife and Natural Resources Conference in Atlanta, Georgia. This annual award recognizes an organization or individual representing a conservation organization for their outstanding leadership in the development and implementation of conservation programs and activities that have directly benefited fish, wildlife, and/or plants on public lands or their use, enjoyment, and appreciation.

GENETICS, COMMON GARDENS, AND SEED ZONES

Adapted Thurber's needlegrass for the Great Basin
Elizabeth Leger and Richard Johnson

- Seedlings of Thurber's needlegrass, grown from seed collected primarily from the Oregon, Idaho and Nevada regions of the Great Basin, were transported to the University of Nevada, Reno in the fall of 2011 and transplanted into a common garden; measurement of plant traits will begin in spring 2012.
- Analysis of the variation in plant traits will be used to map seed transfer zones for Thurber's needlegrass in the Great Basin.

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

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

Conservation, adaptation and seed zones for key Great Basin species
Richard Johnson, Mike Cashman, and Ken Vance-Borland

- Proposed seed zones for Indian ricegrass germplasm, representing the southern and eastern Central Basin and Range across to the Southwestern Tablelands ecoregions, were completed based on data collected from common garden studies established in 2007.
- Germplasm collection for Sandberg bluegrass and Basin wildrye was completed across the Great Basin. Seeds from each location were germinated, grown under greenhouse conditions, and transplanted to common garden sites.
- The Sandberg bluegrass gardens were established in 2008; data was collected in 2009 and 2010. Analyses so far indicate strong differences among plants from different locations indicating strong genetic variation.
- Common gardens of basin wildrye were established in 2010; data collection for phenology, production, and morphological traits was completed in 2011 and will continue in 2012 and 2013.

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

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

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

- Physiological fitness of different seed sources for big sagebrush restoration is under evaluation, utilizing common gardens previously established for the Great Basin Native Plant Selection and Increase Project. The results will fill a key data gap for development of climatic seed-transfer zones.
- Preliminary data suggest that the populations (seed sources) differ appreciably in 1) water status and associated photosynthetic carbon gain and growth at midsummer, and 2) physiological tolerance of freezing during wintertime.
- We anticipate that further analysis of the data will reveal that selection for rapid initial growth appears to confer stress resistance and establishment success, in contrast to the traditional view of a tradeoff between growth potential and stress resistance in plant adaptive strategies.
- Via collaboration, we are determining how physiological performance can distinguish genetic variation, and how the ecophysiological fitness compares with palatability and herbivore-defense compounds.

SEED BIOLOGY AND TECHNOLOGY

Globemallow and sagebrush performance under varying conditions
Anthony 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 seedlings grown from 5 accessions within the current range of this subspecies

Globemallow

- *Sphaeralcea munroana* seeds are physically dormant, possess a water gap responsible for water uptake, and 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 germination, seed weight, purity, and seed conditioning/cleaning protocols for Great Basin grasses and forbs
Robert Karrfalt and Victor Vankus

- Wyoming big sagebrush seed can be stored for 5 years without loss of viability if it is cleaned to a high purity, equilibrated in an atmosphere of 30% relative humidity, sealed in moisture proof containers, and frozen at -20^{o}C. This finding means sagebrush seed can be banked for at least 5 years so that it is readily available for restoration.
- Using the principles of equilibrium relative humidity, and measuring it using inexpensive electronic hygrometers, seed moisture can be managed for maintaining highest seed viabilities at all stages of seed handling from harvest to long-term storage.
- Germination conditions were tested for 31 species. A table of preliminary estimates of best germination temperatures was prepared.

SEED AND SEEDLING ECOLOGY

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

- Using a thermal accumulation model to predict seedling root growth would allow for the assessment of the potential for seedlings to survive under a range of field conditions and possibly suggest opportunities for plant improvement.
- We have conducted all six of the constant temperature runs and all three of the diurnal temperature runs in the growth chamber. As expected, cheatgrass roots grew the fastest at cool temperatures. However, the crested wheatgrasses and Anatone bluebunch wheatgrass definitely grew well enough to compete with cheatgrass. 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.
- We have conducted the field root trials at both the BYU campus and the east side of Onaqui Mountain for two years. We are currently analyzing these data.

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

- The major goal of this study is to identify arbuscular mycorrhizal fungi (AMF) species that colonize Wyoming big sagebrush and begin to characterize the overall diversity of AMF species in sagebrush habitats of southwestern Idaho.
- At present it is not clear whether the phylotypes that we identified in sagebrush habitats are

present in commercial inoculums. Thus, we do not recommend the use of commercial inoculum until more is known about the phylotypes they contain and their effects on sagebrush establishment.
- We have begun to generate monospecific cultures of native mycorrhizae with the goal of testing their usefulness in restoration projects.

Plant Materials and Cultural Practices

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

- Hardseededness is a feature that often limits rapid, uniform germination in legume species. We conducted a greenhouse study to determine the influence of seed scarification and seeding depth on the germination and emergence of six seed lots. Scarification greatly improved emergence in both western and Searls' prairie clover, but much less so for basalt milkvetch.
- Based on the results of the greenhouse experiments, actual field seeding studies were established at three locations in 2011. Establishment data will be collected for two years post-planting, but sites will be kept to allow for long-term observation.
- Two natural-track selected germplasms of western prairie clover (*Dalea ornata*) were released in 2011 for use in revegetation of semiarid rangelands in the western USA.

Great Basin native plant materials development and cultivation
Jason Stettler and Alison Whittaker

- We continued cultivation research on native lupine plots established in 2007 and report the three-year harvest trend data for three *Lupinus* species.
- In 2011, we maintained dense beds of *Balsamorhiza* and *Crepis* species planted in 2009 and 2010, as well as an additional 26 beds planted in 2011. In 2012, the original beds planted will be ready for a proposed transplant study.
- We planted a total of 59 sources of ten native forb species at two farms for stock seed production.
- The purpose of the common garden established at the Desert Experimental Range was to observe survival in hot dry conditions. In 2011 we collected the second year survival data on four *Sphaeralcea* species, and compared the seed source climates with survival.
- Due to the extremely low seed yields and low seed viability observed in 2010 and 2011 in the *Eriogonum ovalifolium* common garden, we have purchased pollination cages to attempt to increase both seed yield and viability. We will be setting up a pollination study in 2012 where we will be force pollinating one replicate of each accession. We will plant increase plots in the fall of 2012.
- We collected establishment and germination data from first and second year plots of the forb island study designed to compare the germination and establishment of seeded species on rangeland plots covered with N-sulate fabric and plots left uncovered. In general the plots covered with N-sulate fabric had higher germination than the plots that were left uncovered.
- Using the Provisional Seed Zone map and historic fire and land treatment GIS records from the last three decades to map wildfires and seeded areas; we identified four zones in each Great Basin partition that, based on acreage of disturbance, would warrant adequate quantities of seed

for restoration. We made these four zones our priorities to produce plant materials that will be adapted to areas being burned and reseeded.
- A Microsoft® Access database was created which houses all related soil analysis, seed viability analysis, seed allocations, seed increase, and location data for our seed collections. This was a collaborative effort between Jason Stettler of the Great Basin Research Center and Forest Service botanist Scott Jensen of the Provo Shrub Sciences Lab, and is a combination of all records for these two researchers. We will further develop the database to be used in keeping farming treatment records, herbaria searches, and germination and increase data. This will assist in species distribution studies, collecting seed from new sources, and farm management.

Applying provisional seed zones to Great Basin forb production, and cultural practice notes
Scott Jensen and Jason Stettler
- A GIS analysis of the Western Fire Map, the seedings layer from the Land Treatment Digital Library and the Great Basin Provisional Seed Zone map provides an historic seed demand perspective and functions as a tool to prioritize plant materials work based on highly impacted zones.
- For the northern Great Basin, projected demand for forb seed for the preceding two consecutive 5-year periods 2000-2004, 2005-2010 in provisional seed zone 5 was in excess of 340,000 pounds. In zones 2, 6 and 8 projected demand during the same time interval was in excess of 24,000 pounds. The remaining 6 zones required less than 10,000 pounds during at least one of the 5-year periods.
- For the central Great Basin, provisional seed zone 5 has the highest projected forb demand and projected demand for zones 6, 2, and 7 all exceed 10,000 pounds for the preceding two 5-year intervals.
- Pooled source provisional seed zone releases are projected to be available for distribution to the private seed industry according to the following schedule:

Ipomopsis aggregata	CBR Zone 6	2013
Ipomopsis macrosiphon	CBR Zone 6	2012
Lomatium nudicaule	CBR Zone 5	2015
Lomatium nudicaule	CBR Zone 6	2015
Heliomeris multiflora var. *nevadensis*	CBR Zone 5	2012
Heliomeris multiflora var. *nevadensis*	CBR Zone 6	2012
Enceliopsis nudicaulis	CBR Zone 2	2013
Enceliopsis nudicaulis	CBR Zone 5	2013
Penstemon pachyphyllus	CBR Zone 5	2012
Penstemon pachyphyllus	CBR Zone 6	2012

Cooperative work between the Great Basin Native Plant Selection and Increase Project and the Aberdeen Plant Materials Center
Loren St. John and Derek Tilley
- Plant Guides were completed for royal penstemon, hotrock penstemon, sharpleaf penstemon, fernleaf biscuitroot, nineleaf biscuitroot, Gray's biscuitroot, Douglas' dusty maiden, and hoary tansyaster.
- Propagation Protocols were completed for Douglas' dusty maiden, hoary tansyaster, nineleaf biscuitroot, fernleaf biscuitroot, Gray's biscuitroot, and Searls' prairie clover.

- Early generation Certified seed of hoary tansyaster and Douglas' dusty maiden is being produced and will be available through Utah Crop Improvement Association and University of Idaho Foundation Seed Program when release is approved.

Identification of herbicides for use in native forb seed production
Corey Ransom
- Field trials of basalt milkvetch (*Astragalus filipes*) and western prairie clover (*Dalea ornata*) were planted in fall 2010 and early summer 2011, respectively. Post-emergence herbicide treatments were applied summer 2011. Field plots treated with 2,4-DB demonstrated little herbicide injury on established basalt milkvetch, but also did not control perennial sowthistle. Overall, trials demonstrated that basalt milkvetch and western prairie clover are relatively tolerant to post-emergence herbicides.
- A trial was established to evaluate the effects of pre-emergence herbicides on western prairie clover germination and establishment in late summer 2011. While injury symptoms were visible on small plants in plots treated with pendimethalin, dimthenamid-p and ethofumesate, small plant size prevented overall injury ratings. Spring 2012 evaluations will document if seedling injury from pre-emergence herbicides causes increased mortality over the winter. Further testing is needed to determine possible herbicide effects on seed yields and viability and to verify crop safety.

Seed production of Great Basin native forbs – Subsurface drip irrigation (SDI) 2006-2011 results, 2011 new plantings; Seeding practices; Legume seed scarification
Clint Shock, Erik Feibert, Lamont Saunders, Cheryl Parris, Nancy Shaw, Doug Johnson, and Shaun Bushman
- Continued research on irrigation requirements of eight species planted in 2005; started research on irrigation requirements of eight species planted in 2009.
- Many forb species had no positive seed yield response to irrigation in 2011 due to unusually abundant snow pack and spring rain. Seed yield of the species *Lomatium triternatum*, *Lomatium dissectum*, and *Cleome serrulata* responded to irrigation in spite of substantial precipitation.
- Continued research on seeding practices for establishment of six species. Row cover was very beneficial for forb stand establishment for forb seed production. Emerging seedlings were protected from bird predation, a possible reason for the large increase in plant stands.
- Started evaluation of seed scarification for establishment of three legume species. Legume seed scarification was detrimental for stand establishment of fall planted *Dalea* species and beneficial for fall planted *Astragalus filipes*.

Etiology, epidemiology and management of diseases of native wildflower seed
Ram Sampangi, Krishna Mohan, and Clint Shock
- Several diseases (leaf spots, blights, rusts, wilts and powdery mildews) were recorded on forbs.
- Arid conditions prevailing in the Pacific Northwest are favorable for the powdery mildew disease cycle.

SEED INCREASE

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

- 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 small-quantity initial accessions and commercial marketplace production, by working with specialized growers who are willing to provide land, time, and expertise to produce increased amounts of stock seed from the former, and with UCIA facilitation, makes it available for the latter.
- The seed market status of 6 grasses and 28 forbs that have been forwarded to growers under the auspices of the GBNPSIP, 2002-2011.

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

- EOSS made 32 research seed collections from three species; *Eriogonum umbellatum, Chaenactis douglasii* and *Machaeranthera canescens* for ARS genetic study.
- EOSS made 27 seed collections from 13 species for GBNPSIP to conduct research or pass on to native seed growers.
- EOSS inspected several forb seed fields in Eastern Washington growing seed for GBNPSIP research and eventually commercial production.

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

- Plots recovered from 2010 treatments and we were able to collect seed yield data.
- At one research site, mechanical killing significantly increased seed yield among treatments. However, these yields were not significantly different than the controls, which would suggest the effort and resources to eliminate the competing sagebrush may not be worth while for seed increase.
- Plant understory was evaluated during 2011 and approximately 39 different species were identified. Treatment effects on the sagebrush have changed the understory plant populations. Cheatgrass had the highest frequency of all understory species at both locations. It might be recommended that areas treated to eliminate sagebrush be seeded with another plant(s) to minimize cheatgrass growth.

Insect pests of grass and forb seed production
Bob Hammon

- Contributed Insect Management of Native Seed Production Fields presentation at the Native Plant Seed Production Field Day at the Oregon State University, Malheur Agricultural Experiment Station, Ontario, OR, May 12, 2011.

- Submitted six documents for review as Colorado State University Technical Notes:
  - Insects affecting fourwing saltbush
  - Pests of Utah sweetvetch
  - Insects affecting mountain mahogany
  - Insects affecting penstemon seed production
  - Managing Lygus in forb seed production
  - Insects affecting globemallow seed production

HORTICULTURAL USES OF NATIVE PLANTS

Adaptation of Roundleaf buffaloberry (*Shepherdia rotundifolia*) to urban landscapes
Heidi Kratsch, Chalita Sriladda, and Roger Kjelgren

- Roundleaf buffaloberry (*Shepherdia rotundifolia*) is extremely drought tolerant and shows ornamental traits that make it an attractive candidate for use in urban home and commercial landscapes. However, the species is difficult to keep alive in culture and is known to be short-lived in irrigated ornamental landscapes. Silver buffaloberry (*Shepherdia argentea*) is widely distributed in riparian areas throughout the West and is common in naturalized designed landscapes in the Great Basin region. We performed reciprocal crosses of *S. rotundifolia* with *S. argentea* and obtained a successful hybrid with intermediate leaf characters.
- The interspecific hybrid between *S. rotundifolia* and *S. argentea* may be better adapted to and more acceptable in urban landscapes than either species alone.

SPECIES INTERACTIONS

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

- Some native forbs such as *Amsinckia tessellata* and *A. intermedia*, show promise as good competitors against *Bromus tectorum.*
- The presence of certain native annual forbs, such as *Mentzelia veatchiana*, can enhance the establishment and restoration of native perennial grasses, such as *Elymus multisetus,* in *B. tectorum* invaded rangelands.
- The presence of native annual forbs provides a positive, indirect effect that promotes 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

- In 2010, density of seeded native grasses was highest in plots that received the combination of disking+spring glyphosate treatment, significantly greater than that of disk-treated plots, 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 2011. We noted an obvious increase in exotic annual forbs during the 2011 growing season, especially tansy mustard (*Sisymbrium altissimum*).
- We conducted a field tour on July 7, 2011 to look at results of applying crested wheatgrass reduction methodologies and seeding native species.

The ecology of native forb establishment in crested wheatgrass stands: A holistic approach
Jeremy James

- Initial demographic work on seeded mixtures of forbs and grasses show that the majority of seeded individuals germinate (> 60%) but less than 10% of these individuals emerge following germination; meaning up to 90% of the seeded plant material dies before seedlings emerge from the soil surface.
- Up to 60-80% of commonly seeded native grasses and forbs germinate in the field but only 2-10% of these germinated seeds emerge from the soil surface.
- In contrast, for introduced species like crested wheatgrass, 20-40% of germinated seeds successfully emerge. This is the main reason why introduced species have higher stand establishment than natives.
- Current research is examining the mechanisms behind these native plant recruitment bottlenecks and identifying management strategies to overcome these limitations.

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

- Over a 13-year period, crested wheatgrass density increased 12-fold while most native bunchgrass density decreased or remained the same
- This suggests that, when seeded together, crested wheatgrass recruits new individuals into the plant community, while native perennial bunchgrasses do not and that crested wheatgrass may be displacing some of the native perennial bunchgrasses.

WILDFIRES, RESTORATION STRATEGIES AND EQUIPMENT

Revegetation Equipment Catalog website maintenance
Robert Cox

- During 2011, the Revegetation Equipment Catalog website was updated with all links checked and corrected. During 2012, the website will be fully transferred to Texas Tech, and the mirroring site at Texas A&M will be removed.

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

- In 2011, few plants remained at the Nephi research location and plots at that location were abandoned. Additional efforts to establish Astragalus filipes and Dalea ornata in the greenhouse trials were unsuccessful. Based on field trials it appears that scarification and stratification will be required to achieve uniform Astragalus filipes germination, while scarification alone appears to greatly improve Dalea ornata germination.

- Preliminary trials evaluating annual grass germination and growth in response to imazapic in petri-dish assays compared to trials conducted with soil filled pots shows that responses differ significantly between the two systems and that petri-dish assays will not likely be useful in predicting forb response to imazapic in the field.
- In 2012, a new research location will be established near Logan, Utah and core treatments will be applied in the spring and the fall.

Smoke-induced germination of Great Basin native forbs
Robert Cox

- An extensive literature search is being conducted for all known smoke effects on as many Great Basin native forb species as possible.
- Based on smoke-response, species will be prioritized for further population-based testing.
- Our aim is to develop smoke-induced germination protocols for Great Basin restoration species.

Pollination and breeding biology studies
James Cane

- In burns of even degraded sage-steppe plant communities across the northern Basin and Range province, our samples show that bee communities are clearly emerging well within the fire perimeter during the spring after the fire. In the weeks following a massive fire, they continued to forage and nest wherever their host plants continue to flower, even miles into the burn where they are clearly resident. Bloom will be needed by resident bee faunas in the year following wildfire, either recovering resident species or newly seeded populations.

Development of seeding equipment for establishing diverse native communities
James Truax

- The evolution of the Roughrider continued during 2011; effort was focused primarily on three areas: durability, shock absorption, and variable planting depth.
- Research and design changes have shown that by changing the stroke control configuration it is possible to provide down forces on the planter assemblies, while at the same time allowing individual planters to flex upward without having to lift the entire machine mass.
- The depth control gage wheels were removed from a Roughrider when planting several plots outside Mountain Home, ID in the late fall of 2010 which allowed the seed furrow to be increased to 1-1/2” to 2” compared to the 1/2” to 1” with the gage wheels installed.

Influence of post-fire treatments on exotic, native residual and seeded species production at the Scooby wildfire site in Northern Utah, 2010
Megan Taylor, Ann Hild, Urszula Norton and Nancy Shaw

- Exotic production, primarily Russian thistle, halogeton, and cheatgrass, was greatest in the undisturbed/unseeded controls and was at least five times as great as the exotic biomass in seeded treatments. Russian thistle and cheatgrass weights were much lower in seeded treatments than the three controls.
- Native grass production (seeded and residual native grasses together) was greater in seeded treatments than in controls. Grass seedings effectively reduced productivity of both cheatgrass and Russian thistle at the Scooby site.
- In the absence of seeding, soil disturbance with empty drills (meant to replicate a failed seeding) appears to enhance recruitment of residual forbs and Russian thistle relative to

undisturbed controls.

- Our data demonstrates that native grasses and forb seedings can effectively reduce the production of annual forb and exotic species following wildfire. Because annuals (especially exotic annuals), can produce large numbers of seeds when they are not challenged by competitive neighbors, it is critical to use post-fire reseeding to limit their success. Managers may be enticed to seed non-native species to dominate sites subjected to wildfire because they are sometimes thought to be more effective competitors than native species. These results indicate natives can provide a strong competitive environment to limit exotic annual production.

Native plant selection and restoration strategies
Nancy Shaw, Matthew Fisk, Erin Denney, Jan Gurr, Alexis Malcomb, and Robert Cox

Plant Materials

- Seventy-eight collections of 22 species were made with the assistance of two Job Corps interns. Samples of 46 collections were distributed to the USDA ARS Western Regional Plant Introduction Station via the Seeds of Success Program. Stock seed of Eagle germplasm western yarrow was provided to the Utah Crop Improvement Association for distribution to growers. Stock seed of four species was provided to growers for commercial production via the Utah Crop Improvement Association. Two species are being increased at the Lucky Peak Nursery. Sixteen collections and two seed mixes were distributed to cooperators and other users.

Post-fire Native Seedings

- Fifth year results from a Wyoming big sagebrush site in northern Nevada: Emergence of a broadcast (small-seeded) mix was enhanced when seeded through a minimum-till drill and pressed into the soil with imprinter units rather than broadcast with a standard rangeland drill. Emergence of the drill (large-seeded) mix was similar with both drills. After 5 years density of drilled, but not broadcast species was generally greater on seeded plots. Thus, the minimum-till drill may provide better emergence, but subsequent survival is dependent upon environmental conditions. In the fifth year there was also a tendency toward reduced basal gap lengths in seeded treatments, indicating a potential reduction in water erosion risk.
- Equipment and strategies for post-fire establishment of native species in sagebrush shrublands – Scooby and Saylor Creek seedings:
    - Selection of clean seedbeds was reflected in low densities of cheatgrass at both locations in the first year following seeding, minimizing competition with seeded species and recovering residual natives.
    - At Scooby, aerial cover of cheatgrass was reduced in seeded treatments compared to the nonseeded controls by the second year indicating suppression by the established seeded perennials.
    - There was a tendency toward improved emergence of drill-seeded species (large seed mix) when seeded with the standard rangeland drill at Scooby, but not Saylor Creek. This effect was lost by the second year at Scooby.
    - Emergence of broadcast shrubs (primarily Wyoming big sagebrush) was greatest when planted at the highest rate through the minimum-till drill.
    - Basal gaps, which are indicative of soil erosion potential, were reduced on seeded treatments by the second year at Scooby.
    - The measure of richness used did not discern differences. Drill seeded grasses dominated the seeded vegetation at both sites.

Project Title: Adapted Thurber's Needlegrass for the Great Basin

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

Principal Investigators and Contact Information:

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Project Description:

Background

The conservation and utilization of native plant resources in the Great Basin, especially after disturbances such as fire, is becoming increasingly important. Yet seed adaptation zones, an understanding of the ecological distance plant material should be transferred from original source populations, is lacking. Thurber's needlegrass is among the most important species in the Great Basin. However, seed supplies are limited and generally collected from wildland stands.

Objectives

1) Obtain Thurber's needlegrass from diverse sites and ecological areas in the Great Basin.
2) Establish common gardens studies at Central Ferry, WA and Reno, NV of diverse Thurber's needlegrass representing Great Basin environmental diversity.
3) Measure a comprehensive set of growth and development factors on Thurber's needlegrass at both common garden sites.
4) Complete genecology studies linking environmental factors at seed source locations with genetic variation across the landscape to establish seed transfer zones.
5) Make source identified plant material available for utilization through the Western Regional Plant Introduction Station seed repository at the WRPIS and the National Plant Germplasm System.

Methods

Objective 1

Thurber's needlegrass accessions have been collected from the Great Basin, primarily from Oregon, Idaho, and Nevada. In fall 2011, common garden studies were established at Central Ferry, WA and Reno, NV to characterize this germplasm and determine seed adaptation zones for the central Great Basin.

Objective 2

Thurber's needlegrass seeds from approximately 40 populations were germinated at the WRPIS. Seedlings were placed in soil in planting cells and transplanted at Central Ferry and Reno (529 plants in the Reno Common Garden). Each location will be represented by plants from two families replicated six times and randomized into complete blocks at each garden site. Individual plants were planted 90 cm apart and watered in after transplanting. Data collection will begin in Spring 2012. The study will continue for at least two years.

Objective 3

In previous work, a set of plant variables were measured or derived for Indian ricegrass (*Achnatherum hymenoides*) (Table 1). A similar approach will be taken at the Central Ferry and Reno gardens on newly collected Great Basin germplasm.

Table 1. Potential measured and derived traits for Indian ricegrass common gardens

Variable	Description
Heading date	DOY†, complete emergence of 1st inflorescence
Bloom date	DOY, Presence of 1st anthers
Maturity date	DOY, Half of seed heads shattered
Leaf width	(mm) Widest point of flag leaf
Leaf length	(cm) Base of flag leaf to tip
Leaf length/Leaf width	Leaf length divided by leaf width
Leaf length*Leaf width	Product of leaf length and width
Inflorescences per plant	Count of inflorescences
Seeds per inflorescence	Count of seed heads on lead inflorescence
Culm length	Length - base of plant to inflorescence (cm)
Inflorescence length	Length - inflorescence base to tip (cm)
Culm length/Inflor. length	Culm length divided by inflorescence length
Habit	Prostrate to upright rating scale (1-9)
Leaf texture	Coarse to fine rating scale (1-9)
Leaf abundance	Low to high rating scale (1-9)
Leaf roll	Flat to cylindrical rating scale (1-9)
Crown diameter area	Plant base length (cm) x width (cm) / 2 (cm^2)
Dry weight	Harvest weight after drying (g)
Regrowth weight	2nd harvest weight after drying (g)
Dry weight less regrowth	1st harvest weight less 2nd harvest weight (g)
Germination	AOSA Rules for Testing Seeds

†DOY= day if year form 1 January

Objective 4

Genecology studies will be completed as outlined by Erickson et al. (2004) for blue wildrye and St Clair et al. (2005) on Douglas fir. Univariate analyses of variance will be completed on each variable from which a set of traits will be selected. The traits will be used in principle component analysis to reduce data dimensions. The principal component scores derived for locations will be used in multivariate regression to model environmental variable with plants genetic traits. The regression models will be used to map seed transfers zones for Thurber's needlegrass in the Great Basin.

Results

Seedlings of Thurber's needlegrass were transported to the University of Nevada, Reno in the Fall of 2011 and transplanted into a common garden. Measurement of plant traits will begin in spring 2012.

Publications:

Forbis, T.; Leger, E.; Goergen, E. 2011. The role of native annual forbs in the restoration of the invaded rangelands. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 141-143.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Leger, E.; Goergen, E.; Espeland, E. 2011. Evolution of native plants in cheatgrass invaded systems. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 144-146.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Presentations:

Goergen, E.; Leger, E.; Forbis, T. 2011. The role of native annual forbs in the restoration of invaded rangelands. Great Basin Native Plant Selection and Increase Project Annual Meeting, February 22-23, Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Management Applications and Seed Production Guidelines:

This research will ultimately result in the production of seed of key populations for multiplication and utilization in the Great Basin in conjunction with BLM seed buys and other revegetation or restoration programs.

Products:

Recommendations for adapted Thurber's needlegrass for the Great Basin and conservation of key germplasm within the National Plant Germplasm System. The germplasm will be freely available for research.

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

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

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Project Description:

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

Objectives

1) Using common gardens, determine the magnitude and patterns of genetic variation among bluebunch wheatgrass populations from a wide range of source environments in the Great Basin, Columbia 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 USFS Lucky Peak Nursery near Boise, ID. Data was collected for 20 traits of growth, phenology and morphology at each of the three contrasting test sites during years 2007 and 2008. Seed was collected from the common gardens in 2008 and germination tests conducted in 2009 to evaluate population variation in germination. Analyses have been done to evaluate differences among test sites, years, populations, and families within populations, as well as their interactions, and to look at the relationship between population variation and climatic variation at source locations. Maps of genetic variation across the landscape have been produced, and 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 greater than 30% of the variation of individual plants could be attributed to differences among populations. Variation among families within populations was small.

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

Correlations of 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. Large population differences consistently correlated with environmental variables in ways that make sense suggests adaptively significant genetic variation that should be considered when moving populations in restoration projects.

Regressions between traits, including PCs, and climatic and geographic variables were done and the resulting models were used in GIS to produce maps of genetic variation in adaptive traits. Seed zones were delineated by dividing the first PC into three homogeneous areas, and the second and third PCs into two areas, then overlapping them to indicate areas that were of similar values for the three independent multivariate traits that account for the most of the variation in all traits that were evaluated (Figure 1). The trait maps and seed zones largely reflect differences among Level III ecoregions, but with variation within ecoregions corresponding to temperature, precipitation and aridity.

Publications:

St. Clair, B.; Johnson, R.; Shaw, N. 2011. Genetic diversity and genecology of bluebunch wheatgrass (*Pseudoroegneria spicata*). In: Great Basin Native Plant Selection and Increase Project. p. 1-3.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Presentations:

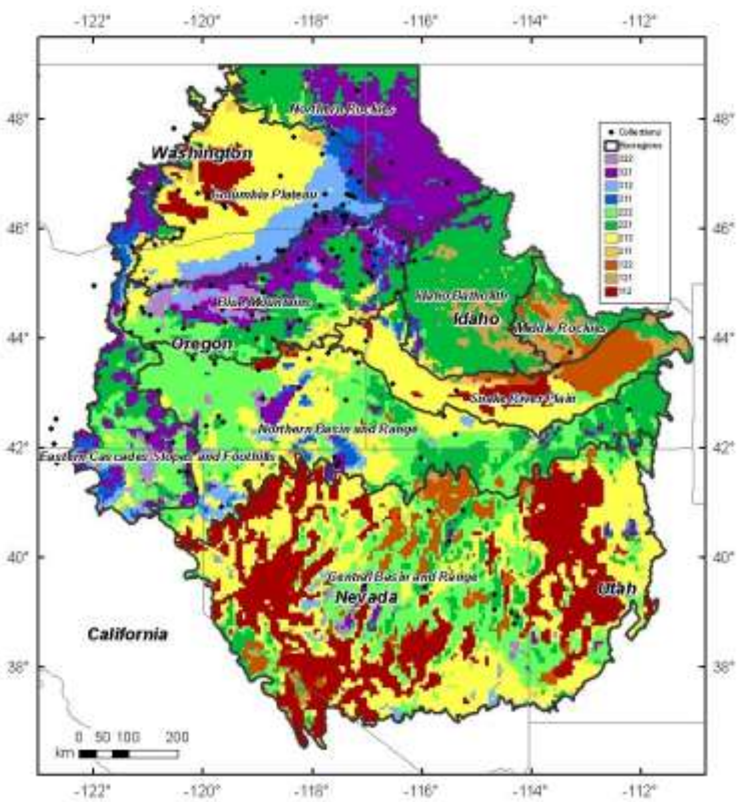
St.Clair, J.B., R.C. Johnson, and N.L. Shaw. 2011. Genecology and seed transfer guidelines for bluebunch wheatgrass (*Pseudoroegneria spicata*). Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22-23, Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Bower, A.; St. Clair, B.; Erickson, V. 2011. Generalized provisional seed zones for native plants. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22-23, Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Management Applications and Seed Production Guidelines:

This study indicates that populations of bluebunch wheatgrass 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 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, and provides guidelines for conservation of germplasm within the National Plant Germplasm System. Results are being submitted to a peer-reviewed journal, and will be disseminated through symposia, field tours, training sessions, or workshops.



		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.

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

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

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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), and Basin wildrye (*Leymus cinereus* [Scribn. & Merr.] Á. Löve). These species are critical for wildlife habitat, livestock grazing, soil stabilization, and ecosystem function in the most of the Western United States. Current releases of these species do not specifically match the natural genetic diversity within the species with local climatic variation to develop seed zones. Seed zones 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 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 linked to seed source location climates and conflated into composite plant traits using multivariate statistics.
3) Regression models linking plant traits and sources climate are developed and used with GIS to map seed transfer zones.

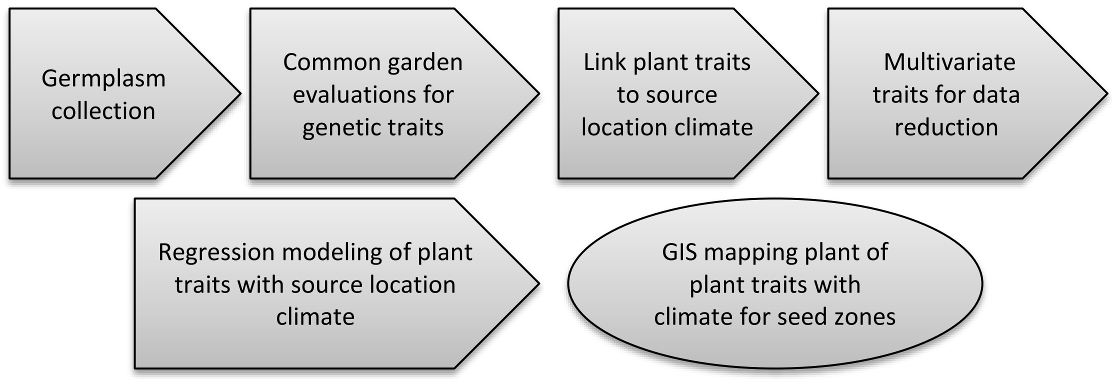

Figure 1. Schematic showing the steps for genecology studies to establish seed zones.

Indian Ricegrass

Germplasm and Common Gardens

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

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

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

Canonical Correlation and Composite Plant Traits

The purpose of the multivariate analysis was to obtain a smaller set of composite plants traits that represented a large fraction of the overall variation to facilitate regression modeling and mapping of seed zones (Johnson et al. 2010). Plant traits for the phenology (Phen), production (Pro), and morphology (Morph) categories were used with climatic variables (temperature and precipitation) at source locations to obtain sets of Phen, Pro, and Morph composite traits that correlated with the set of climatic variables (St Clair et al. 2005). For phenology, only the first canonical variate, Phen1, was significant; for production, only Pro 1 and 2 were significant, and for morphology, Morph 1, 2, and 3 were significant (Table 2). Phen1 explained almost half the variation, Pro 1 and 2 a total of 55% of the variation, and Morph 1, 2, and 3 a total of 54% of the variation (Table 2).

Monthly correlation of composite plant traits with temperature and precipitation showed different patterns (Fig. 2). Precipitation tended to be most important to plant traits in the spring, during active growth and development, especially Phenology 1 and Production 1, whereas for temperature those traits were significant every month without the strong seasonal pattern observed with precipitation (Fig. 2).

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

	2007				2008			
Plant trait	Mean	Env (E) †	Source (S)	E x S	Mean	Env (E)	Source (S)	E x S
Phenology		-------------P-values----------				------------P-values----------		
Panicle emergence, doy	191.3	0.0087	<.0001	0.8217	148.1	0.7141	<.0001	0.2093
Blooming, doy	179.7	0.0115	<.0001	0.0566	138.8	0.5014	<.0001	0.8715
Maturity, doy	205.1	0.0008	<.0001	0.1285	166.4	0.0014	<.0001	<.0001
Blooming to maturity	25.44	0.6285	0.0073	0.7612	27.60	0.0222	<.0001	0.1886
Production								
Leaf abundance, 1(low) to 9(high)	4.810	0.0370	0.0001	0.0076	3.752	0.0242	<.0001	0.6676
Panicle number per plant	13.19	0.0190	<.0001	0.3323	105.8	0.2830	<.0001	0.7563
Seeds per panicle	48.02	0.0963	<.0001	0.4535	43.59	0.2698	<.0001	0.7041
Dry weight, g	22.17	0.0265	<.0001	0.1797	45.96	0.7055	<.0001	0.5229
Crown diameter area, (length x width)/2	25.73	0.0071	<.0001	0.1540	34.33	0.9130	<.0001	0.6350
Regrowth weight, g	3.578	0.5322	<.0001	0.4160	11.054	0.0371	<.0001	0.1501
Morphology								
Habit, 1(prostrate) to 9 (upright)	5.541	0.1807	<.0001	0.4093	6.018	0.1771	<.0001	0.7828
Leaf roll, 1(flat) to 9(cylindrical)	4.544	0.0975	<.0001	0.0105	6.854	0.6338	<.0001	0.8734
Leaf texture, 1(coarse) to 9(fine)	5.237	0.0407	<.0001	0.3761	5.635	0.9885	<.0001	0.5725
Leaf width, cm	0.184	0.0557	<.0001	0.5135	0.1551	0.8942	<.0001	0.3380
Leaf length, cm	14.57	0.9388	<.0001	0.8779	13.11	0.4156	<.0001	0.2985
Lf length x Lf width, cm^2	2.832	0.3468	<.0001	0.9163	2.128	0.7312	<.0001	0.5189
Culm length, cm	25.12	0.3058	<.0001	0.1262	27.01	0.8575	<.0001	0.0963
Panicle length, cm	14.90	0.3145	<.0001	0.6343	12.86	0.1564	<.0001	0.2347

† Environments were irrigated and dryland common gardens at Central Ferry, WA.

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

	Phen1	Pro1	Pro2	Morph1	Morph2	Morph3
Explained variance %	49	35	20	25	18	11
Canonical correlation	0.75	0.78	0.69	0.83	0.79	0.71
F-value	1.51	1.62	1.33	1.66	1.46	1.29
P-value	0.002	<0.001	0.010	<0.001	<0.001	0.004
Correlation, average temperature	0.48**	-0.48**	0.21*	0.31**	0.25**	0.22*
Correlation, average precipitation	-0.33**	0.33**	-0.21*	-0.24*	-0.26**	-0.38**

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

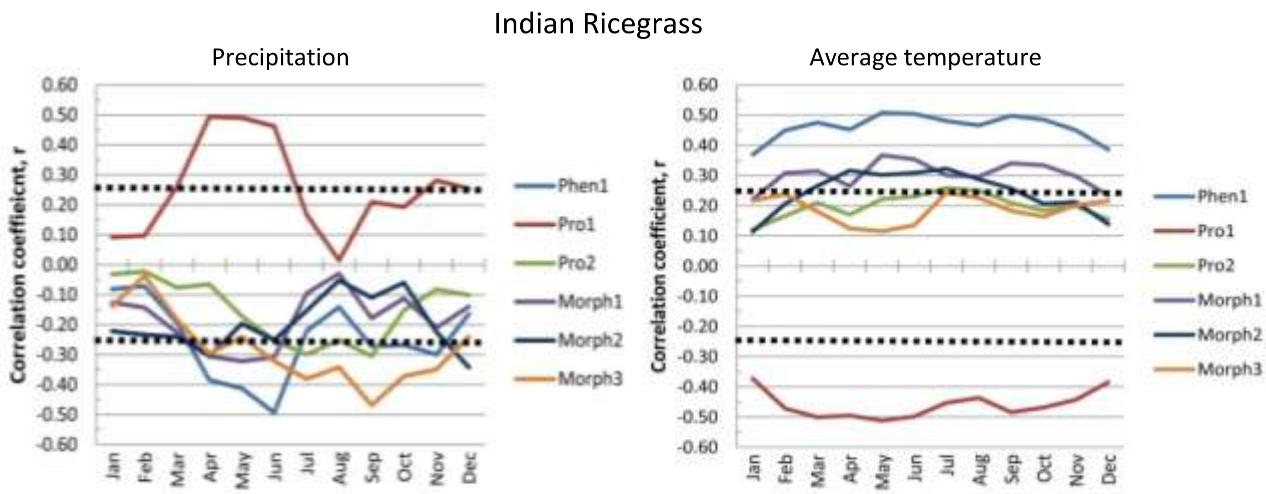

Figure 2. Linear correlation coefficients between monthly temperature and precipitation and significant (P<0.01) canonical variates for phenology (Phen), production (Pro), and morphology (Morph) for Indian ricegrass locations in the Southwestern United States (n=106). The dashed line represents the P=0.01 significance level.

The six significant canonical variates (Table 2) represented too many traits to easily produce a comprehensive two-dimensional seed zone map. Thus, an additional canonical correlation analysis using Phen 1, Pro 1 and 2, and Morph 1, 2, and 3 traits with temperature and precipitation and was completed.

For seed zones, the combined attributes of cancorr extracts 1, 2, and 3, which explained 81% of the variation associated with the original six canonical variates (Table 2), were included by overlaying maps based on regression models (Fig 3). This resulted in 12 seed zones representing 1 084 475 square kilometers (Table 3). A total of 92% of the eight ecoregions studied were within the range of the cancorr extract scores and were thus mapped (Fig. 3). The largest seed zone was M1L2H3 representing nearly 30% of the total mapped area and the smallest zone was the reddish brown L1H2L3 represented just 1.4 % (Fig. 3, Table 3). Areas outside the range of the cancorr extract scores usually corresponded to high elevation areas in the Wasatch and Unita Mountains and the Southern Rockies (Fig. 3).

The seed zone map revealed general differences between the warmer deserts in the south compared with the cooler deserts of the north. For example most of the warm Mojave Basin and Range mapped to a separate seed zone shown in the lighter blue H1L2H3 (Fig. 3), which was 11% of total mapped area (Table 3). The Central Basin and Range, however, included four major seed zone areas: the lighter green M1L2H3, the darker green M1H2H3, the tan L1L2H3, and the darker brown L1H2H3 (Fig. 3). Often the same seed zone transected different ecoregions (Fig. 3). Thus, ecoregions alone were not a reliable surrogate for seed zones in Fig. 3 derived from genetic and climate data.

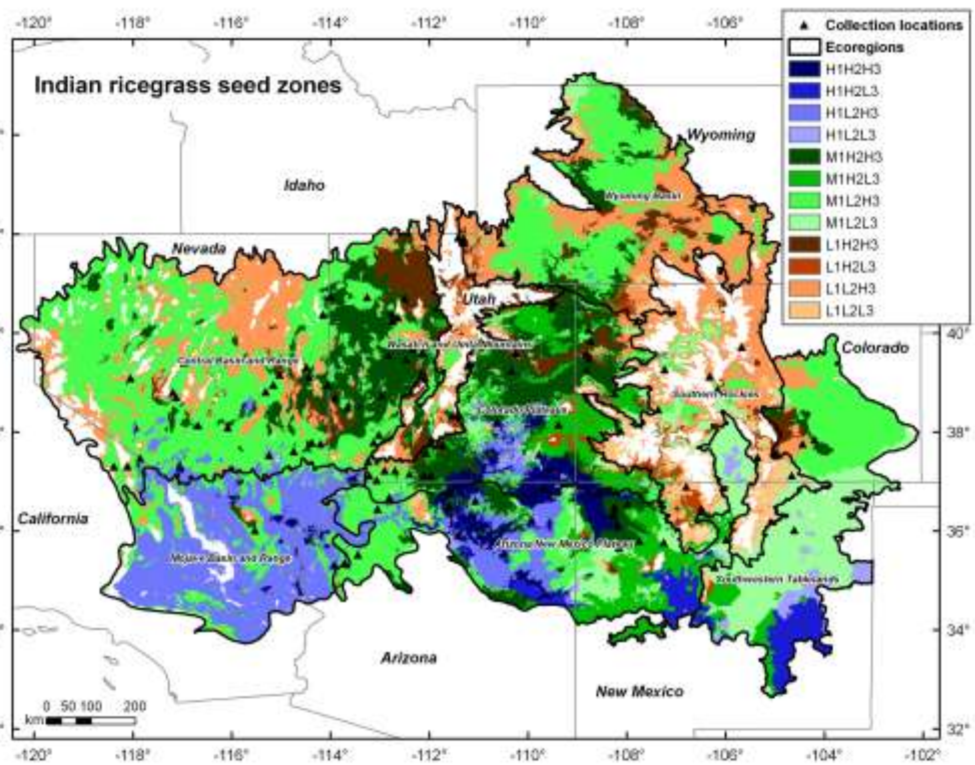

Figure 3. Proposed seed zones for Indian ricegrass in the Southwestern U.S. resulting from overlays of canonical variate scores (cancorr extracted) derived from phenology 1, production 1 and 2, and morphology 1, 2, 3. Abbreviations H1, M1, and L1 refer to high, middle and low ranges of cancorr extract 1 scores; H2 and L2, and H3 and L3, refer to high and low ranges of cancorr extracts 2 and 3, respectively. This resulted in 12 seeds zones. Model predictions outside the range for the original canonical variate scores, shown in white, were not mapped.

We sought to develop seed zones as large as possible to promote efficient use of resources without unduly compromising the association of climate and genetic diversity, naturally resulting in some subjectivity. The contour interval for mapping, twice the $LSD_{0.05}$ of the regression model error, resulted in relatively wide contour intervals and large seed zones. For restoration, the knowledge of land mangers and restoration practitioners is especially critical. Modifications to our zones based on management considerations and experience should be encouraged. For example, coalescence of relatively small areas within zones, or zones with smaller areas (Table 3), may facilitate efficient management. Smaller or larger zones may be recommended by land managers in a certain areas or ecoregions, and these could be developed using the basic regression models and error terms developed for the proposed seed zones in Fig. 3. Transfer of germplasm over long distances across ecoregion may not be prescribed even if within the same seed zone. Also, special consideration of microclimates, challenges of mined sites, invasive weeds, or other types of serve degradation may affect the choice of germplasm for a certain area.

Table 3. Area represented by each seed zone for Indian ricegrass collection locations across the Southwestern US 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	100.00	106

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

Within the Southwest 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, 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 released germplasm. Nor are significant portions of the Colorado and Arizona/New Mexico Plateaus that mapped in blue hues. Thus, it appears there are significant germplasm needs for Indian ricegrass in the Southwestern United States.

This need could be approached within seed zones through expansion of the traditional selection of single ecotypes or their variants with the goal of enhancing agronomic characteristics, such as seed production and reduced seed dormancy (USDA, NRCS 2000, Jones et al. 2010). Alternatively, collections of unselected populations within seed zones could be grown, released, and replanted within each seed zone. Although the former allows more efficient seed production, the latter encourages restoration based on more locally adapted, diverse populations over the landscape, allowing greater scope for adaptation to changing climates.

Sandberg bluegrass and Basin wildrye

Germplasm collection for Sandberg bluegrass and Basin wildrye was completed across the Great basin prior to establishing common gardens. Seeds from each location were germinated, grown under greenhouse conditions, and transplanted to common garden sites.

The Sandberg bluegrass 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 randomized complete blocks replicated six times. Data was collected in 2009 and 2010. Analyses so far indicate strong differences among plants from different locations indicating strong genetic variation (Table 4).

Common gardens of Basin wildrye were established at Pullman and Central Ferry sites in 2010 and included plants from 114 collection locations with two families per location, randomized in complete blocks with six replications. Data collection for phenology, production, and morphological traits was completed in 2011 and will continue in 2012 and 2013.

Table 4. Analysis of variance for Sandberg bluegrass collected in the Great Basin and grown in a common garden at Central Ferry, WA, 2009 (n=130).

Trait	Mean	F-value	P-value
Phenology			
Heading, day of year	116.4	3.72	<0.0001
Anthesis, day of year	132.2	4.43	<0.0001
Maturity, day of year	160.3	2.88	<0.0001
Heading to anthesis, days	15.9	3.29	<0.0001
Anthesis to maturity, days	27.7	2.80	<0.0001
Heading to maturity, days	43.5	2.68	<0.0001
Production			
Leaf abundance, 1 to 9 rating	4.23	3.17	<0.0001
Crown diameter, cm	9.55	3.53	<0.0001
Crown area, cm^2	50.8	3.62	<0.0001
Inflorescence quantity	53.7	2.50	<0.0001
Dry weight, g per plant	21.6	4.88	<0.0001
Morphology			
Leaf length, cm	6.39	7.21	<0.0001
Leaf width, cm	6.98	6.98	<0.0001
Plant height, cm	11.0	4.09	<0.0001
Inflorescence length, cm	11.7	5.13	<0.0001
Culm length, cm	33.3	3.16	<0.0001
Plant habit, 1 to 9	5.51	1.96	0.0002

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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 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 to ensure plant materials used for restoration are adapted and suitable.
- 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.
- Through 2011, a total 2,150 SOS accessions were distributed for research and utilization by the NPGS (Table 5).

Table 5. Distributions of Seeds of Success germplasm from the National Plant Germplasm System from 2005 through 2011.

	2005	2006	2007	2008	2009	2010	2011	Total
Taxa	1	21	135	315	338	359	348	1517
Accessions	1	23	161	438	467	558	502	2150
Total orders	1	3	54	128	118	116	126	546

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

Project Location: USFS Rocky Mountain Research Station, Shrub Sciences Laboratory, Provo, Utah

Principal Investigators and Contact Information:

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Project Description:
Big sagebrush (*Artemisia tridentata*) is one of the most ecologically important and landscape dominant plant species in western North America. This species is a major focus for ecosystem restoration after disturbances because of its importance in wildlife forage, invasive weed exclusion (e.g., cheatgrass), snow catchment and nutrient cycling. Big sagebrush is divided into three major subspecies, *tridentata, vaseyana, 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 its adaptive breadth will lead to continued ecosystem degradation and encroachment of invasive species. Successful restoration of big sagebrush requires understanding the climatic factors involved in defining subspecies and populations.

Objectives
1) Establish common gardens from collected seed sources across the range of big sagebrush.
2) Develop molecular markers from transcriptome data of subspecies *vaseyana* and *tridentata.*
3) Elucidate genetic structure using molecular markers and adaptive traits.

4) Determine climatic factors important to adaptation within and among big sagebrush ecological races.
5) Develop climate-based seed zone maps for the entire range of big sagebrush

Project Status

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 of 2010. First-year measurements were conducted in October and November of 2010. Measurements included height, diameter at the ground and overhead photos to calculate crown area. Plants were supplemented with water until August and mortality was minimal for the first year at < 2%. No supplemental water will be added in the future. Overall, the subspecies preliminary growth patterns have met expectations. Subspecies *tridentata* yielded the greatest heights and diameters and the Ephraim plot produced the highest yields among all subspecies. The preliminary data also indicated different allocations of wood development to height. Subspecies *tridentata* had lower ratios (i.e., greater height to wood develop) compared to ssp. *vaseyana* (data not shown). Much of this data will be analyzed after the 2012 field season.

Table 1. Location information of three sagebrush common garden sites.

Site name	Latitude	Longitude	Elevation (m)
Orchard, Idaho	43.328	-116.003	976
Ephraim, Utah	39.369	-111.580	1686
Majors Flat, Utah	39.337	-111.521	2088

Molecular genetics

In September of 2009, leaf tissue was collected from two big sagebrush specimens (subspecies *tridentata* and *vaseyana*) growing in Provo, Utah. Total RNA was extracted and the transcriptomes were sequenced for both subspecies using a Roche 454 FLX Genome Sequencer. The DNA sequence data has been compiled and annotated with over 21,000 sequences identified with putative function. This data includes over 20,000 SNPs (single-nucleotide polymorphisms) and 119 polymorphic microsatellite markers that will be a resource for downstream projects such as the development molecular markers for population genetic and phylogenetics studies. In September of 2010 further RNA sequencing of was complete on two ssp. *wyomingensis* from Utah (UTW-1) and Montana (MTW-1). After aligning DNA sequence reads from the *wyomingensis* samples with the previous reference sequence developed from the ssp. *tridentata* and *vaseyana* samples, it was found that some interesting SNP patterns emerged. Out of approximately 1,000 SNPs between ssp. *tridentata* and *vaseyana*, ssp. *wyomingensis* was heterozygous for over 1/3rd. For the remaining SNPs, the most, approximately 60%, match ssp. *vaseyana* compared to ssp. *tridentata* at 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 in 48 sites, approximately 7 individuals per site (Figure 1). Phylogenetic relationships based on approximately 12,000 base pairs of DNA show diploid *A. t. 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* (Fig. 2).

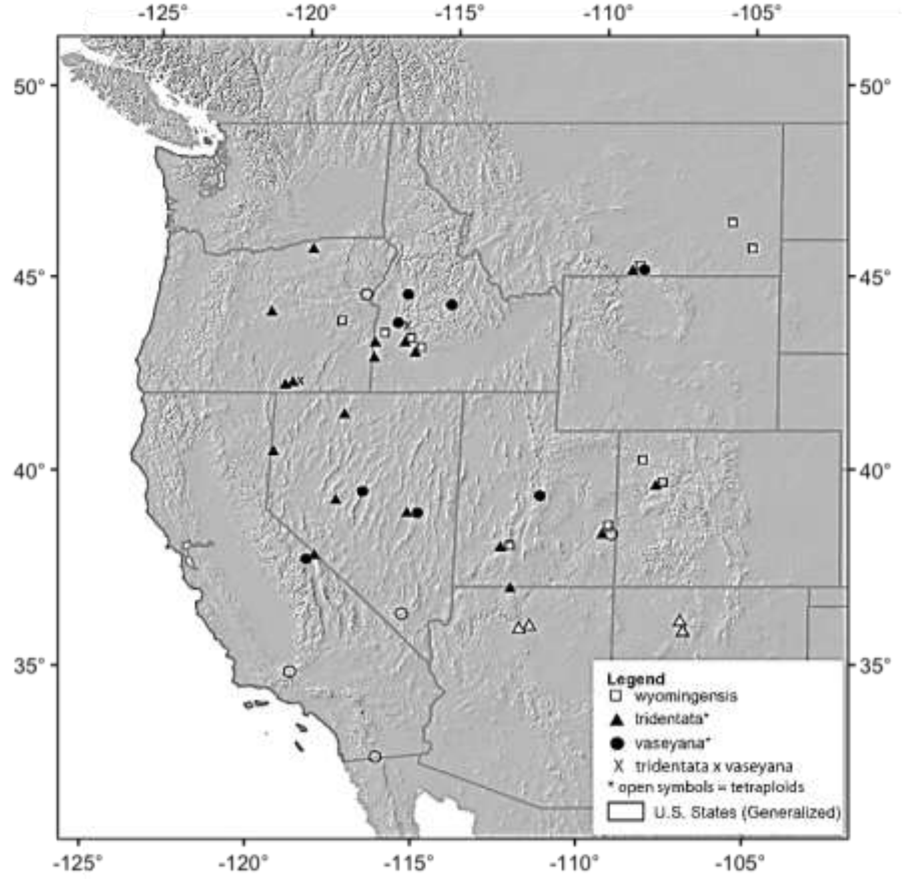

Figure 1. The location of 48 seed collection sites for *Artemisia tridentata* used in the molecular genetic study. The symbols identify subspecies *wyomingensis*, *tridentata* and *vaseyana*.

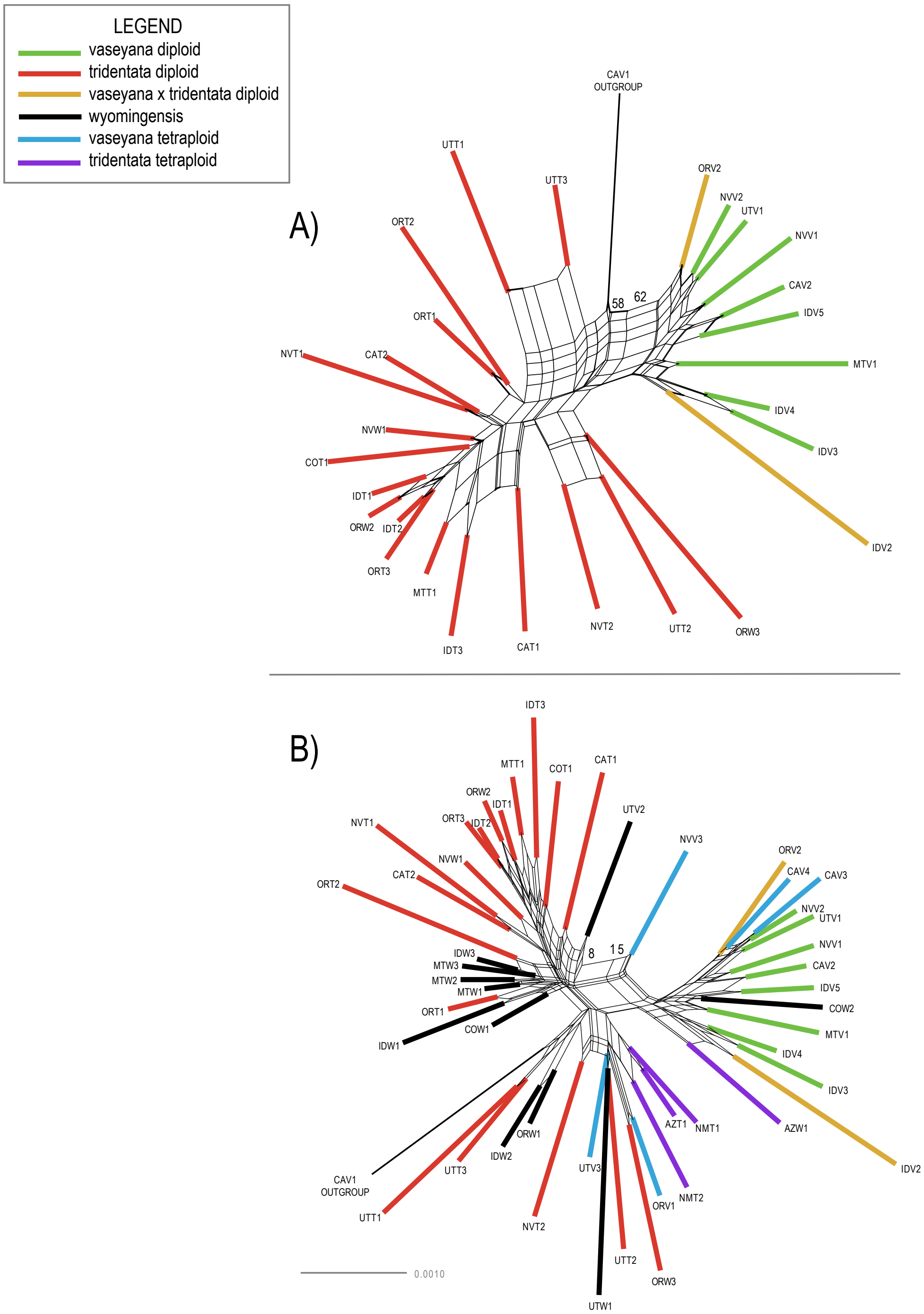

Figure 2. Unrooted phylogenetic networks using neighbor-net algorithm. The networks were constructed from uncorrected p-distances based on 24 contigs of consensus sequences of each collection site. A) Illustrates relationships between 28 diploid collections and B) includes diploid collections and 20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

Future plans

Common gardens

Continued measurements of common garden plants will occur on a monthly basis during the growing season of 2012. Weather data will be collected at each common garden site. Such data can be used in the development of genecological models for delineation of seed zones. Progress is being made in taking physiological measurements at these gardens during the 2012 season.

Molecular genetics

Future questions addressed with molecular genetics include: 1) geographically defining tetraploid lineages of big sagebrush, 2) assessing the phylogenetic relationships between big sagebrush and other sagebrush species, 3) determining whether interspecific hybridization is an important evolutionary process.

Publications:

Richardson, B.A.; Page, J.T.; Bajgain, P.; Sanderson, S.C.; Udall, J.A. In prep. Deep sequencing of amplicons reveals widespread intraspecific hybridization and multiple origins of polyploidy in big sagebrush (*Artemisia tridentata*).

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Richardson, B.A.; Bajgain, P.; Udall, J.A.; Shaw, N.L. 2011. Assembling the adaptive genetic and genomic pieces in Intermountain shrub species to provide conservation and restoration guidelines. Western Forest Genetics Association. 2011 July 25-28, Portland, OR.

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

Products:
Development of molecular markers and annotated genes in big sagebrush for use in future studies. Data deposited into Genbank (completed).

Elucidate evolutionary relationships between and within big sagebrush subspecies (manuscript in preparation).

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

Leveraged funding: National Fire Plan, Western Forest Transcriptome Survey,

Media reports: Land Letter (April 28, 2011 issue). They highlighted the uses of next-generation sequencing on the genetic relationships of sagebrush.

Project Title: Selecting Sagebrush Seed Sources for Restoration in a Variable Climate: Ecophysiological variation among genotypes

Project Location: U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Snake River Field Station, Boise, Idaho

Principal Investigators and Contact Information:

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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 ecological potential of this ecosystem type, particularly in the Great Basin. Choice of appropriate seed sources for restoration efforts is currently unguided due to knowledge gaps on genetic variation and local adaptation as they relate to a changing landscape. We are assessing 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. Seedlings were previously planted into common gardens by US Forest Service collaborators Drs. B. Richardson and N. Shaw, (USFS Rocky Mountain Research Station, Provo, Utah and Boise, Idaho) as part of the Great Basin Native Plant Selection and Increase Project. Seed sources spanned all states in the conterminous Western United States. Germination, establishment, growth and ecophysiological responses are being linked to genomics and foliar palatability. New information is being produced to aid choice of appropriate seed sources by Bureau of Land Management and USFS field offices when they are planning seed acquisitions for emergency post-fire rehabilitation projects while considering climate variability and wildlife needs.

<u>Objectives</u>

1) Assess the 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; determine if 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) Determine whether physiological performance relates to genetic relatedness (determined by Dr. Richardson from gene sequencing), which will help establish that the identity of plants indeed relates to their ability to perform in the gardens.

Progress

Since beginning the project in August 2011, we have measured survival, growth, shoot morphology, water status, photosynthetic carbon uptake, stomatal conductance, transpiration, photochemical efficiency, and freezing points repeatedly on plants in the common garden located near the Orchard Research Center, Idaho (hereafter "Orchard common garden"). Field sampling has occurred in the peak heat and dryness of mid-August, and at the coldest part of year in wintertime. In collaboration with USDA ARS (Parma, ID), we established a new method for measuring the freezing point of leaf tissue. We have also analyzed the modeled climate-of-seed origin, and evaluated the soil profiles of the garden. Several new proposals to US Geological Survey and the Idaho National Science Foundation Experimental Program to Stimulate Competitive Research EPSCoR were submitted, and support for an undergraduate to add measurements of anti-defense (palatability) compounds was procured and progress is underway.

Methods

Between 5 and 10 individual plants of nearly 20 populations per each of the three subspecies were planted into the Orchard common garden in spring of 2010. Starting in August 2011, we began measurements on the plants, which were all >18 months in age and ranged in height from 0.25 to > 1 meter height, and all measurements are still ongoing. We measure 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, and other derivative parameters are then calculated. Gas exchange rates are determined on a leaf mass basis, a projected leaf-area basis, and a silhouette leaf area basis. Leaf area and mass are determined using digital photography and by weighing following 48 hours of drying at 60°C. Chlorophyll fluorescence is measured at pre-dawn on dark adapted leaves using a fluorometer (Mini-PAM, Walz, Germany), specifically to determine the ratio of variable to maximum flouresence as an indicator of maximum intrinsic light-use efficiency. The freezing point of leaves is determined by pressing leaves against a semi-conductor plate that records the exotherm released by cell water when incubator temperatures cause water to freeze. Differences in ecophysiology among subspecies or populations are determined using univariate and multivariate statistics.

Preliminary results

We have collected over 4000 data points for 14 response variables combined and data collection and analyses are still underway, so a limited number of preliminary results are presented here. When populations were combined, major differences in growth and survival are evident in the garden, with 20% mortality and the lowest growth rates for *A. t. vaseyana* (mountain big sagebrush), and the greatest growth (crown volume) in *A. t. tridentata* (basin big sagebrush). Mortality of *A. t. tridentata* and *A. t. wyomingensis* (Wyoming Big Sagebrush) is 6.5% as of February 2012. However, for these and nearly all responses measured to date, there were larger differences within subspecies (among populations, i.e. seed lots) than among subspecies.

One variable that appears relatively invariant among the populations and subspecies is freezing point (temperature which causes cell water to freeze), which was -7.3°C ± 0.1, similarly in November and January. Mean photosynthetic rates were highest in early December (compared to

August), but quickly decreased to near zero once minimum air temperatures decreased to about -10°C. Following this chilling, chlorophyll fluorescence (Fv/Fm, the ratio of variable to maximum fluorescence) values decreased by more than 60% from August maximum values. Physiological tolerance of freezing can be measured as the freezing-induced decrease in the chlorophyll fluorescence ratio Fv/Fm, which indicates loss of photochemical efficiency and the onset of a syndrome known as low-temperature photoinhibition of photosynthesis. By this measure, freezing tolerance appears to differ among the subspecies and populations, and climate-of-seed origin appears to influence frost resistance (Fig. 1). Populations that originated from a warmer home range had relatively greater loss of photochemical efficiency and expressed more photoinhibition of photosynthesis, particularly in *A. t. tridentata* (Fig. 1). In a separate test in January, we chilled excised leaves of nine populations per subspecies to -20°C, and measured their reductions in Fv/Fm compared to unchilled control leaves, and found that the reductions were greatest in *A. t. wyomingensis* (-0.22 ± 0.04 change in Fv/Fm) and least in *A. t. tridentata* (-0.05 ± 0.02). Resistance to freezing may be a key factor to consider in seed source selection, and it may be predictable from subspecies identity and by climate-of-seed origin, although further analysis of the relationship of freezing resistance to growth and survival is needed to substantiate its importance.

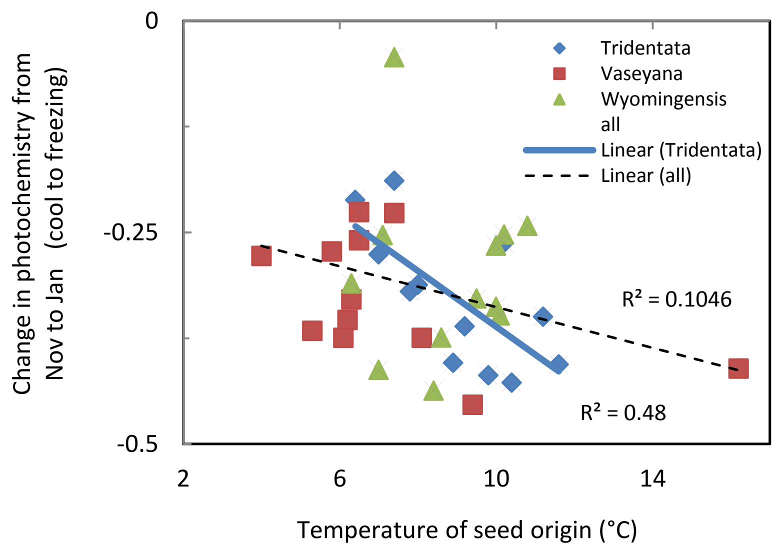

Figure 1. Relationship of loss in photochemical efficiency (change in chlorophyll fluoresence, Fv/Fm) during the seasonal transition from cool to freezing conditions) to the mean annual air temperature from where each population's seed was collected. Each datum is a population with 5-10 replicate plants. The regression shown by the dashed line is for all populations, whereas the blue line is for *A. t. tridentata*.

In the warmest and driest part of the year, preliminary data suggest water status and photosynthesis were greatest in *A. t. tridentata* and least in *A. t. vaseyana*. Again, differences were greatest among populations within each subspecies. Greater photosynthesis on a per-leaf-unit basis appeared to correlate well with increased growth (not shown, $P<0.0001$, $r^2=0.9$). Greater photosynthesis, in turn, did not appear to result from either greater capacity for photosynthesis at a given hydration level (Fig. 2, left) or greater photosynthetic water-use efficiency (Fig. 2, right panel). Unexpectedly, these efficiencies appear to be greater in *A. t.*

vaseyana, but we will corroborate these "snapshot" findings made from short-term measurements of gas exchange in the future, with more robust determinations of water-use efficiency from stable-isotope approaches. We hypothesize that the differences in physiological performance result primarily from relatively greater soil-water uptake by *A. t. tridentata* and the populations within it that had the greatest photosynthesis and thus growth. We will test this hypothesis using stable isotopes of water as natural tracers of depth-of-water uptake.

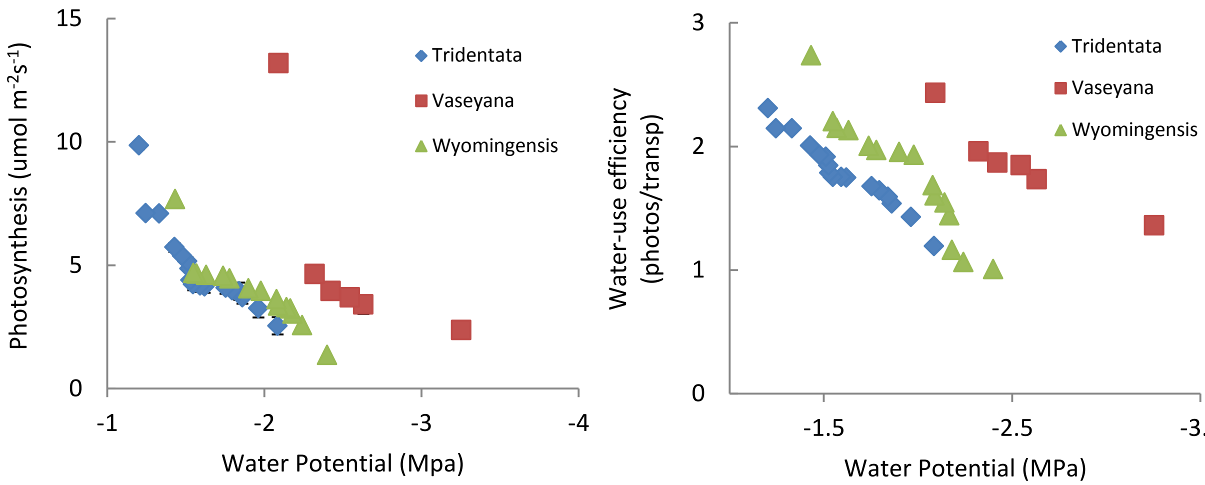

Figure 2. Left panel: midday photosynthesis as a function of pre-dawn water status. Right panel: photosynthetic water-use efficiency, determined as the ratio of photosynthesis divided by transpiration (mmol/mol). Each symbol represents a unique seed source and population, and the values shown are the mean of all replicate plants of the population surviving in the common garden (ranges from 4 to 10 plants).

Lastly, we have used multivariate statistics to determine how the combination of all ecophysiological traits measured can be used to distinguish relatedness of the populations and subspecies. Dendrograms produced with hierarchical clustering (JMP, SAS Institute, Inc.) of all ecophysiological data combined revealed clusters of populations that have related ecophysiological performance, but the clusters are not related taxonomically (e.g. all clusters of plants having similar ecophysiology had mixes of all three subspecies). In a subsequent and separate analysis, we created a composite index score of all the ecophysiological variables by first assigning a rank value for each parameter (population with highest score received highest rank value), and then we summed the rank scores of all variables into a "total rank score" for each population. We then plotted this rank score against a measure of genetic similarity (PCA Eigenvector in Fig. 3) provided by Dr. B. Richardson. This "PCA Eigenvector" is the principle-components analysis axis that explains about 30% of the genomic variability among all populations. Preliminary results show that genetically similar plants tended to have similar values of the composite rank index, indicating that populations that are more related genetically also tended to have a similar physiological performance ($P<0.05$). Although there is some clustering of taxonomic groups (e.g., the lower left points are often *A. t. vaseyana* that had high mortality), the relationship suggests a better correspondence of ecophysiological performance to the genetic constitution rather than taxonomic identity of populations. These preliminary findings may suggest that genetic rather than taxonomic criteria can predict fitness of seed sources to a site, but further analyses are needed and are underway to substantiate this potential finding.

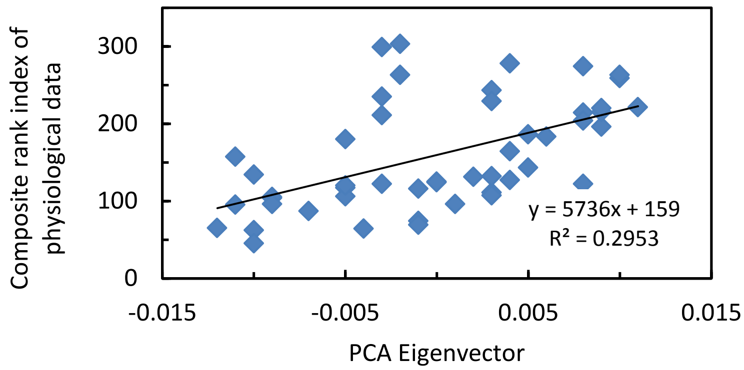

Figure 3. Relationship of a composite index of rank values for all physiological variables to the Principle-Components Eigenvector that explains 30% of the genomic relatedness. Each point is a population, with multiple plants measured for each population.

Future Plans

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. We will also determine the carbon isotopic ratio (13C:12C) in dried leaf tissue in order to develop a more robust and integrative measure of photosynthetic water-use efficiency. 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. The common garden in Orchard Idaho is one of three established by Dr. Richardson using the same seed collections, and we will extend our isotopic analyses to samples from his other two gardens. The other two gardens, located near Ephraim UT, differ in climate and soils from the Orchard ID site.

Secondly, with collaborators from Boise State University (Dr. J. Forbey and students), we are beginning an analysis of palatability to herbivores, which is one of the major criteria for selecting sagebrush where it is planted to enhance habitat for greater sage-grouse and other species, but has rarely been evaluated. We are measuring total phenolic, monoterpene, and antioxidant content in the same sagebrush shoots previously measured for physiology. We anticipate determining the relationship between establishment success (mainly growth), winter stress level that relates to chemical changes in leaves, and the biochemical expression of herbivore defense compounds.

Lastly, we will continue relating our findings to the genomic work and analyses of Dr. Richardson. The majority of seedling mortality occurred in the year prior to our initiating measurements (the critical establishment phase), and so there is a practical limit to our ability to describe factors most directly affecting successful establishment. To overcome this, our continued collaboration will expand to use the remaining seed stock from populations that experienced high mortality rates in order to more closely examine physiological performance in early life.

Publications:

We are in our 7th month on this project (from timing of project idea inception and implementation), and our intent was to analyze plant performance over a year of seasonal climate variability for the established plants. We are preparing a manuscript on wintertime chilling effects for peer-reviewed publication, and will produce another following completion of our year-long analysis and stable isotope determinations.

Presentations:

Germino M.J. 2011. Great Basin Landscape Conservation Cooperative. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011, February 22-23. Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Management Applications and Seed Production Guidelines:

Our short-term, "snapshot" 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 be combinable with other evidence to begin establishing bases for seed-transfer guidelines. Our preliminary data suggest the subspecies and populations with the greatest growth and survival also had greater photosynthesis as a result of better hydration, which we postulate is linked to their tapping into deeper soil-water sources. Additionally, physiological threshold responses, such as freezing tolerance, also may be related to growth and survival and may emerge as a useful and predictable consideration in planning seed acquisitions for particular climates. These preliminary results suggest selection for rapid growth may contribute to stress resistance and establishment success. Fitness, in terms of ecophysiological performance, may be more distinguishable from genetic rather than taxonomic identity, which may imply a role for genetic testing of seed sources.

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) Laser spectrometers for carbon and water isotope determination, and a combustion elemental analyzer and microbalance for sample preparation were purchased based partly on sample processing needs for this project, with the project foremost in mind, at an expense of nearly $200K.

Project Title: Globemallow and Sagebrush Performance under Varying Conditions

Project Location: University of Idaho, Moscow, Idaho

Principal Investigator and Contact Information:

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Project Description:

Big Sagebrush Seedling Cold Storage

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 two months beginning March 2011. In May 2011, seedlings were transplanted into 1 gal pots containing 2:1 sand:vermiculite and watered every five days. After two months of growth in a greenhouse at the University of Idaho Pitkin Forest Nursery (Moscow, ID), the study was terminated. Morphological parameters were measured and calculated, including: 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 ANOVA showed that storage treatment had no effect on any of the morphological parameters measured; however seedling mortality was higher for freezer-stored seedlings. Overwinter storage in a cooler can be recommended. 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 of five accessions within the current range of Wyoming big sagebrush. Five, one-year old seedlings were transplanted into 9.63 L (2.55 gal) pots containing 2:1 sand:vermiculite. Height growth, RCD growth, root and shoot volume growth, specific leaf area, and seedling dry weights were measured four months after transplanting. Biweekly gas exchange measurements were also conducted. 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 of five accessions within the current 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 four month study. At the end of 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.

<u>Globemallow</u>

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 is able to tolerate drought, extreme temperatures, and establish 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) Understand the dormancy mechanisms in seeds of *Sphaeralcea munroana*.
2) Evaluate the feasibility and efficiency of various dormancy breaking techniques.
3) Evaluate the morphological and physiological characteristics of *S. munroana* 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 *S. munroana* 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 (N43°52’49.6”, W116°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 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 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 a 1) control, 2) mechanical scarification, 3) stratification, and 4) combined scarification and stratification treatments. Mechanical scarification procedures were consistent with those mentioned above. Seeds were stratified at 4.5±0.02°C for six 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 (GA_3) on germination we subjected seeds to eight treatments: 1) control; 2) mechanical scarification; 3) 24-hour and 4) 48-hour soak in 100 ppm GA_3 solution; 5) scarification and 24-hour or 6) 48-hour soak in DI water; 7) scarification and 24-hour or 8) 48-hour 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 second submergence in 100°C), 3) tumbling, 4) burning, 5) dry-heat, and 6) burning and heating scarification. Seeds were tumble-scarified in a rotary rock tumbler with dry aluminum oxide grit for 72 hours (Kildisheva 2011; Kildisheva et al. [in review]). Following tumbling, seeds were separated from grit using a series of sieves (Dreesen 2004). For burning scarification, seeds were placed in a single layer on a metal mesh screen, submerged uniformly in 95% ethyl alcohol (C_2H_5OH) for one minute, placed on a fire-resistant surface, ignited with a hand-held butane torch, and allowed to burn for 10 seconds before being extinguished with DI water (Sugii 2003; Kildisheva et al. (in review)). For dry-heat scarification seeds were subjected to (80°C) for 60 minutes (Baskin and Baskin 1997). Seeds in the burning and dry-heat scarification treatment were burned first.

General Findings

Results indicate that *S. munroana* 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 seven hours, but seed mass gain was highest for mechanically scarified seeds. Although mechanical scarification and scarification plus H_2O 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 *Sphaeralcea munroana*

Sphaeralcea munroana 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 prep.]). 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 temperature (17/3°C or 23/9°C) treatments. Each temperature and moisture treatment combination was randomly assigned to 20 seedlings, which remained under these growing conditions for 25 days. Mortality and assessments of physiological (photosynthesis, stomatal conductance, and transpiration), as well as morphological (number of true leaves, leaf area, above- and belowground biomass, and the root-to-shoot ratios) condition were made at the end of the testing 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 *S. munroana* 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 *Sphaeralcea munroana* (Kildisheva 2011; Kildisheva and Davis [in prep]).

Future Research Recommendations

- Trials with boiling water and other forms of scarification are necessary to further improve the germination and seed handling practices of *S. munroana* 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 that evaluate plant responses to environmental conditions during the entire life cycle are necessary.

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Pavek, P.L.S.; Cane, J.H.; Kildisheva, O.A.; Davis, A.S. 2011. Plant guide for Munro's Globemallow (*Sphaeralcea munroana*). Pullman, WA: USDA Natural Resources Conservation Service. 5 p.
http://www.fs.fed.us/rm/pubs_other/rmrs_2011_pavek_p001.pdf

Presentations:

Kildisheva O.A.; Davis, A.S. 2011. Munro's globemallow: Exploring seed dormancy. Great Basin Native Plant Selection and Increase Project Annual Meeting, February 22- 23, Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Kildisheva, O.A.; Davis, A.S. 2011. Restoration strategies for a native perennial: Germination and seedling physiology of *Sphaeralcea munroana*. Western Forest and Conservation Nursery Association Annual Meeting, August, Denver, CO.

Overton, E.C.; Brown, J.; Pinto, J.R.; Davis, A.S. 2011. Cold storage of sagebrush seedlings: Implications for native plant management. 11th Intertribal Nursery Council Meeting, September 13-15, Temecula, CA.

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 *Artemisia tridentata* ssp. *wyomingensis* can aid in understanding of differences in growth patterns that may occur between populations on the landscape.
- *Sphaeralcea munroana* 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.
- *Sphaeralcea munroana* 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 rower 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: Development of Germination Protocols, Seed Weight, Purity and Seed Conditioning/Cleaning Protocols for Great Basin Grasses and Forbs

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

Principal Investigators and Contact Information:

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

Publications:

Karrfalt, R.P.; Vankus, V. 2011. Development of germination protocols, seed weight, purity and seed conditioning/cleaning protocols for Great Basin grasses and forbs. In: Great Basin Native Plant Selection and Increase Project 2010 Progress Report. p. 34-36. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Presentations:

Karrfalt, R.P. 2011. 41 Month storage data for *Artemisia tridentata* ssp. *wyomingensis*. Great Basin Native Plant Selection and Increase Project Annual Meeting. 2011 February 22-23, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Karrfalt, R.P. 2011. Using Equilibrium Relative Humidity technology to preserve the short-lived seeds of *Artemesia tridentata* ssp. *wyomingensis*. Intertribal Nursery Council Annual Meeting. 2011 September 13 – 15, Temecula, CA.

Management Applications:
The sagebrush seed storage study indicates that sagebrush seed can be stored for several years longer than previously thought if it is properly prepared and frozen. This implies that banking sagebrush seed is a possibility so that quality seed of the right genetic source is readily available for restoration work, even in years of poor seed crops.

The positive results with sagebrush seeds can be used as a model to store other short-lived seeds such as winterfat (*Kraschenninikovia lanata*).

Growers now have an estimate of how to break dormancies to prepare seeds for sowing and what germination temperatures are required.

Products:
<u>Seed germination protocols</u>
Germination protocols were examined for 31 species (Table 1). The germination temperatures in table 1 are preliminary because more seed lots need to be tested and more temperature variations on the best conditions from these trials must be tested before endorsing a final best temperature or temperature range. However these results should be useful to growers. In summary it can be said that all legumes require scarification with some needing moist chill periods as well. Some species are non dormant while the penstemons, flax, desert frasera, Nevada goldeneye, balsamroots, and biscuitroot are very dormant requiring months of pregermination moist chilling. Work continued on *Achnatherum hymenoides*, but a reliable prescription for germination is still not defined.

All protocol results and 1000 seed weights determined to date can be found at: http://www.nsl.fs.fed.us.

<u>Wyoming big sagebrush seed storage</u>
Storage of Wyoming big sagebrush *Artemisia tridentata* ssp. *wyomingensis* in sealed moisture proof containers has proven to maintain high germination for 5 years if the seed is cleaned to high purity, dried to an equilibrium relative humidity of 30% and frozen at – 8^o or -20^o C. The methods and materials of this study have been reported in the 2009 report of the GBNPSIP. The bar graph below summarizes the 5-year data.

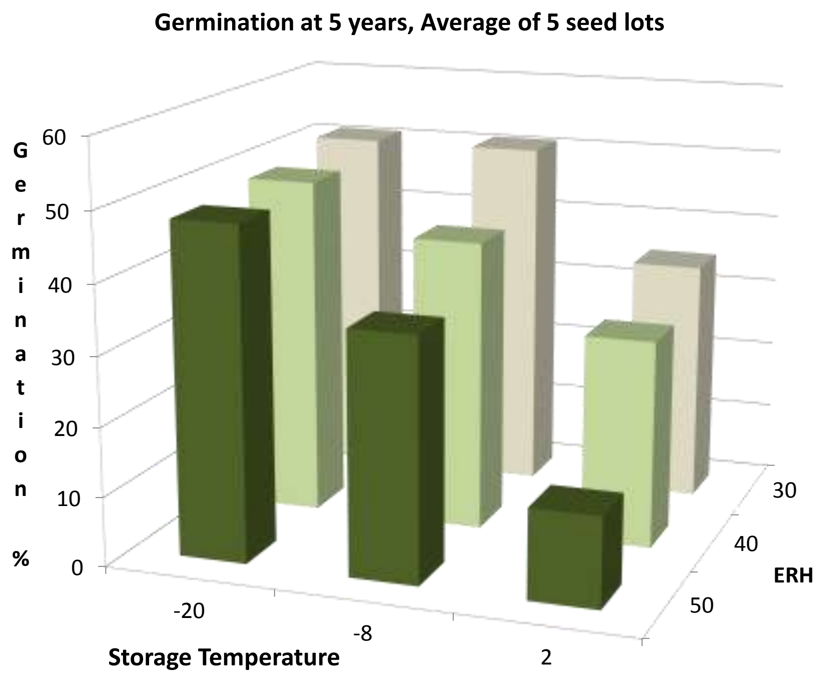

Figure 1. The effect of equilibrium relative humidity and storage temperature on the germination of Wyoming big sagebrush seeds sealed in moisture-proof bags.

Table 1. Preliminary germination requirements for 31 species in the Great Basin Native Plant Selection and Increase Project.

Scientific Name	Best temperature (°C)*	Moist chill period (weeks)	Scarify
Arenaria macradenia ssp. *ferriseae*	15, 20	4, 4+	No
Astragalus beckwithii	10, 15, 20	4	Yes
Astragalus utahensis	15, 20	4	Yes
Balsamorhiza hookeri	10, 15, 20	10	Yes
Balsamorhiza sagittata	10, 15, 20	10	Yes
Cleome lutea	10, 15, 20	4	Yes
Cleome serrulata	10, 15, 20	4	Yes
Crepis acuminata	10, 15, 20	0, 4	No
Crepis intermedia	10, 15, 20	0, 4	No
Cryptantha rugulosa	20	0	No
Enceliopsis nudicaulis	15, 20	4	No
Eriogonum heracleoides	10, 15, 20	4, 4+	No
Eriogonum ovalifolium	10, 15, 20	4, 4+	No
Eriogonum villiflorum	10, 15, 20	4, 4+	No
Frasera albomarginata	10, 15, 20	12+	No
Heliomeris multiflora var. *nevadensis*	10	8	No
Ipomopsis aggregata	10, 15, 20	24	No
Linum lewisii	10, 15, 20	4	No
Linum rigidum	20	6, 12	No
Lomatium nudicaule	5/10	8, 8+	No
Lupinus arbustus	10, 15, 20	4	Yes
Lupinus argenteus	10, 15, 20	0	Yes
Lupinus polyphyllus	10, 15, 20	0	Yes
Mentzelia laevicaulis	20	0	No
Nicotiana attenuata	15, 20	4+	No
Packera streptanthifolia	20	4+	No
Penstemon deustus	10	12	No
Penstemon pachyphyllus	10, 15, 20	12+	No
Penstemon rydbergii	10, 15, 20	12+	No
Stanleya pinnata var. *integriflolia*	20	4	No
Thelypodium milleflorum	20	4+	No

***** 5/10 indicates night temperature of 5° for 16 hours and day temperature of 10° for 8 hours. A single number means a constant temperature was used. Several numbers denotes several temperatures were equally good.

Project Title: Modeling Seedling Root Growth of Great Basin Species

Project Location: Brigham Young University, Provo, Utah

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

<u>Objectives</u>

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

<u>Growth Chamber Study</u>

We have 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. Black plexiglass holders were constructed to hold 70 (5 replicates x 14 collections) clear plastic root tubes 2.5-cm 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 and minimized root exposure to light. For each of six constant temperature 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 a planting tube. Prior to sowing, Utah milkvetch seeds were scarified in sulfuric acid for 15 minutes followed by stratification at 1.5° C for two weeks along with squirreltail seeds. Tubes were checked six days per week and the depth of the deepest root was recorded. Time to germination was recorded for 25 seeds of each collection in petri dishes that were placed on racks below the root experiment in the incubation chamber. Soil temperatures were measured with six thermocouples per block placed into the ends of root tubes and attached to a Campbell Scientific, Inc. CR10X micrologger. Temperatures were read each minute and average hourly temperatures recorded. At the end of each temperature run, one tube of each collection per block was harvested and dry weight of root biomass 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 with root depths predicted from thermal accumulation models.

Table 1. Plant materials tested in root study.

	Scientific name	Common name	Cultivar	Source	Collection date
Forbs	*Achillea millefolium*	Western yarrow	Eagle	Eastern WA	2003
	Achillea millefolium	Common yarrow	White-VNS	Granite Seed	2003
	Agoseris heterophylla	Annual agoseris		USFS Shrub lab	2007
	Astragalus utahensis	Utah milkvetch		USFS Shrub lab	2002
	Linum perenne	Blue flax	Appar	UDWR	2003
	Lupinus arbustus	Longspur lupine		Wells, NV; UDWR	2004
Perennial grasses	*Agropyron cristatum x A. desertorum*	Crested wheatgrass	Hycrest	UDWR	2003
	Agropyron desertorum	Crested wheatgrass	Nordan	Granite Seed	2003
	Elymus elymoides	Squirreltail	Sanpete	UDWR	2003
	Elymus wawawaiensis	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

Field Experiment

The same experiment as described above was conducted at two locations in Utah for two years, 1) on the Brigham Young University campus, and 2) on the east side of the Onaqui Mountains in a Utah juniper/Wyoming big sagebrush plant community where the juniper trees have been shredded. In the 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 the root tubes, but inside soil or sand surrounding the tubes. These sensors were read every minute and hourly averages recorded with Campbell Scientific, Inc. CR10X microloggers.

Modeling

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

Project Status

Growth Chamber Experiment

We have conducted all 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 (Figure 1 and 2). In soil, Secar, squirreltail, and longspur lupine predicted degree days were significantly greater than their actual degree days. In sand, squirreltail and Nordan predicted degree days were greater than actual. These differences among predicted and actual degree days can be used to adjust future model predictions.

Actual vs. Predicted for Diurnal Root Trial 9-17°C. In sand for diurnal trial 9-17°C, there were no significant differences except predicted squirreltail required more degree days than actual (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 ’05, cheatgrass ’07, 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 cheatgrass ’05 otherwise, there were no inter-species differences in sand. Comparing across species in soil, flax required more degree days than any other species. The invasive annuals required fewer degree days than all of the forbs and the perennial grasses Secar and Hycrest. Annual agoseris required more degree days than all of the grasses except Secar and Hycrest. The general trend across species in soil was that annual grasses required the least amount of thermal time, forbs required the most thermal time, and perennial grasses were intermediate although, Secar was quite slow for a grass.

Inter-species Comparisons for Diurnal Root Trial 9-17°C. For inter-species comparisons in sand for the 9-17°C root trial, there were few significant differences, but cheatgrass ’05 did require fewer degree days than Anatone. For inter-species comparisons in soil, flax required the most degree days of any species. Cheatgrass ’05 and ’08 required fewer degree days than annual agoseris, Utah milkvetch, longspur lupine, and squirreltail.

As expected, cheatgrass roots grew the fastest at cool temperatures. However, the crested wheatgrasses and Anatone bluebunch wheatgrass definitely grew well enough to compete with cheatgrass. The importance of faster root growth to establishment is suggested by comparing the heat accumulation requirement of the forbs and that of the grasses. Forbs are known to not establish as well as grasses in rangeland revegetation projects. Blue flax, one of the most successfully-seeded forbs requires about 700-800 degree days to reach 15-cm root depth, while Anatone bluebunch wheatgrass requires 250-350 (Figure 2). SageSTEP data from four Great Basin pinyon-juniper locations for two years were used to calculate wet degree days in spring 2008 and 2009. Degree day accumulations when the soil is wet ranged from around 300 in early spring (March and April) to around 700 in late spring (May and June). As long as soil moisture is available from March into June, robust plants of both forbs and grasses should establish because they will have 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 the BYU campus and the east side of Onaqui Mountain for two years. We are currently analyzing these data.

<u>Future Work and Research Perspective</u>
We have conducted all of our experimental work for this grant and are now analyzing data and preparing 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:
An important application of thermal accumulation modeling is to predict which seeded species are most likely to establish given site specific soil temperature and moisture patterns and interspecies interference. As plants have to establish in communities, rates of root depth by invasive weeds influence the duration of resource availability to other species through resource preemption as the soil dries down from spring into summer. Knowing which species are most likely to establish on a site should save money by avoiding the planting of species that are not likely to establish on certain sites. Thermal accumulation modeling can also serve as a cultivar development tool selecting for more consistent and vigorously establishing native plants.

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

Research Phase: **Characterize Seedbed Environment**

Past and Current Work

- Soil moisture and temperature measurements from 30 sagebrush/bunchgrass, pinyon-juniper, crested wheatgrass, and cheatgrass sites and 170 stations in the Great Basin.

Major Findings

- 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 the spring, only slightly in the 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 2 sites and is being determined for the other sites.

Published or Planned Publications

Published

Chambers et al. 2007; Roundy et al. 2007; Rawlins et al. (2011b)

In preparation or submitted

Young, et al. Effects of shredding Utah juniper on soil moisture and temperature (submitted).
Cline et al. The germination environment of Great Basin seedbeds
Cline et al. Soil moisture availability and temperature of the seedling root zone in the Great Basin
Roundy et al. Effects of woodland fuel control treatments on soil moisture availability and temperature in the Great basin.

Table 2. Continued.

Research Phase: Develop models of germination and seedling growth

Past and Current Work

- Roundy's lab developed germination models for 14 collections while Hardegree's lab developed models for numerous desirable species collections and weed collections.
- Roundy's lab developed root growth models for 14 collections.

Major Findings

- 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.
- 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 or Planned Publications

Published

Roundy et al. 2007; Rawlins (2011a)

In preparation

Young et al. Thermal accumulation modeling of seedling root depth.

Research Phase: Compare modeled and actual responses in lab and field

Past and Current Work

- Roundy's lab has compared predicted and actual timing of germination under simulated field seedbed temperatures in the lab and in field seedbeds for 2 sites and 2 years.

Major Findings

- Thermal accumulation tends to overestimate time required to germinate seed subpopulations, but is accurate enough for field predictions. Wet thermal accumulation models using 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.
- Data from field and laboratory comparisons of predicted and actual seedling root depth is being analyzed.

Published or Planned Publications

Published

Rawlins (2011a,b)

In preparation

Young et al. Field prediction of seedling root depth using a wet-thermal accumulation model.

Research Phase: Extend predictions to a range of plant materials, environments, and land treatments

Past and Current Work

- Roundy et al. (2007) Cheatgrass germination prediction analysis for 9 sites in Great Basin
- 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.
- 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.

Major Findings

- 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 or Planned Publications

Published

Roundy et al. (2007)

In analysis and preparation

Cline et al. Potential germination of weed and revegetation species in the Great Basin: Effects of seasonal weather, site characteristics, and treatments.

Roundy or TBA et al. Predicting seedling mortality from thermal accumulation models of germination and root growth.

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Young, K.; Roundy, B. 2011. Modeling seedling root growth of Great Basin species. Ecological Society of America Annual Meeting, 2011 August 08-12, Austin, TX.

Cline, N.L.; Roundy, B.; Hardegree, S. 2011. Germination prediction from soil moisture and temperature in the Great Basin. Interior West Fire Ecology Conference, 2011 November 14-17, Snowbird, UT.

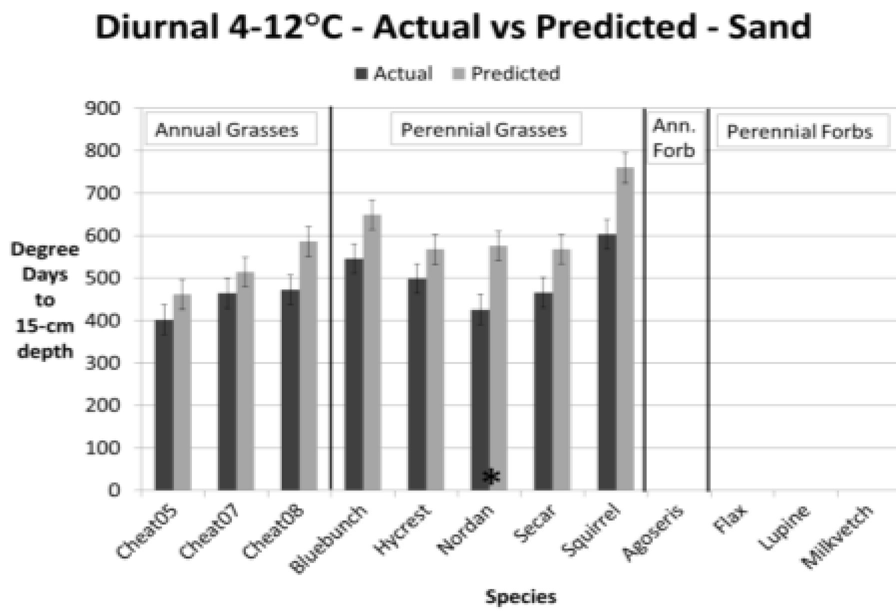

Figure 1. Actual vs predicted degree days to 15-cm root depth in sand for the growth chamber diurnal root trial 4-12°C. Asterisk indicates significant difference at 95% confidence level.

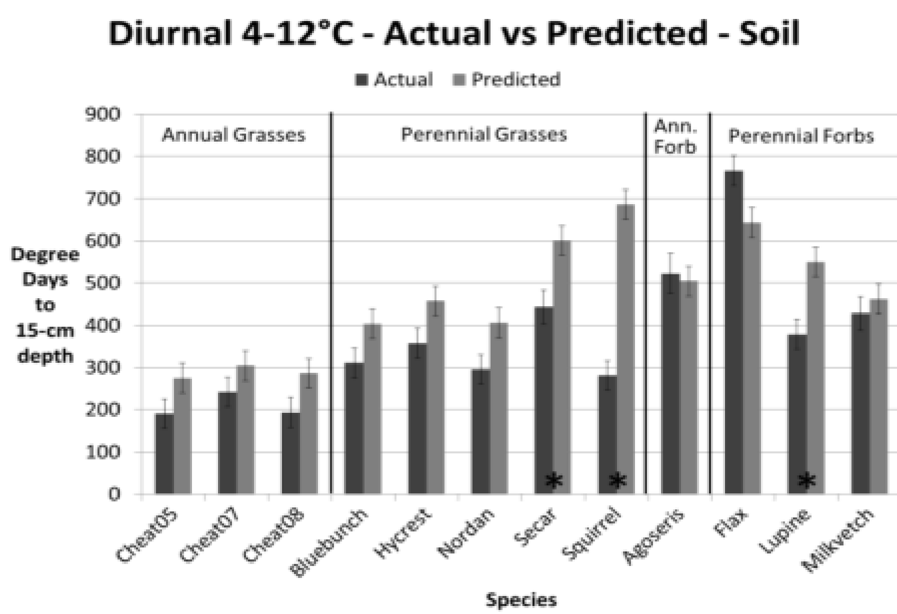

Figure 2. Actual vs predicted degree days to 15-cm root depth in soil for the growth chamber diurnal root trial 4-12°C. Asterisk indicates significant difference at 95% confidence level.

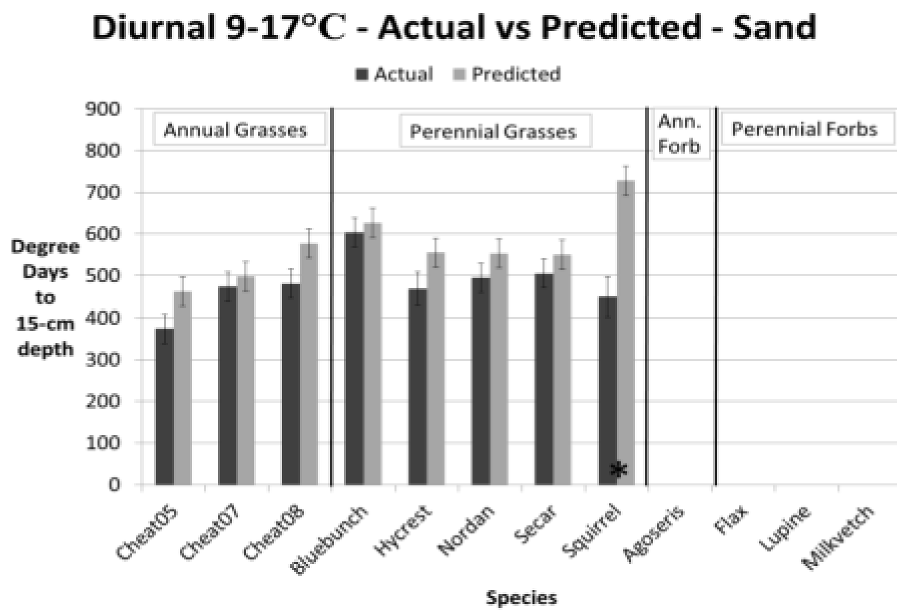

Figure 3. Actual vs predicted degree days to 15-cm root depth in sand for the growth chamber diurnal root trial 9-17°C. Asterisk indicates significant difference at 95% confidence level.

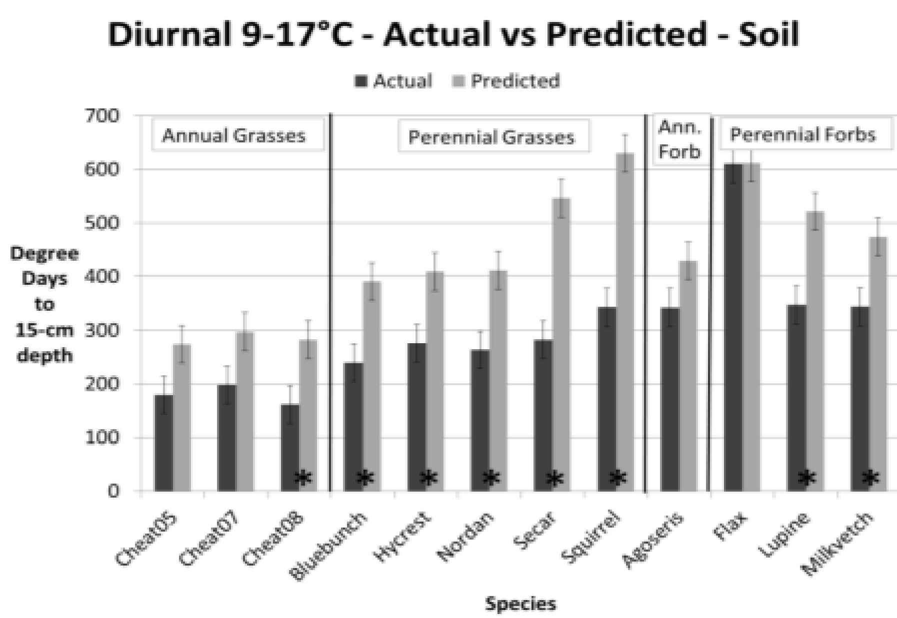

Figure 4. Actual vs predicted degree days to 15-cm root depth in soil for the growth chamber diurnal root trial 9-17°C. Asterisk indicates significant difference at 95% confidence level.

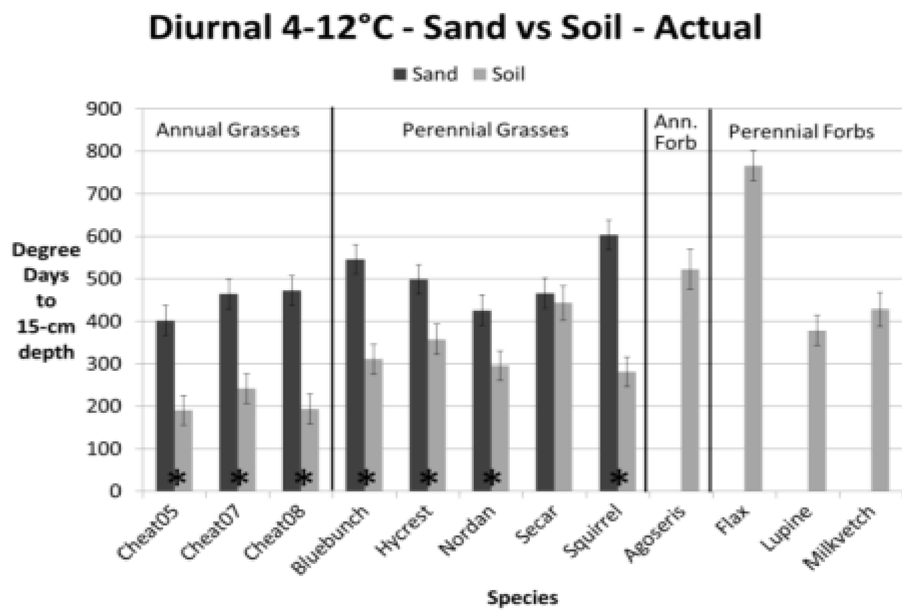

Figure 5. Actual sand vs soil degree days to 15-cm root depth for the growth chamber diurnal root trial 4-12°C. Asterisk indicates significant difference at 95% confidence level.

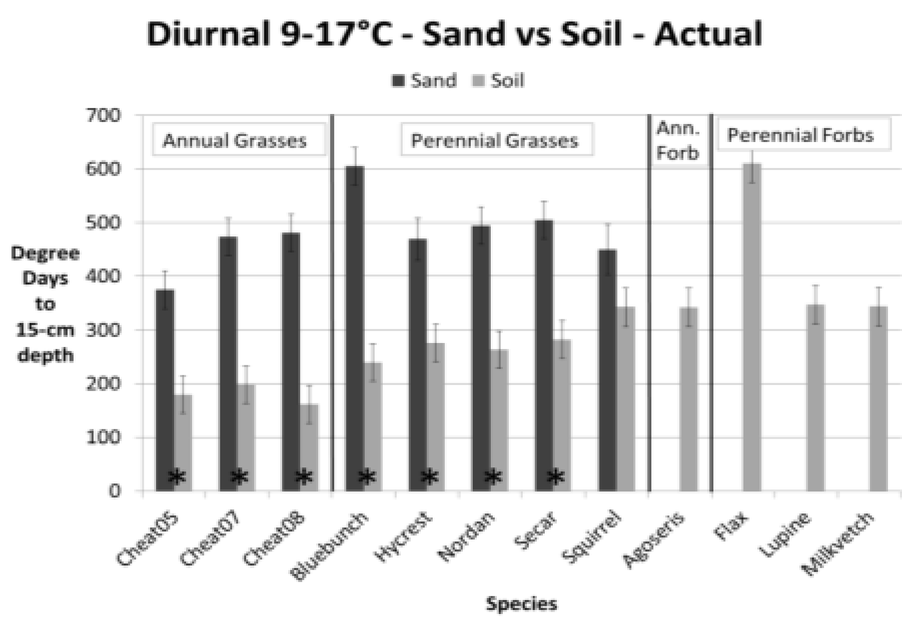

Figure 6. Actual sand vs soil degree days to 15-cm root depth for the growth chamber diurnal root trial 9-17°C. Asterisk indicates significant difference at 95% confidence level.

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

Project Location: Boise State University, Boise, Idaho

Principal Investigator and Contact Information:

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Project Description:

In semiarid steppe communities of the Intermountain West, reintroduction of *Artemisia tridentata* ssp. *wyomingensis* (Wyoming big sagebrush) following fires has proven difficult. This is in large part due to high seedling mortality during the dry summer period. Several studies suggest a factor that could improve seedling survival is the establishment of symbiotic associations with arbuscular mycorrhizal fungi (AMF) (Stahl et al. 1988, 1998). Furthermore, low levels of colonization in disturbed sites may limit the ability of seedlings to tolerate stress conditions (Stahl et al. 1988, 1998, Wicklow-Howard 1989).

Wyoming big sagebrush associates with AMF in natural habitats (Stahl et al. 1998). However, the species that participate in this association have not been well characterized. Knowledge about the AMF species that colonize Wyoming big sagebrush is important because the functionality of AMF-plant symbioses is variable and depends on the AMF and plant species involved (Klironomos 2003, Jones and Smith 2004, van der Heijden 2004). The major goal of this study is to identify AMF species that colonize Wyoming big sagebrush and begin to characterize the overall diversity of AMF species in sagebrush habitats of southwestern Idaho.

<u>Specific objectives</u>

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

<u>Methods</u>

Collection sites: For the identification of mycorrhizae, seedlings and soil samples were collected from seven sites in southwestern Idaho (Figure 1**).** The selected sites have natural populations of Wyoming big sagebrush and appeared relatively pristine as judged by the presence of biological soil crust, native grasses, and low density of invasive weeds.

Figure 1. Location of collection sites. The map on the right shows an enlarged portion of the map on the left.

Site Name (code)	Latitude/Longitude
Kuna Butte (K)	N 43° 26.161' W 116° 25.848'
Birds of Prey (E)	N 43° 19.272' W 116° 23.643'
Simco Road (S)	N 43° 11.047' W 115° 58.181'
Old Oregon Trail Rd (F)	N 43° 05.353' W 115° 38.702'
Bennett Mountain Rd (H)	N 43° 03.755' W 115° 19.088'
Summer Camp Rd (D)	N 43° 27.566' W 116° 50.712'
Cinder Cone Butte (C)	N 43° 13.160' W 115° 59.598'

DNA extraction, cloning, and sequencing: DNA was extracted separately from roots and soil collected from the field sites. In addition, AMF present in the soil were multiplied in pot cultures using Sudan grass as a host; this material was also used for DNA extraction. The presence of mycorrhizal DNA in the extracts was determined via nested PCR. General fungal primers LR1 and FLR2 were used in the first amplification and their products were amplified in a second PCR reaction with the Glomeromycota specific primers FLR3 and FLR4 (Gollotte et al. 2004). These primers amplify regions of the large subunit ribosomal RNA gene (LSU rDNA). The PCR products were cloned and the inserts were amplified, and sent for sequencing to a commercial facility. With the DNA sequences a phylogenetic analysis was conducted to identify species and phylotypes based on comparison with a reference data set for phylotaxonomy of AMF (Kruger et al. 2012). We defined phylotypes as terminal clades with a posterior probability larger than 80%.

Results

From the DNA extracted from the roots and soil at the different sites, we obtained PCR products of the expected length, which ranges from 300 to 380 bp. Each of the amplified products can contain more than one sequence. Consequently, they were cloned and the inserts from single transformed colonies copied again by PCR and sent for sequencing. Sequences were trimmed, annotated, and manually aligned.

The most current phylogenetic analysis includes more than 350 distinct sequences from samples collected from seven sites, and from greenhouse pot cultures grown with soil from these sites. This analysis reveals at least nine phylotypes, which were surrounded by boxes in Figure 2. Three of the phylotypes correspond to known species, *Claroideoglomus claroideum* (Figure 2, box A), *Glomus microaggregatum* (Figure 2, E), and *Funneliformis mosseae* (Figure 2 I).

Similarly, another phylotype with a large number of sequences clustered close to *Glomus intraradices*, which has been recently renamed *Rhizophagus intraradices* (Figure 2, D). This species is, however, undergoing revisions. Thus, some of the sequences in 2D may require splitting into more than one phylotype. The phylogenetic analysis also reveals several clusters that do not match any reported sequence (Figure 2 C, F, G, and H). These phylotypes may represent new species or alternatively known species whose sequence has not been reported for the LSU rDNA gene.

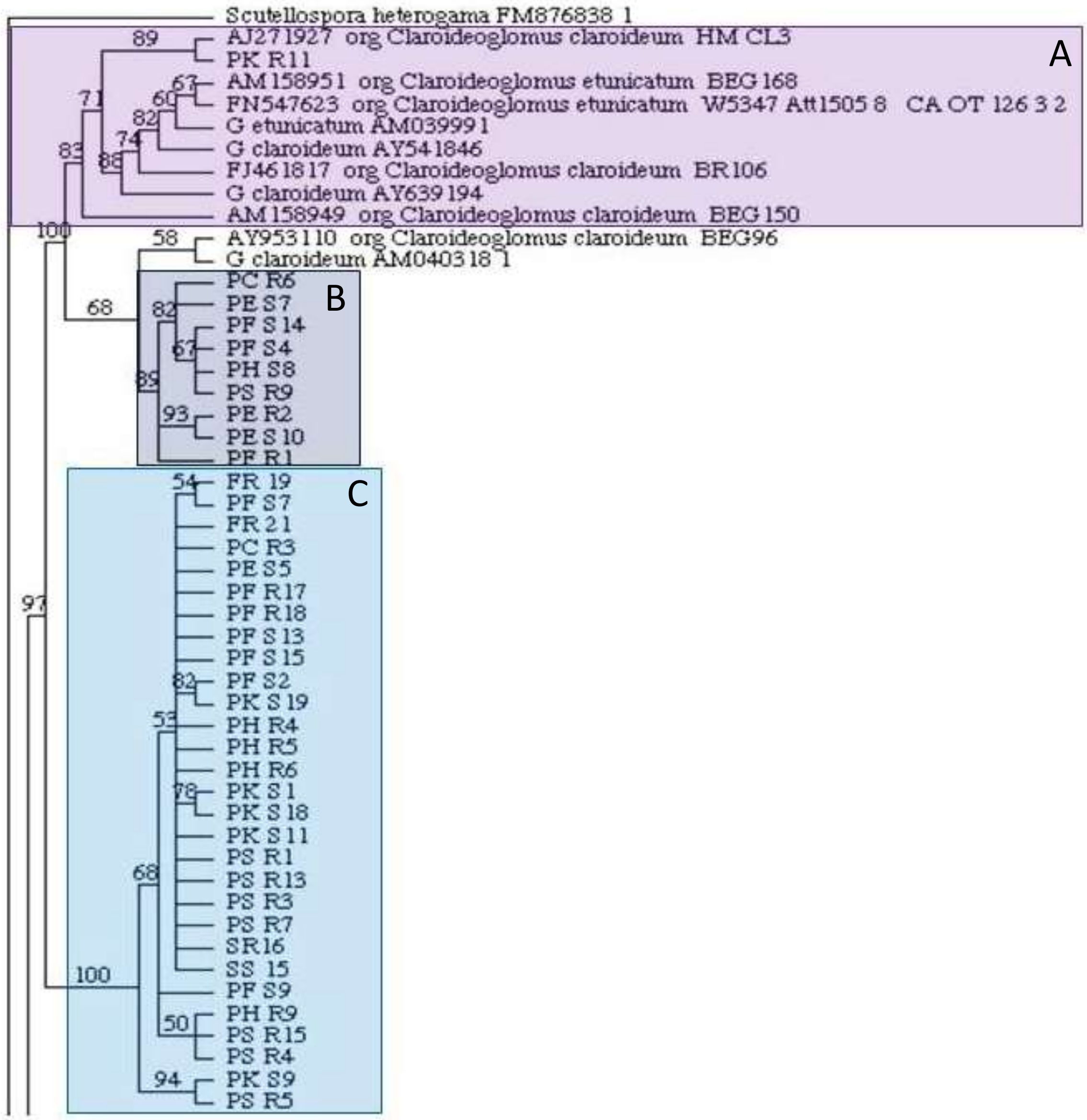


Figure 2. Phylogenetic analysis of mycorrhizal DNA sequences. Tree with bootstrap values. For each site and type of sample, we obtained ten to fifteen sequences. The first letter indicates the abbreviation for the site and the second the type of sample (R = roots and S = soil). Sequences obtained from pot cultures are indicated with a P followed by the abbreviation for the site. One hundred bootstrap replicates with 10 random additions each, rearrangements limited to 1 million per search.

Figure 2. (continuation)

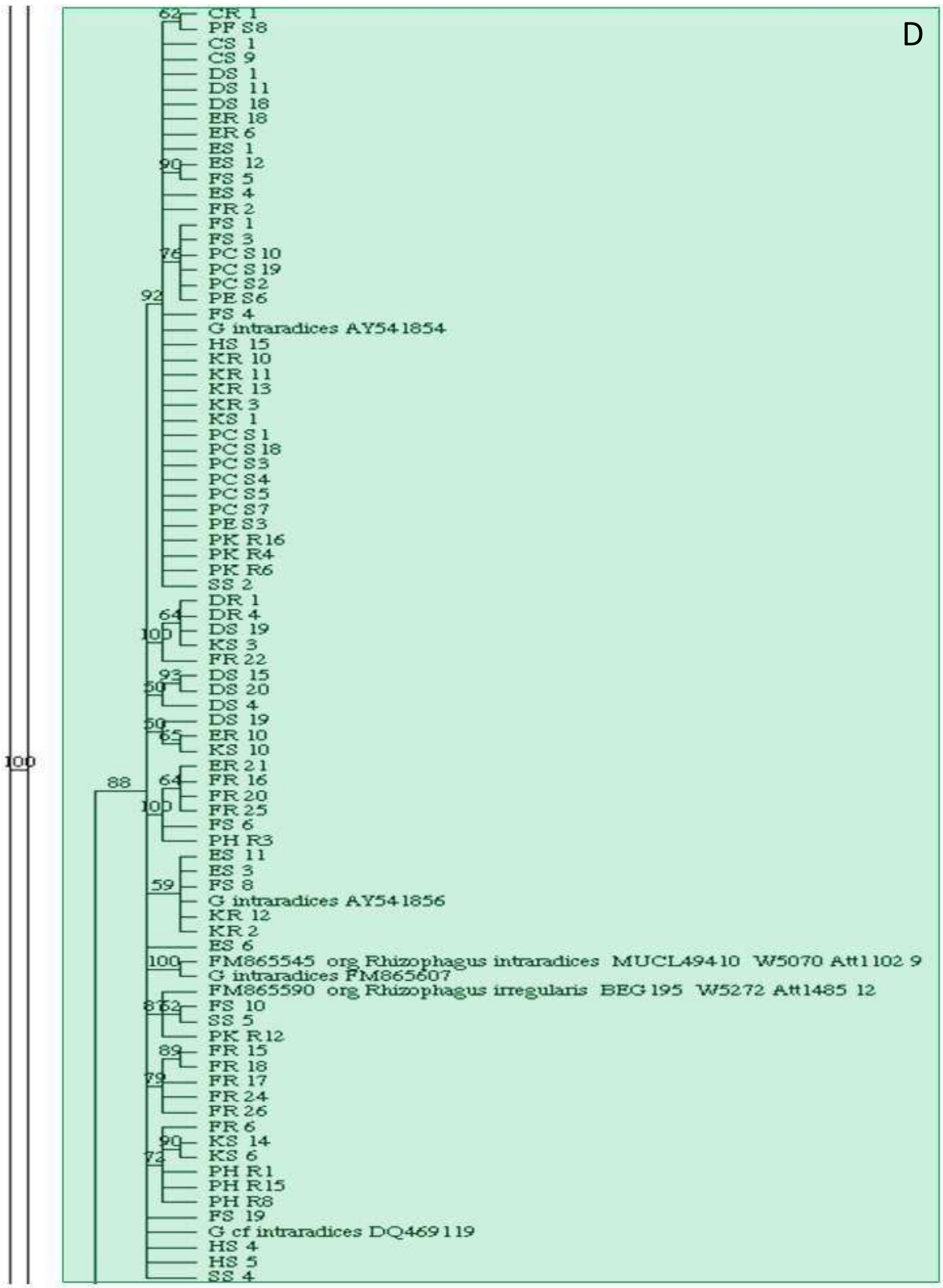
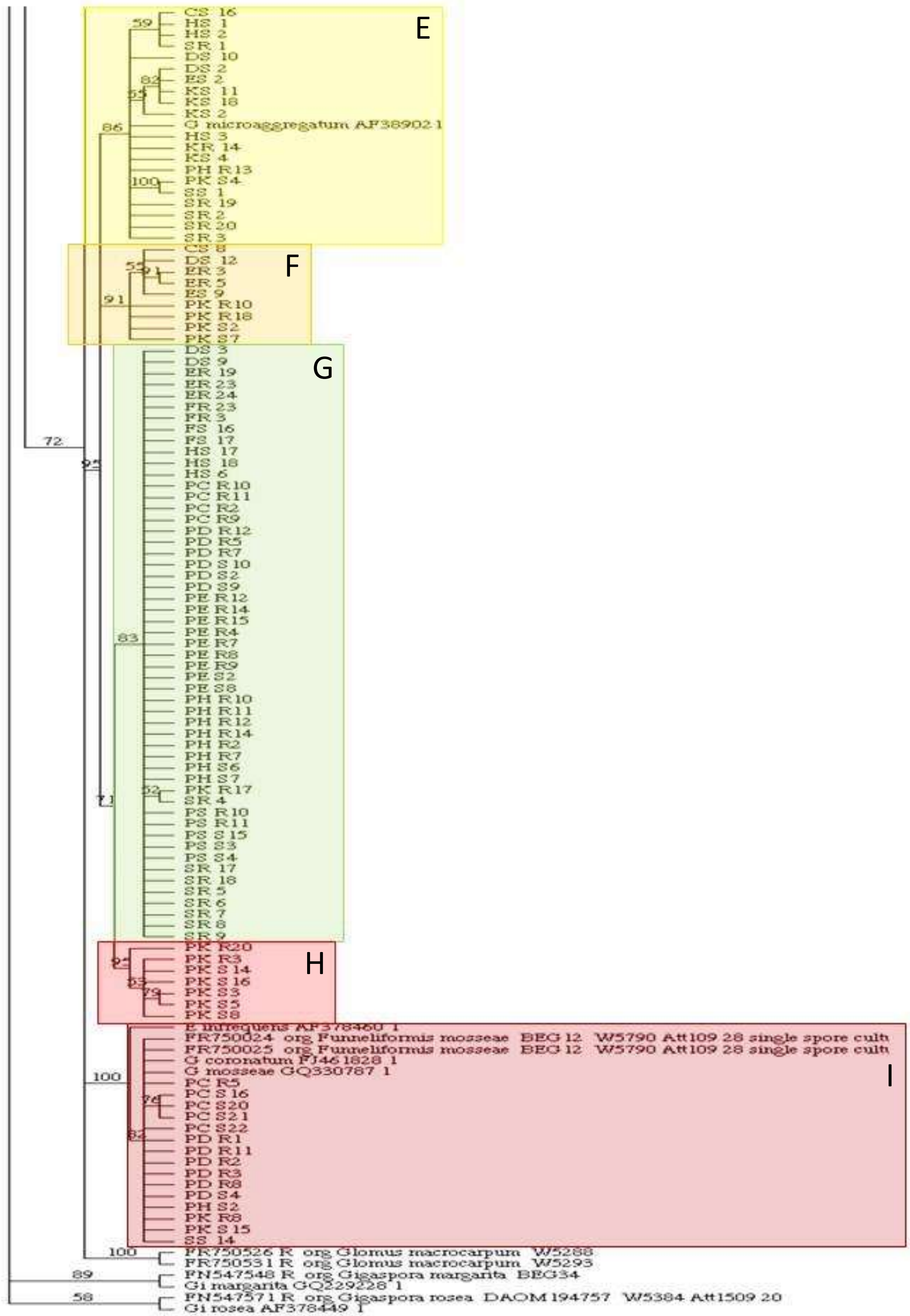


Figure 2. (continuation)



Of the six phylotypes found in the soil, five were also present in sagebrush roots (Figure 3). The exception was phylotype I (*F. mosseae*), which may be rare since only one sequence of this phylotype was detected among all the field collected samples. In pot cultures, we detected all the phylotypes found in the original field samples. However, some biases during multiplication in pot cultures were apparent. For example, phylotype E (*G. microaggregatum*) was detected in six sites, but only in one of the pot cultures from these sites. As expected, the pot cultures revealed additional phylotypes, which perhaps were undetected in the field samples due to their low occurrence.

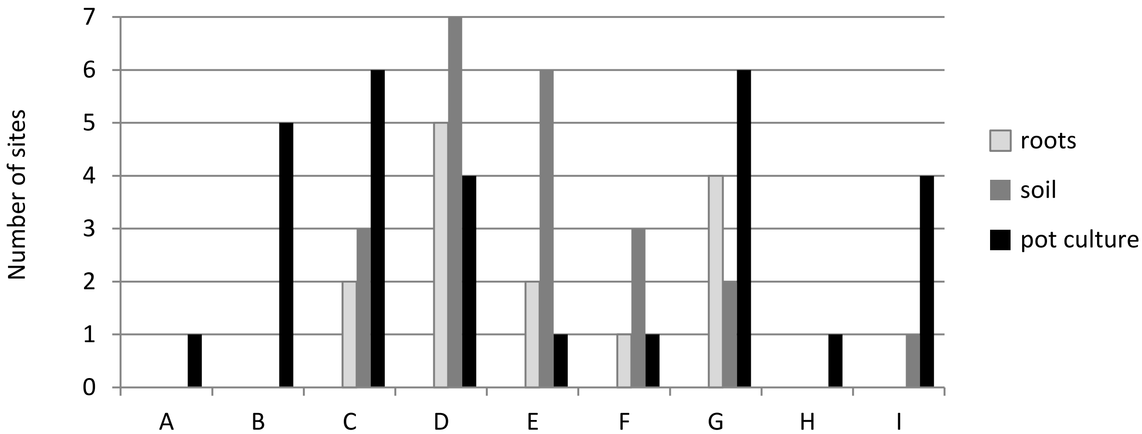


Figure 3. Number of sites at which each phylotype was found in sagebrush roots or soil. A total of seven sites were sampled.

Per site, the number of phylotypes ranged from two to five (Table 1). Phylotype D (*R. intraradices*) was found in root samples from five sites and phylotype G was found at four sites. In some sites, some phylotypes were found in roots, but not in the soil, strongly suggesting that our sampling intensity was not sufficient to detect all the phylotypes present at a particular site. The phylotypes that we detected are probably the most common and consequently those most likely to have an impact on the vegetation.

Table 1. Phylotypes found at each site in soil or sagebrush roots. Ten to fifteen sequences were analyzed per root and soil sample from each site.

Site	Roots	Soil	Total
Kuna Butte	D, E	D, E	2
Oregon Trail	C, D, G	D, G	3
Birds of Prey	D, F, G	D, E, F	4
Simco Road	C, E, G	C, D, E	4
Bennett Road	G	D, E	3
Summer Camp Road	D	D, E, F, G, I	5
Cinder Cone Butte	D	D, E, F	3

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Wicklow-Howard, M.C. 1989. The occurrence of vesicular-arbuscular mycorrhizae in burned areas of the Snake River Birds of Prey Area, Idaho. Mycotaxon 34**:**253-257.

Publications:

Serpe, M. 2011. Diversity of mycorrhizal fungi associated with *Artemisia tridentata* ssp. *wyomingensis*. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 52-54.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

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http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Presentations:

Carter, K.; Serpe, M. 2011. Identification of native mycorrhizal species that colonize *Artemisia tridentata* ssp. *wyomingensis* seedlings in Southwestern Idaho. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22-23, Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Carter, K.; White, M.; Serpe, M. 2011. Molecular identification of mycorrhizal fungi in seedlings of *Artemisia tridentata* ssp. *wyomingensis* from Southern Idaho. Annual meeting of the Mycological Society of America, 2011 August 2-5, Fairbanks, AK.

Management Applications and Seed Production Guidelines:
We identified various phyloptypes in sagebrush roots. Some of these correspond to cosmopolitan species, while others represent clusters of previously unsequenced species.
At present it is not clear whether the phylotypes that we identified in sagebrush habitats are present in commercial inoculums. Thus, we do not recommend the use of commercial inoculum until more is known about the phylotypes they contain and their effects on sagebrush establishment.

The identification of mycorrhizal phylotypes that colonize sagebrush represents a first step towards improving the availability of native mycorrhizae. We have begun to generate monospecific cultures of these mycorrhizae with the goal of testing their usefulness in restoration projects.

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

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

Principal Investigators and Contact Information:

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Project Description:

Greenhouse Seedling Emergence Studies

Hardseededness is a feature that often limits rapid, uniform germination in legume species. We were interested in identifying techniques that can be used to optimize seed germination and seedling emergence in three legume species native to the Great Basin of the western United States including basalt milkvetch (*Astragalus filipes*), western prairie clover (*Dalea ornata*), and Searls' prairie clover (*Dalea searlsiae*). We conducted a greenhouse study to determine the influence of seed scarification and seeding depth on the germination and emergence of six seed lots. The various seed lots were analyzed for germination and seed viability with germination and tetrazolium tests by the Utah State Seed Laboratory. Although total viable seed in the non-treated seed lots was greater than 84%, viable hard seed was extremely high for the seed lots ranging from 73-96%. Seed lots were left untreated, acid-scarified, or sandpaper-scarified for the greenhouse studies. The acid-scarified seeds were treated by soaking the seeds in concentrated sulfuric acid for five minutes, rinsing in tap water, and air-drying the seed. The sandpaper-scarified seed lots were scarified by rubbing the seed between two pieces of 120-grit sandpaper. Besides the three seed treatments, seeds were planted at either a 0.6 cm (1/4 inch) or 1.9 cm (3/4 inch) depth in sandy loam soil. A total of 50 seeds were planted in each treatment, and four replications were used in a randomized complete block design in a greenhouse. Two complete runs of the experiment were conducted. Seedling counts were obtained on twelve dates starting at Day 3 and going to Day 28.

Results of the greenhouse experiment are shown in Table 1. The main effects of seed treatment, soil depth, and seed lot were all significant ($P \leq 0.01$), and all two- and three-way interactions were also significant ($P \leq 0.05$), except the seeding depth X seed treatment interaction. Seedlings of western prairie clover and Searls' prairie clover emerged well at both the 0.6- and

1.9-cm planting depths. Scarification greatly improved emergence in both western and Searls' prairie clover, but much less so for basalt milkvetch. Scarification by acid was significantly better than sandpaper scarification for the two prairie clover species in all cases. For basalt milkvetch, sandpaper scarification resulted in slightly higher emergence than acid scarification; however, total emergence was still less than 40% (on a pure live-seed basis) in basalt milkvetch compared to more than 95% for the acid-scarified seed lots of the western and Searls' prairie clover species.

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

Factor	df	F value	Significance
Depth	1	20.45	**
Seed lot (S)	5	263.45	**
Seed Treatment (T)	2	3,382.43	**
S X T	10	70.23	**
Depth X S	5	2.68	*
Depth X T	2	0.12	NS
Depth X S X T	10	2.21	*

** = P < 0.01, * = P < 0.05, NS = not significant

<u>Field Seeding Studies</u>

Based on the results of the greenhouse experiments, actual field seeding studies were established at three locations. Studies at Clarno, OR and Powell Butte, OR were established cooperatively with Matt Horning during late October 2011. Field plots at Ontario, OR were planted in early November 2011 in cooperation with Clint Shock and Erik Feibert. 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. Duplicate seeding studies will be established at each of the three locations during spring 2012. Establishment data will be collected for two years post-planting, but sites will be kept to allow for long-term observation.

<u>Release of Majestic Germplasm and Spectrum Germplasm Western Prairie Clover</u>

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. 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. A release notice for Majestic germplasm and Spectrum germplasm western prairie clover was prepared and published in *Native Plants Journal*.

Publications:

Bhattarai, K.; Bushman, B.S.; Johnson, D.A.; Carman, J.G. 2011. Searls' prairie clover (*Dalea searlsiae*) for rangeland revegetation: Phenotypic and genetic evaluations. Crop Science 51:716-727.

Johnson, D.A.; Bushman, B.S. 2011. Developing protocols for maximizing establishment of two Great Basin legume species. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 55-56.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_Progress_Report.pdf

Johnson, D.A.; Bushman, B.S.; Bhattarai, K.; Connors, K.J. 2011. Notice of release of Majestic Germplasm and Spectrum Germplasm Western Prairie clover. Native Plants Journal 12:249-256.

Presentations:

Bushman, S.; Johnson, D.; Bhattarai, K. 2011. Genetic and phenotypic evaluations of western prairie clover and germination/establishment considerations. Great Basin Native Plant Selection and Increase Project Annual Meeting, February 22-23, Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Johnson, D.A.; Bhattarai, K.; Bushman, B.S. 2011. Utilizing common-garden and genetic diversity structure analyses to determine strategies for releasing Wildland Plant Germplasm for Rangeland Revegetation. IX International Rangeland Congress, April 1-8, Rosario, Argentina.

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 or planting seasons and planting practices.

Products:

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

Project Title: Great Basin Native Plant Materials Development and Cultivation

Project Location: Great Basin Research Center, Ephraim, Utah

Principal Investigators and Contact Information:

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Project Description:
We are continuing to work on developing cultural practice guidelines and procedures for several Great Basin forb species. We continue to research life histories, drought tolerance, and nutrient deficiencies of forbs in cultivation. We maintain research properties in Fountain Green and Ephraim, Utah where stock seed plots and seed increase fields are being established. We make wildland seed collections that are used for seed increase, and distributed to growers.

<u>Cultural Practices</u>
Native Lupine Cultivation
Relatively little is known about native lupines in cultivation. In October 2007 two research plots were prepared for planting with *Lupinus arbustus, L. argenteus, L. prunophilus,* and *L. sericeus* to study germination, establishment, seed production, and life histories in agronomic settings. Three cultivation techniques were implemented: seed drilled in rows and left uncovered, seed broadcast and covered with sawdust and N-sulate® fabric, and seedling transplants were planted into weed-barrier fabric the following spring.

L. arbustus and *L. prunophilus* seedlings exhibited chlorosis and necrosis. All *L. arbustus* planting senesced and did not resprout the following year. The *L. prunophilus* plantings in the broadcast and covered treatment persisted and resprouted the following year. *L. prunophilus* showed signs of chlorosis every year and did not flower and set seed until 2011.

We report our findings in seed production and life histories of the three surviving species. Only *L. argenteus* and *L. sericeus* produced seed in the second and third years. Seed yields for *L. argenteus* on the Ft. Green and Snow Field farms showed an increase in production in the second year and significantly dropped in the third year of production. Seed yields for *L. sericeus* have increased production each year at both locations. In 2011 *L. prunophilus* flowered and set seed at both locations but yields varied between 35 lbs/acre at Ft. Green and 110 lbs/acre at Snow Field. All yield estimates are based on plots that produced seed and do not take into account the total areas seeded where crops failed.

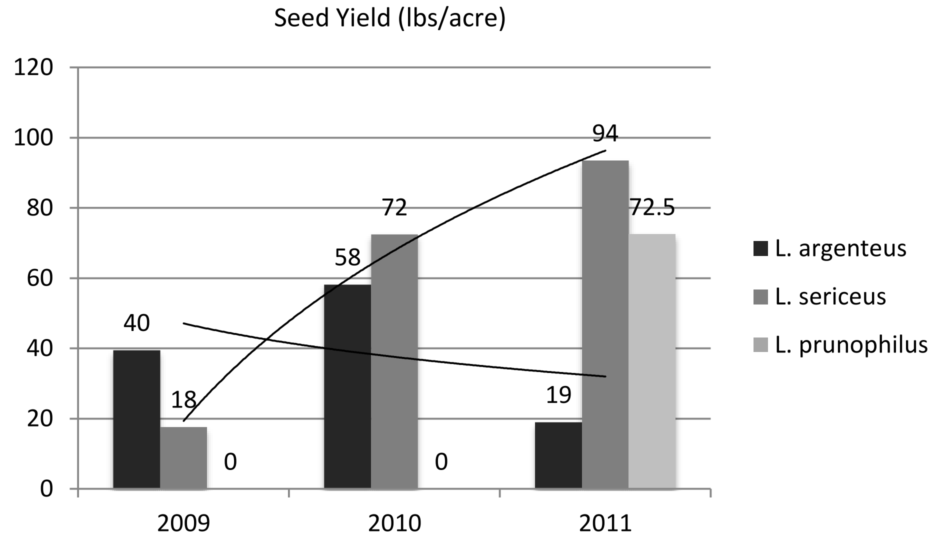

Figure 1. Three year harvest trend data for three species of *Lupinus*.

Due to the total loss of *L. arbustus* plots and the 66% loss of *L. prunophilus* plots from iron deficiency chlorosis, as well as the stunted and delayed growth of surviving *L. prunophilus* plots, we have designed and began implementing a study of iron deficiency chlorosis. This study focuses on the four species in the native lupine cultivation study, and four treatments of EDDHA chelated iron: control or no treatment, seed applied iron, foliar applied iron, and iron applied to both seed and foliage. We will measure germination, establishment, time to flower, seed yield, and overall greenness with a chlorophyll meter. We will also do some random destructive sampling to determine nutrient content of seedlings. Our objective is to identify a practical and effective method of treating iron deficiency chlorosis for these species.

Transplant Study

Species like *Balsamorhiza sagitatta, B. hookeri, Crepis acuminata,* and *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. We began the experiment by seeding beds with 6-inch row spacing to create a dense bed of seedlings that can be transplanted before they are large enough to begin to flower. In 2009 three beds were planted, in 2010 eight beds were planted, and in 2011, 26 additional beds were planted. In 2012 the original beds planted will be ready to transplant. We will categorize the root stock by crown diameter and root length. These factors will be important to consider after transplanting because the time it will take for them to flower after transplanting remains unknown.

Seed Increase and Foundation Fields

We continued to maintain the stock seed accessions planted in 2009 and 2010. These are the seed increase fields for our pooled source releases that will be distributed to growers. In 2009 we planted 55 accessions of 19 species at Fountain Green, and 44 accessions of 9 species at Snow

Field. In 2010 we planted 62 accessions of 32 species at Fountain Green and 32 accessions of 11 species at Snow Field.

<u>Common Gardens</u>

Sphaeralcea

In 2009 two *Sphaeralcea* common gardens were planted; one in Nephi, Utah and one at the Desert Experimental Range (DER) located in Utah's West Desert, southeast of Garrison, Utah. The common garden in Nephi was destroyed by grasshoppers and was removed the following year. The purpose of the common garden established in the DER was to observe survival in hot dry conditions. The DER has a mean annual precipitation of 165 mm and temperatures (PRISM Climate Group 2010)[1] in July commonly reach 32° C (PRISM Climate Group 2010)[1]. In 2011 we collected the second year survival data, and compared the seed source climates with survival.

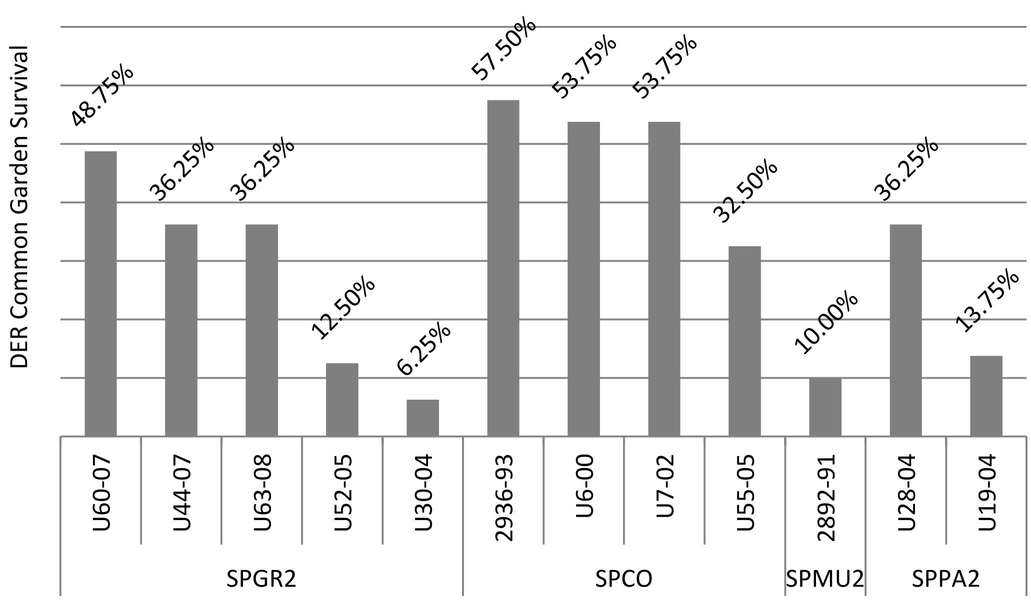

Figure 2. Desert Experimental Range (DER) *Sphaeralcea* common garden survival data. The best survival for *S. grossulariifolia* (SPGR2) was U60-07, which is a source 40 miles east of the DER. The survival of this source may indicate local adaptation to the conditions at the DER. The *S. coccinea* (SPCO) lots had best overall survival and all came from areas receiving 14-24 inches of annual precipitation. *S. coccinea* appears to be the most drought tolerant and broadly adapted species.

Eriogonum ovalifolium

In 2009 flower number and height data were collected from the common garden plants to use as a surrogate for seed set. After analyzing the seed yield data from 2010 and 2011 we have concluded that flower number is a poor indicator of seed set. In 2011 the highest seed yield was an estimated 57 lbs/acre, but its viability was 58%. The next best seed yield was 11 lbs/acre with 36% viability. The accession U30-2004, from Bingham county Idaho, was the top seed producer in both 2010 and 2011 with estimated seed yields of 56.1 lbs/acre and 57.5 lbs/acre respectively. Due to the extremely low seed yields and low seed viability of most accessions, we have purchased pollination cages to attempt to increase both seed yield and viability. We will be setting up a randomized pollination study in 2012 where we will be force pollinating one replicate of each accession. When we have found the top producers we will plant increase plots in the fall of 2012.

Table 1. *Eriogonum ovalifolium* common garden top ten seed producers by estimated acre yield for 2010 and 2011.

2010 Top Seed Producers				2011 Top Seed Producers			
Lot	Acre Yield	Viability	PLS lbs	Lot	Acre Yield	Viability	PLS lbs
U30-04	56.1	65%	36.5	U30-04	57.5	58%	33.36
U11-02	51.8	61%	31.6	U23-05	11.6	36%	4.17
U11-05	51.2	44%	22.5	U29-05	9.8	35%	3.43
U28-05	20.6	46%	9.5	U8-02	9.5	63%	5.96
U11-05	16.5	59%	9.7	U28-05	7.6	55%	4.21
U8-02	14.2	40%	5.7	U13-02	7.6	18%	1.38
U32-05	9.2	2%	1.8	U8-02	6.6	63%	4.15
U28-05	8.9	61%	5.4	U27-05	4.8	55%	2.65
U23-05	3.4	22%	0.7	U7-02	4.5	33%	1.48
U27-05	1.4	14%	0.2	U20-05	4.2	42%	1.77

Implementation Studies

Forb Island Study

In previous work on our research farms using N-Sulate fabric, 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. In 2009 we established the first treatment year of this study. Four sites were selected, two in Tooele County, one in Sanpete County and one in Carbon County. The treatments were replicated again in 2010 on the same sites. This study compares the germination and establishment of seeded species on plots covered with N-sulate fabric and plots left uncovered. Initial germination data was collected in 2010 and 2011 (Fig. 3). In 2011 we also collected establishment data for the second growing season on the plots treated in 2009. In 2012 we plan to collect data again from these plots to see if the treatment is effective over time.

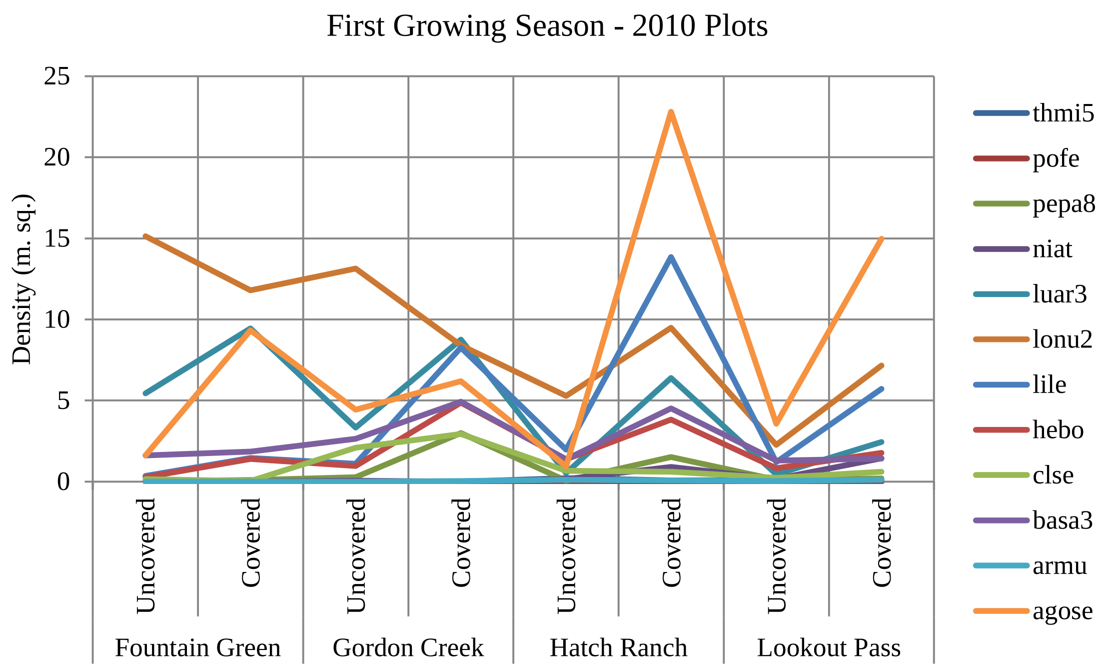

Figure 3. Germination of seeded species by treatment and by site. In general the plots covered with N-sulate fabric had higher germination than the plots that were left uncovered. The effect of the N-sulate fabric on *Lomatium nudicale*, however varied by site. The N-sulate fabric had a larger positive effect on the sites that had lower precipitation, Hatch Ranch and Lookout Pass.

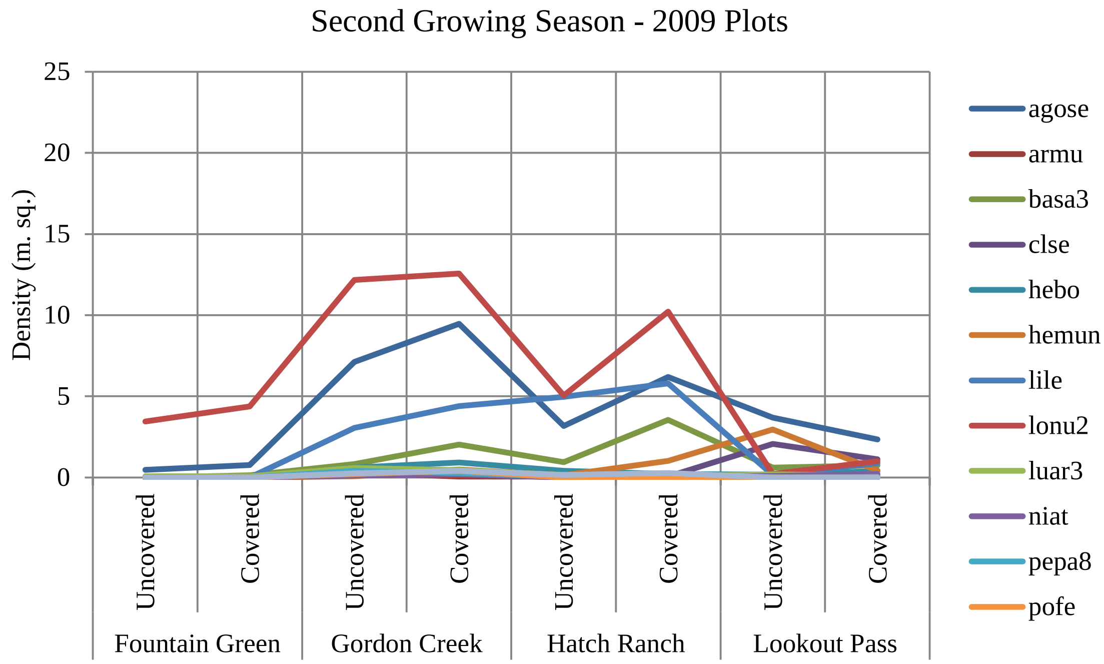

Figure 4. Establishment of seeded species by treatment and by site. Two years post treatment the treatment effect was still positive for most species but the effect was not as large except at the Hatch Ranch site. In the previous year the treatment only had a positive effect on *L. nudicale* on two of the sites. Two years post treatment the treatment had a positive effect on *L.nudicale* on all sites indicating that the treatment improved establishment for this species.

Geospatial Analysis of Great Basin Provisional Seed Zones

For revegetation to be successful, the plant materials utilized must be adapted to the area. Bower et al. (2010) developed Provisional Seed Zones for the Great Basin forbs and grasses based on annual precipitation and average summer high temperatures. He also recommended partitioning the Great Basin into two areas by Omernik's Level III ecoregions Omernik (1987); the Central Basin and Range as one and the Northern Basin and Range and the Snake River Plain as the other. Each of these areas contained 10 provisional seed zones.

Provisional Seed Zones provide a tool for selecting materials for planting. Using the Provisional Seed Zone map we extracted the location information from our database and assigned each species and site a seed zone. Based on the results, we began planting pooled source releases for our target species in 2010.

After analyzing the data from our identified sites and herbaria records we found the majority of the distributions for many species were localized within three or four provisional seed zones. We used historic fire (Finn et al. 2012) and land treatment (Pelliod 2009) GIS records from the last three decades to map wildfires and seeded areas. We identified four zones in each Great Basin partition that, based on acreage of disturbance, would warrant adequate quantities of seed for restoration. We made these top four zones our priorities to produce plant materials that will be adapted to areas being burned and reseeded.

Table 2. The two boundaries of the Great Basin provisional seed zones showing total area, acres burned and acres treated in the decade 2000-2010. Zone 5 in both groups has the greatest land area, as well as area burned and treated.

Northern Great Basin				
PSZ	Zone Description	Total Land Area (acres)	Acres Burned 2000-2010	Acres Treated 2000-2010
Zone 1	< 10 in precip / > 80 deg	722,843	17,810	90,773
Zone 2	< 10 in precip / < 80 deg	6,195,455	403,380	253,355
Zone 3	10-14 in precip / 80-90 deg	918,798	49,301	15,640
Zone 4	14-24 in precip / 80-90 deg	19,161	644	-
Zone 5	10-14 in precip / 70-80 deg	24,343,753	2,335,702	1,194,510
Zone 6	14-24 in precip / 70-80 deg	7,393,185	783,495	213,745
Zone 7	10-14 in precip / < 70 deg	1,297,922	60,867	11,305
Zone 8	14-24 in precip / < 70 deg	4,955,727	462,867	81,887
Zone 9	< 60 deg	3,165	-	-
Zone 10	> 24 in precip	2,540,833	86,092	3,177
Central Basin and Range				
PSZ	Zone Description	Total Land Area (acres)	Acres Burned 2000-2010	Acres Treated 2000-2010
Zone 1	< 10 in precip / > 80 deg	18,266,390	157,086	104,398
Zone 2	< 10 in precip / < 80 deg	15,184,265	374,052	135,018
Zone 3	10-14 in precip / 80-90 deg	3,465,157	257,885	54,758
Zone 4	14-24 in precip / 80-90 deg	541,330	27,700	29,103
Zone 5	10-14 in precip / 70-80 deg	22,903,115	1,528,432	717,666
Zone 6	14-24 in precip / 70-80 deg	9,387,606	476,825	300,009
Zone 7	10-14 in precip / < 70 deg	1,310,725	89,345	42,328
Zone 8	14-24 in precip / < 70 deg	4,151,275	119,367	79,596
Zone 9	< 60 deg	222,054	628	785
Zone 10	> 24 in precip	1,159,001	14,511	11,107

Database Compilation

A Microsoft® Access database was created which houses all related data with our collections. This includes soil analysis, seed viability analysis, seed allocations, seed increase, collection data, and location data. This was a collaborative effort between Jason Stettler of the Great Basin Research Center and Forest Service botanist Scott Jensen of the Provo Shrub Science Lab, and is a combination of all records for these two researchers. This new database took two databases housed in two different database programs and combined them for ease of use and its features in updatability. Microsoft® Access 2007 has a function which allows multiple users to update a single database through Microsoft® Outlook. This is ideal because multiple users from multiple offices can update the database as frequently as needed throughout the collecting and farming season.

We will further develop the database to be used in keeping farming treatment records, herbaria searches, and germination and increase data. This will assist in species distribution studies, collecting seed from new sources, and farm management.

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Bower, A.; St. Clair J.B.; Erickson, V.J. 2010. Provisional seed zones for native plants. http://www.fs.fed.us/wildflowers/nativeplantmaterials/rightmaterials.shtml

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Pilliod, D. 2009. Land Treatment Digital Library. U.S. Geological Survey Fact Sheet 2009-3095, 2 p. http://greatbasin.wr.usgs.gov/ltdl/Default.aspx

Publications:

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Jones, C., Whittaker, A. 2011. Native plant material development and cultivation trials for native Great Basin forbs and grasses. In: Great Basin Native Plant Selection and Increase Project 2010 Progress Report. p. 57-63. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Whittaker, A.; Summers, D. 2011. Establishment of native forbs following mechanical soil disturbance in Wyoming big sagebrush communities in the Great Basin. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 167-172. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Presentations:

Jones, C. 2011. Plant materials research at GBRC. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22-23, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Whittaker, A. 2011. Establishment of native forbs in wildland settings. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22-23, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Jones, C. 2011. Cultural practices and seed scarification of four native *Lupinus* species (Fabaceae) from across the Great Basin. 2011 June 17, Brigham Young University, Provo, UT.

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 the site. More research needs to be done to test cost/benefit and to test other row covers that may be more cost effective.

Seed Producers

After growing several species of native lupines for four years we have a few recommendations based on observed life histories. *Lupinus argenteus* will only produce seed for two years, beginning in the second year after planting. Our plots had reduced seed yield in the third producing year and should be replanted after the second harvest. *L. sericeus* has had an increase in seed yield for three consecutive seasons. We will continue to observe plots of this species and make recommendations for stand life-spans in the future. After four years our *L. prunophilus* plots flowered and produced seed. Several plots produced estimated seed yields at around 100 lbs per acre; overall average was 72.5 lbs/acre (Fig. 1). This species' growth and development was delayed by iron deficiency chlorosis. We were able to sustain these plots with supplemental EDDHA chelated iron. More research is being done with these species and iron deficiency chlorosis.

Products:

Wildland Seed Collection

- 41 collections of 21 species of forbs

Stock Seed Production – Seed Increase Plots

- 59 sources of 10 native forb species were planted into 107 beds on two Utah farms

Stock Seed Production – Seed Increase

- *Eriogonum ovalifolium*, 191.1 g
- *Lupinus argenteus*, 380.2 g
- *L. sericeus*, 2327.3 g
- *L. prunophilus*, 727.7 g

Seed Distribution

- *Crepis acuminata* seed was supplied to Nicole DeCrappeo, Ecologist, USGS Forest and Rangeland Ecosystem Science Center Corvallis, OR, for a revegetation study

Project Title: Applying Provisional Seed Zones to Great Basin Forb Production, and Cultural Practice Notes

Project Location: USFS Rocky Mountain Research Station, Provo, Utah

Principal Investigators and Contact Information:

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Project Description:

1. Applying Provisional Seed Zones to Native Forb Development in the Great Basin

Use GIS analysis to evaluate fire disturbance and historic seed use in the Great Basin in an effort to prioritize plant materials development work.

For grasses and herbaceous plants, the Great Basin is partitioned into 10 provisional seed zones (PSZ) based on precipitation and maximum temperature. Further partitioning the Great Basin by Omernik's Level III ecoregions results in 20 seed zones; 10 each in the Northern Basin and Range/Snake River Plain (NBR) and Central Basin and Range (CBR) ecological provinces (Figure 1). Seed zones vary vastly in size from just over 3,000 acres for NBR zone 9 to over 24,000,000 acres for NBR zone 5 (Fig. 2). Wildfire has consumed on average over 1,000,000 acres annually (Fig. 3) between 1995 and 2007 and is the largest source of disturbance requiring restoration in the region. A GIS layer of historic (1980–2007) fires was prepared from the Western fire map dataset and combined with the provisional seed zone layer to compute acreage burned by seed zone. This provides a good indication of the extent to which zones are impacted by fire. However, only a portion of burned land is ever reseeded, and fire, while prominent, is not the only disturbance requiring restoration in the region.

The Land Treatment Digital Library is a comprehensive system for entering, storing, retrieving, and analyzing USDI Bureau of Land Management seeding data. A portion of the dataset houses reseeding data due not only to fire but all other impacts. The majority of available Great Basin data has been entered into the system. Seeding data from the Land Treatment Digital Library was combined with the provisional seed zone layer to compute the acreage seeded by seed zone. These three datasets; the size of each seed zone, areas impacted by fire, and the extent to which restoration efforts have been employed within each seed zone provide a good starting point for prioritizing plant materials work.

Of these three variables the acreage seeded provides the best estimate of historic seed demand. Based on seed mix recommendations (11 lbs./acre for zones 1-2, 13 lbs./acre zones 3-10) and historic native forb seed use (5% native forbs) by the Bureau of Land Management (BLM) and Utah Division of Wildlife Resources (UDWR) (2010 BLM, 2009-2011 UDWR) we projected historic forb seed demand by provisional seed zone (Fig. 4). Seed zone cells in Figure 4 are color coded to the volume of seed needed for restoration corresponding to the market triangle in Figure 5.

Seed demand is categorized into three markets (Fig. 5); niche market species characterized by total annual seed sales ≤ 2,000 lbs. and requiring contract production (red); special use markets characterized by total annual seed sales between 2,000 and 20,000 lbs. produced under market conditions (yellow); and revegetation species where total annual seed sales typically exceed 20,000 lbs. and seed is produced under market conditions (green). Figure 5 shows where commonly used species fit in this categorization. A given species location in this pyramid is dependent on ease of production, yield, competition and market price. Many of our native forbs exhibit characteristics that make agronomic production difficult and will be found in the niche market price and availability category. Our objective is to identify species that can break into the special use market and be produced in adequate volume to impact the acres annually requiring reseeding.

<u>Summary</u>

Adequate quantities of seed must be purchased annually for speculative growers to keep a particular species in production. Due to zone sizes and the amount of disturbance, primarily fire, four zones in both NBR (zone 5, 6, 2, 8) and CBR (zone 5, 6, 2, 7) have historically (2000 – 2010) utilized reliably adequate quantities of seed to permit market production. These zones are our priority areas for developing plant materials. The remaining zones will likely require contract seed production due to lower historic annual demands.

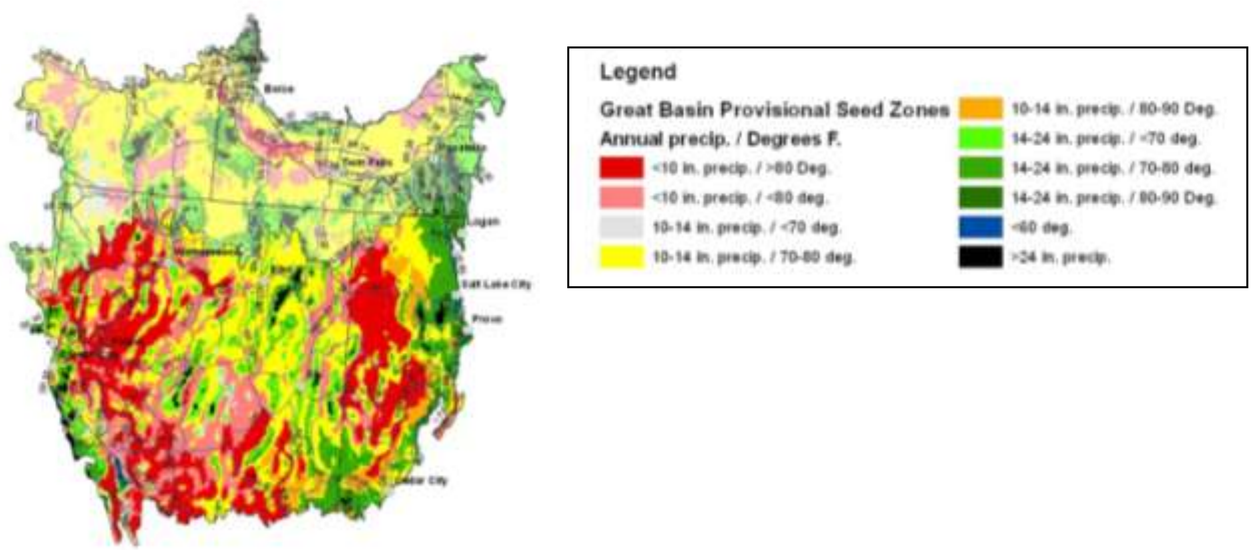


Figure 1. Provisional seed zones of the Great Basin.

Central Basin and Range		
PSZ	**Zone Description**	**Area (acres)**
Zone 1	<10 in. precip. / >80 Deg.	18,266,390
Zone 2	<10 in. precip. / <80 deg.	15,184,265
Zone 3	10-14 in. precip. / 80-90 Deg.	3,465,157
Zone 4	14-24 in. precip. / 80-90 Deg.	541,330
Zone 5	10-14 in. precip. / 70-80 deg.	22,903,115
Zone 6	14-24 in. precip. / 70-80 deg.	9,387,606
Zone 7	10-14 in. precip. / <70 deg.	1,310,725
Zone 8	14-24 in. precip. / <70 deg.	4,151,275
Zone 9	<60 deg.	222,054
Zone 10	>24 in. precip.	1,159,001
	Total Area	**76,590,918**

Northern Basin and Range		
PSZ	**Zone Description**	**Area (acres)**
Zone 1	<10 in. precip. / >80 Deg.	722,843
Zone 2	<10 in. precip. / <80 Deg.	6,195,455
Zone 3	10-14 in. precip. / 80-90 Deg.	918,798
Zone 4	14-24 in. precip. / 80-90 Deg.	19,161
Zone 5	10-14 in. precip. / 70-80 Deg.	24,343,753
Zone 6	14-24 in. precip. / 70-80 Deg.	7,393,185
Zone 7	10-14 in. precip. / <70 Deg.	1,297,922
Zone 8	14-24 in. precip. / <70 Deg.	4,955,727
Zone 9	<60 Deg.	3,165
Zone 10	>24 in. precip.	2,540,833
	Total Area	**48,390,842**

Figure 2. Provisional seed zone acreage.

Acres Burned in the Northern Great Basin							
PSZ	**Zone Description**	**1980-1984**	**1985-1989**	**1990-1994**	**1995-1999**	**2000-2004**	**2005-2007**
Zone 1	**< 10 in precip / > 80 deg**	88,379	65,627	883	59,619	6,725	11,085
Zone 2	**< 10 in precip / < 80 deg**	209,865	283,513	41,435	288,697	159,046	244,334
Zone 3	**10-14 in precip / 80-90 deg**	28,759	23,214	2,545	35,640	34,313	14,988
Zone 4	**14-24 in precip / 80-90 deg**	51	629	1,016	1	360	284
Zone 5	**10-14 in precip / 70-80 deg**	917,665	720,564	478,787	1,440,316	972,255	1,363,447
Zone 6	**14-24 in precip / 70-80 deg**	162,819	221,523	170,435	245,963	357,024	426,471
Zone 7	**10-14 in precip / < 70 deg**	1,482	6,510	17,750	62,115	30,526	30,340
Zone 8	**14-24 in precip / < 70 deg**	50,040	44,276	69,374	159,486	183,918	278,950
Zone 9	**< 60 deg**	0	0	0	0	0	0
Zone 10	**> 24 in precip**	10,532	75,388	9,724	34,369	37,827	48,265
TOTALS		1,469,591	1,441,244	791,948	2,326,207	1,781,994	2,418,163

Acres Burned in the Central Basin and Range							
PSZ	**Zone Description**	**1980-1984**	**1985-1989**	**1990-1994**	**1995-1999**	**2000-2004**	**2005-2007**
Zone 1	**< 10 in precip / > 80 deg**	7,596	14,898	8,035	194,234	59,314	97,772
Zone 2	**< 10 in precip / < 80 deg**	65,528	187,012	8,331	641,403	175,619	198,434
Zone 3	**10-14 in precip / 80-90 deg**	15,485	1,104	6,847	51,880	23,166	234,719
Zone 4	**14-24 in precip / 80-90 deg**	110	0	715	8,802	8,571	19,128
Zone 5	**10-14 in precip / 70-80 deg**	81,365	365,691	68,121	1,159,920	668,878	859,554
Zone 6	**14-24 in precip / 70-80 deg**	46,614	40,421	48,370	395,961	293,289	183,536
Zone 7	**10-14 in precip / < 70 deg**	3,438	1,844	6,444	9,014	38,053	51,291
Zone 8	**14-24 in precip / < 70 deg**	4,947	13,210	13,426	96,205	82,339	37,028
Zone 9	**< 60 deg**	41	0	0	14	616	13
Zone 10	**> 24 in precip**	3,428	541	8,997	8,118	11,439	3,072
TOTALS		228,553	624,722	169,287	2,565,551	1,361,284	1,684,548

Figure 3. Acres burned in the Northern Basin and Range and Central Basin and Range corresponding to 10 seed zones and grouped in 5 year increments. Values are totals for the 5 year period.

Northern Basin and Range - Estimated seed (lbs) volume used during the 5 year increment.							
PSZ	Zone Description	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2010
Zone 1	< 10 in precip / > 80 deg	184	4021	0	10297	45573	4352
Zone 2	< 10 in precip / < 80 deg	14808	7183	77	42215	45436	93909
Zone 3	10-14 in precip / 80-90 deg	0	0	0	4537	6626	3540
Zone 4	14-24 in precip / 80-90 deg	0	0	0	0	0	0
Zone 5	10-14 in precip / 70-80 deg	45799	34232	18895	121730	430421	346011
Zone 6	14-24 in precip / 70-80 deg	1989	109	648	6142	62576	76358
Zone 7	10-14 in precip / < 70 deg	225	641	0	43	3943	3405
Zone 8	14-24 in precip / < 70 deg	226	535	28	5020	24796	28430
Zone 9	< 60 deg	0	0	0	0	0	0
Zone 10	> 24 in precip	0	0	705	1052	2044	21

Central Basin and Range - Estimated seed (lbs) volume used during the 5 year increment.							
PSZ	Zone Description	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2010
Zone 1	< 10 in precip / > 80 deg	0	0	1849	1814	53266	4153
Zone 2	< 10 in precip / < 80 deg	0	353	3780	37793	50519	23741
Zone 3	10-14 in precip / 80-90 deg	261	130	3272	5182	8193	27400
Zone 4	14-24 in precip / 80-90 deg	143	0	167	1696	3956	14961
Zone 5	10-14 in precip / 70-80 deg	320	13320	24030	99340	270136	196348
Zone 6	14-24 in precip / 70-80 deg	3269	6892	8164	36525	101521	93485
Zone 7	10-14 in precip / < 70 deg	0	36	132	605	16896	10617
Zone 8	14-24 in precip / < 70 deg	0	87	1040	5284	42798	8939
Zone 9	< 60 deg	0	0	0	0	510	0
Zone 10	> 24 in precip	0	0	372	29	7220	0

Figure 4. Tabular data of projected historic seed use based on seeding acreage and location data from the Land Treatment Digital Library, and a seed mix consisting of 5% native forbs in an 11 lb/acre seed mix for zones 1, 2 and 13 lb/acre seed mix for zone 3-10. Cells are color coded relative to three market categories described in Figure 5.

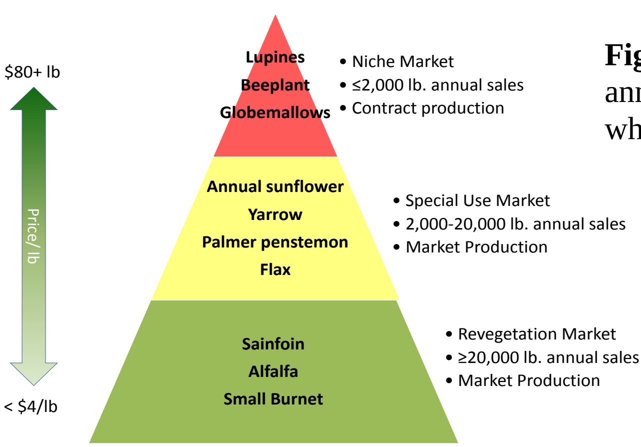


Figure 5. Three seed market categories based on annual sales volume along with examples of where common restoration species currently fit.

2. Seed Increase for Pooled Source Provisional Seed Zone Releases

In 2010 we began increasing seed supplies of promising materials based on the pooled provisional seed zone concept. Table 1 indicates the species and sources we currently have in production at Fountain Green, UT (FG) or Snow Field Station (SFS) in Ephraim, Utah, the year material was planted, the provisional seed zone where the source material originates and the year we anticipate seed production or the volume of seed produced in 2011.

Table 1. Seed increase at Fountain Green or Snow Field Station, Ephraim, UT.

Species / Source	Location	Plant Date	Provisional Seed Zone	Seed Produced
Ipomopsis aggregata		**Scarlet gilia**		
Soldier Canyon	FG	2009	14-24 in. precip. / 70-80 deg.	2500g
Secret Valley	FG	2010	14-24 in. precip. / 70-80 deg.	2012
Soldier Canyon	FG	2010	14-24 in. precip. / 70-80 deg.	2012
Little Lake Pass	FG	2010	10-14 in. precip. / 70-80 deg.	2012
Aragonite	FG	2010	14-24 in. precip. / 70-80 deg.	2012
Chicken Rock	FG	2010	14-24 in. precip. / 70-80 deg.	2012
Old Irontown	FG	2010	14-24 in. precip. / 70-80 deg.	2012
Chicken Rock	FG	2011	14-24 in. precip. / 70-80 deg.	2013
Old Irontown	FG	2011	14-24 in. precip. / 70-80 deg.	2013
Secret Valley	FG	2011	14-24 in. precip. / 70-80 deg.	2013
Aragonite	FG	2011	14-24 in. precip. / 70-80 deg.	2013
Soldier Canyon	FG	2011	14-24 in. precip. / 70-80 deg.	2013
Ipomopsis macrosiphon		**Longtube ipomopsis**		
Suzie Creek	SFS	2010	14-24 in. precip. / 70-80 deg.	2012
Pequop Summit IPMA4	SFS	2010	14-24 in. precip. / 70-80 deg.	2012
Hinkley Summit IPMA4	SFS	2010	> 24 in. precip.	2012
Lomatium nudicaule		**Barestem biscuitroot**		
Big Butte	FG	2009	10-14 in. precip. / 70-80 deg.	??
Big Butte	FG	2010	10-14 in. precip. / 70-80 deg.	??
Willow Creek	FG	2010	10-14 in. precip. / 70-80 deg.	??
BY08 - Castle Rock	FG	2011	10-14 in. precip. / 70-80 deg.	??
Halfway Summit	FG	2011	< 10 in. precip. / < 80 deg.	??
Soldier Canyon LONU2	SFS	2010	14-24 in. precip. / 70-80 deg.	??
Oxley peak	SFS	2010	14-24 in. precip. / 70-80 deg.	??
Duck Valley Indian Res.	SFS	2010	14-24 in. precip. / 70-80 deg.	??
Arthur LONU2	SFS	2010	14-24 in. precip. / 70-80 deg.	??
Heliomeris multiflora* var. *nevadensis		**Nevada goldeneye**		
Patterson Pass	FG	2009	14-24 in. precip. / 70-80 deg.	1825g
Pioche	FG	2010	14-24 in. precip. / 70-80 deg.	2011
Jackrabbit Mine	FG	2010	14-24 in. precip. / 70-80 deg.	2011
Newcastle	FG	2010	14-24 in. precip. / 70-80 deg.	2011

Table 1. (continued)

Species / Source	Location	Plant Date	Provisional Seed Zone	Seed Produced
Heliomeris multiflora* var. *nevadensis		**Nevada goldeneye**		
Newcastle	FG	2011	14-24 in. precip. / 70-80 deg.	2012
Basin S of Silver King	SFS	2010	10-14 in. precip. / 70-80 deg.	2011
Patterson Pass	SFS	2010	10-14 in. precip. / 70-80 deg.	2011
Jackrabbit Mine	SFS	2010	10-14 in. precip. / 70-80 deg.	2011
Enceliopsis nudicaulis		**Nakedstem sunray**		
W. of Milford	SFS	2011	10-14 in. precip. / 70-80 deg.	2013
Majors Place	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Halfway Summit	FG	2009	<10 in. precip. / <80 deg.	2011
Blind Valley	FG	2010	<10 in. precip. / <80 deg.	2012
Painted Pot Road	FG	2010	<10 in. precip. / <80 deg.	2012
Crystal Peak	FG	2010	<10 in. precip. / <80 deg.	2012
Crystal Peak	FG	2011	<10 in. precip. / <80 deg.	2013
Penstemonp pachyphyllus		**Thickleaf beardtongue**		
Pleasant Valley	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Ward Mountain	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Schellbourne	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Robinson Pass	FG	2009	14-24 in. precip. / 70-80 deg.	3400g
Robinson Pass	FG	2010	14-24 in. precip. / 70-80 deg.	2012
Cave Lake	FG	2010	14-24 in. precip. / <70 deg.	2012
Goshute Canyon	FG	2010	14-24 in. precip. / <70 deg.	2012
Sacramento Summit	FG	2010	14-24 in. precip. / 70-80 deg.	2012
Cave Creek	FG	2010	14-24 in. precip. / <70 deg.	2012
Frasera albomarginata		**Desert frasera**		
Fairview Wash	FG	2009	10-14 in. precip. / 70-80 deg.	2012
Major's Place	FG	2010	10-14 in. precip. / 70-80 deg.	2013
Bristol Wells	SFS	2010	14-24 in. precip. / 70-80 deg.	2013
Castleton	SFS	2010	14-24 in. precip. / 70-80 deg.	2013
Newcastle	SFS	2010	14-24 in. precip. / 70-80 deg.	2013
Robinson Pass FRAL5	SFS	2010	14-24 in. precip. / 70-80 deg.	2013
Uvada	SFS	2010	14-24 in. precip. / 70-80 deg.	2013
Ward Mountain	SFS	2010	14-24 in. precip. / 70-80 deg.	2013
Cave Springs	SFS	2010	14-24 in. precip. / 70-80 deg.	2013
Cleve Creek	SFS	2010	14-24 in. precip. / 70-80 deg.	2013
Linum lewesii		**Lewis flax**		
Basin S. of Silver King	FG	2011	10-14 in. precip. / 80-90 Deg.	2013
Jackrabbit Mine	FG	2011	10-14 in. precip. / 70-80 deg.	2013

Table 1. (continued)

Species / Source	Location	Plant Date	Provisional Seed Zone	Seed Produced
Lewis flax		**Lewis flax**		
Little Lake Pass	FG	2011	10-14 in. precip. / 70-80 deg.	2013
Long Hill '08	FG	2011	10-14 in. precip. / 70-80 deg.	2013
Major’s place	FG	2011	10-14 in. precip. / 70-80 deg.	2013
North Cave Valley	FG	2011	10-14 in. precip. / 70-80 deg.	2013
North of Wells	FG	2011	10-14 in. precip. / 70-80 deg.	2013
Patterson Pass	FG	2011	10-14 in. precip. / 70-80 deg.	2013
South Newe Rd.	FG	2011		2013
Water Canyon Win.	FG	2011	10-14 in. precip. / 70-80 deg.	2013
Water Cyn Arg/Battle	FG	2011	10-14 in. precip. / 70-80 deg.	2013
West Ely	FG	2011	10-14 in. precip. / 70-80 deg.	2013
Hesperostipa comata		**Needle and thread**		
Sand Pass	FG	2010	<10 in. precip. / <80 deg.	2012
South Osgood	FG	2010	<10 in. precip. / <80 deg.	2012
Proctor Flat	FG	2010	<10 in. precip. / <80 deg.	2012
Fish Springs	FG	2010	<10 in. precip. / <80 deg.	2012
Century Peak	FG	2010	<10 in. precip. / <80 deg.	2012
Blind Valley - Side Valley	FG	2010	<10 in. precip. / <80 deg.	2012
Black Rock Road	FG	2010	<10 in. precip. / >80 Deg.	2012
Indian Peaks	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
King Top	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
White Mountain	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
North Whitehorse	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Eureka	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
English Village	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Pioche	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
East Wells	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
South of Scipio	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Bitner Knoll	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Aragonite	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Road to Lund	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Camouflage Mailbox	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Deeth	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Gunnison Reservoir	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
J.B.'s	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Minersville Reservoir	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
Near B Hill	SFS	2010	10-14 in. precip. / 70-80 deg.	2012
North Delta Power Plant	SFS	2010	10-14 in. precip. / 80-90 Deg.	2012
Modena	SFS	2010	10-14 in. precip. / 80-90 Deg.	2012
West of Milford	SFS	2010	10-14 in. precip. / 80-90 Deg.	2012

3. Species Screening

In 2009 we initiated a concerted effort to screen a large number of species to assess their agronomic potential and develop cultural practices. Table 2 identifies the species currently in our screening program.

Table 2. Species in screening program.

Species / Source	Location	Plant Date	Provisional Seed Zone	Seed Produced
Nicotiana attenuata		**Coyote tobacco**		
Mud Springs	FG	2009	14-24 in. precip. / 70-80 deg.	2010
PSSL-193	FG	2011	14-24 in. precip. / 70-80 deg.	2012
Mentzelia laevicaulis		**Smoothstem blazingstar**		
Beowawe	FG	2009	---	
Secret Creek	SFS	2010	14-24 in. precip. / 70-80 deg.	
Silver Peak	SFS	2010	14-24 in. precip. / 70-80 deg.	
Thelypodium milleflorum		**Manyflower thelypody**		
West of Carlin	FG	2009	<10 in. precip. / <80 deg.	683g
West of Carlin	FG	2011	<10 in. precip. / <80 deg.	2013
West of Carlin	FG	2010	<10 in. precip. / <80 deg.	2012
Phacelia crenulata		**Cleftleaf wildheliotrope**		
Lucky Boy	FG	2009	10-14 in. precip. / 70-80 deg.	2200g
U Dig Fossil	SFS	2010	<10 in. precip. / >80 Deg.	
Aster		**Aster**		
P3-08 Gold Creek	FG	2009	14-24 in. precip. / <70 Deg.	2011
Penstemon linarioides		**Toadflax penstemon**		
P5-07	FG	2009	14-24 in. precip. / 70-80 deg.	2011
Agoseris grandiflora		**Bigflower agoseris**		
LPN G1 2007		2010		2011
Potentilla gracilis		**Slender cinquefoil**		
Bear Creek Summit	FG	2009	>24 in. precip.	20??
Linum subteres		**Sprucemont flax**		
Snake Pass	FG	2011		2012
Crystal Peak	FG	2011	<10 in. precip. / <80 deg.	2012
Wyethia amplexicaulis		**Mule-ears**		
Adobe Summit	FG	2011	10-14 in. precip. / 70-80 deg.	2013
Mentzelia albicaulis		**Whitestem blazingstar**		
Water Canyon	SFS	2010	10-14 in. precip. / 70-80 deg.	288g
Sand Pass	SFS	2010	10-14 in. precip. / 70-80 deg.	176g
North Battle Mountain	SFS	2010	10-14 in. precip. / 70-80 deg.	24g

Table 2. (continued)

Species / Source	Location	Plant Date	Provisional Seed Zone	Seed Produced
Arenaria macradenia ferrisea		**Ferris' sandwort**		
Nephi Canyon	FG	2011	-----	2013
Lathyrus brachycalyx		**Bonneville pea**		
Maple Hollow	FG	2011	-----	20??
Agastache urticifolia		**Nettleleaf giant hyssop**		
P1-09	FG	2011	14-24 in. precip. / <70 Deg.	20??
Cryptantha rugulosa		**Wrinkled cryptantha**		
PSSL-135	FG	2011	10-14 in. precip. / 70-80 deg.	2012
Stenotus acaulis		**Stemless mock goldenweed**		
PSSL-118	FG	2011	10-14 in. precip. / 70-80 Deg.	20??
Senecio		**Ragwort**		
Charleston Deeth	FG	2011	10-14 in. precip. / 70-80 deg.	2013
Stanleya pinnata* var. *integrifolia		**Golden princesplume**		
PSSL-78	FG	2011	<10 in. precip. / >80 Deg.	20??
Oenothera		**Evening primrose**		
Oenot-P1-2009	FG	2011	14-24 in. precip. / 70-80 deg.	2013
Cleome lutea		**Yellow spiderflower**		
PSSL-139	FG	2011	10-14 in. precip. / 80-90 Deg.	2012
Lupinus arbustus		**Longspur lupine**		
Deep Creeks	SFS	2007	14-24 in. precip. / <70 deg.	2084g

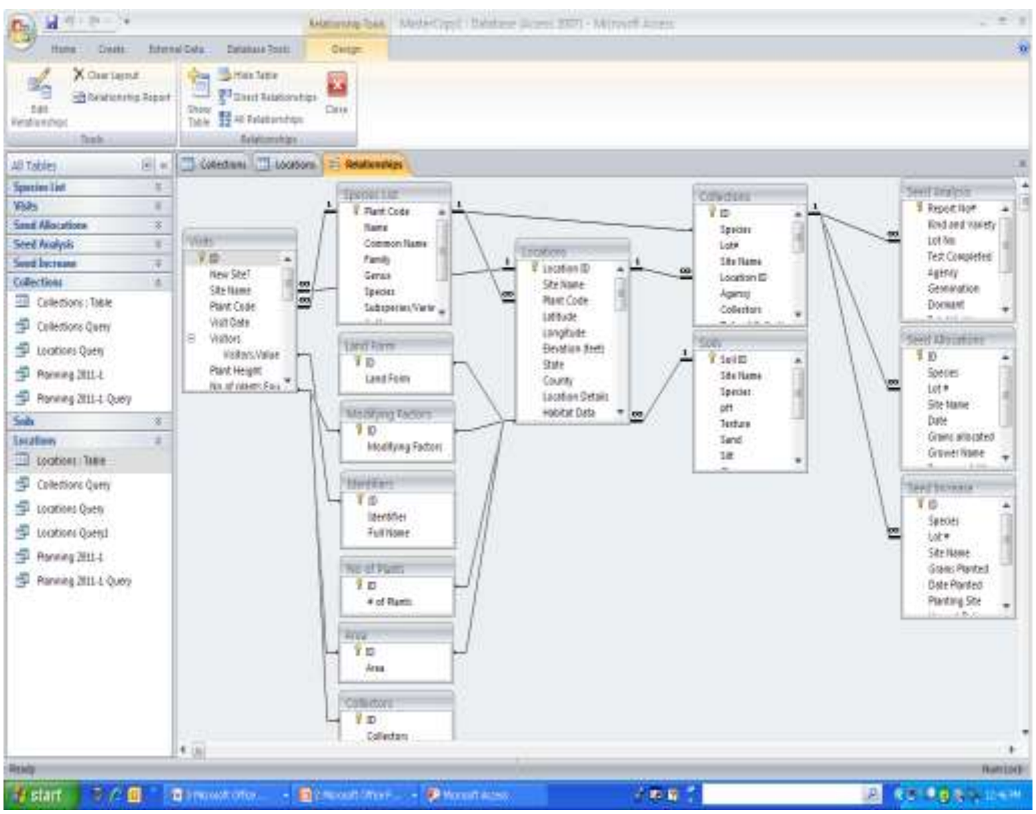
4. Technology Incorporation

<u>Staying Straight with Rotary Lasers</u>

The combination of inexperienced equipment operators, annual employee turnover and small framed tractors left us struggling with the ability to maintain straight rows in our farming operations. In 2011 we adopted laser guidance technology outlined in Gary Kees, June 2008, Reforestation and Nurseries Tech Tip, “Staying Straight with Rotary Lasers at the Coeur d’Alene Nursery”. The technology utilizes a rotary laser mounted on its side to cast an oscillating vertical beam the length of the plot, and two laser detectors, one positioned at the far end of the plot to establish the line and the second mounted to the tractor. We purchased a CST/Berger rotary laser package with an 800 foot range. In operation, the CST/Berger laser detector is mounted to a tripod at one end of the plot. The rotary laser is horizontally mounted on the package tripod at the other end of the plot and micro-adjusted to be in line with the detector. The CST/Berger laser detector features an audible indication of laser alignment once the laser engages the detection screen. Fine-tuning with the micro-adjust button moves the laser from the edge of the detection window to its center where a unique beep indicates precision. An AGATEC MR360R laser detector with a 9 ¾" laser capture width is mounted to the center of the bucket with magnets and elevated above the tractor. The detector features a five LED position indicator and transmits the lasers location via a wireless RF link to a remote display unit mounted on the windshield inside the tractor cab. Blinking arrows indicate the direction of travel necessary to be in precision alignment with the laser. Using the system requires additional setup time but permits a high degree of accuracy permitting more mechanical operations and minimizing the extent of handwork necessary to correct for poor alignment.

<u>Microsoft Access Database Development</u>

From the GBNPSIP's inception until 2010 we utilized DDH software's HanDBase database manager to house our plant materials data. In 2011 we developed a Microsoft Access version that offers added functionality, primarily in the ability to extract data from multiple tables during data queries. The Locations table is the database's central feature. Tied to it are, a number of tables used to populate a record with predefined values, and additional tables to house other information relating to that location such as Soils information and Seed Collections. Our Seed Collections table is further related to Seed Analysis, Seed Allocations and Seed Increase tables. The entire relationship structure can be viewed in the following image.



Additional tables are currently being developed to house information related to species screening and field trials. As the databases complexity increases it is becoming a one stop shop to house all of our plant material related information.

5. Updates

Transplanting *Lomatium* rootstock

Lomatium dissectum, when started from seed requires four or more years to produce its first harvestable seed crop. This experiment evaluates the potential of transplanting rootstock from high-density production beds into seed production fields in an effort to minimize the duration of the non-seed producing time. Rootstock of *L. dissectum* was not available to evaluate however, materials from two other biscuitroot species, *L. grayi* and *L. triternatum* were lifted from Oregon State University's Malheur Experiment Station spring 2010. Both of these species produce seed the second year following sowing and as such are not of themselves prime candidates for root transplanting for this purpose, however they serve as a surrogate for evaluating challenges encountered in the lifting and transplanting process. Rootstock was separated into size classes based on crown diameter and transplanted into shovel-dug holes at locations in Utah or transplanted into private production fields in Nevada using a tree transplanter. Rootstock was initially sheared at a 10” depth which proved to be 2 inches longer than the tree transplanter could place without J planting the rootstock. So *L. triternatum* rootstock was re-trimmed to an 8” length. In a planting process some rootstock fell horizontally in the trough rather than remaining vertical. The 2 inch basal sections of *L. triternatum* were also planted in the bottom of the trough with no care given to orientation.

Plant response in 2011 was quite similar across locations. On April 13, 2011 multiple leaflets and flowering stems had emerged from most roots of both species at one location in Nevada. Plants generally produced a canopy of leaves and flowers proportional to the size of transplanted rootstock. Plant height, including the bolted flower stem, was typically less than 8 inches for the most robust plants. Fine root hairs were present, growing from the main taproot. Survival through the first spring, though not quantified, was good. Root orientation appeared to have no impact on the roots ability to send up leaf tissue and surprisingly the 2 inch segments cut from the bottom of the *L. triternatum* roots also produced leaves. Seed production though present was not adequate to warrant collection.

Soil solarization

Heat treating soil with steam to reduce soil pathogens is a common practice in greenhouse nursery operations. A typical approach is to elevate soil temperatures to a thermal threshold (60-65 C), then maintain the temperature for a period of time (45-60 min), that kills most fungi and bacteria. Although several attempts have been made to develop machinery for similar application in field settings, none have proven viable. Alternative approaches, including solarization, have been tried with some success. Soil solarization involves tightly covering moist soil with thin clear plastic and leaving it in place during the hottest weeks of summer. In some geographic locations, temperatures similar to steam treatments can be achieved in the upper layers of soil during the warmest parts of the day, resulting in mortality of plant pathogens. More commonly a longer exposure to a lower temperature provides a similar effect. A number of soil borne pathogens including *Verticillium, Pythium, Rhizoctonia* and *Theilaviopsi,* have been reported to be controlled through soil solarization.

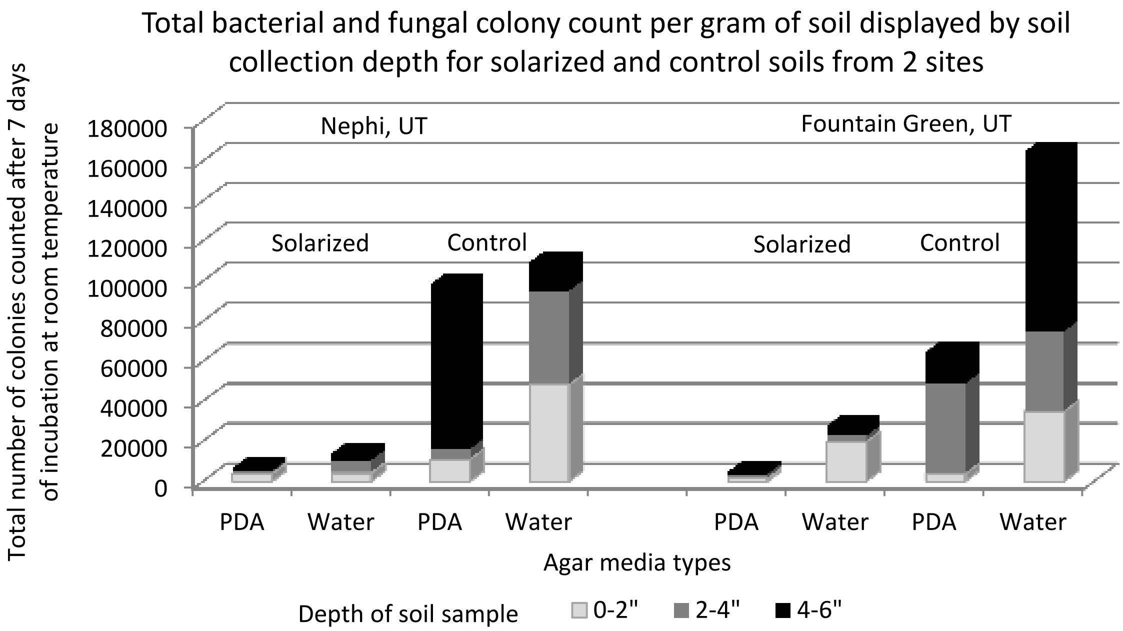
Recent work by James et.al (2010) assessing common grasses and forbs planted for wildfire restoration demonstrated a 72% average germination rate of planted species across years and treatments; however 85 to 98% of that germinated seed failed to emerge. These poor emergence percentages can be attributed to a variety of different factors, potentially including soil pathogens. In seed increase beds at two sites in Utah we experience similarly poor establishment rates among seeded species. Our general rule of thumb is to plant 25 pure live seeds (PLS) per linear foot, expecting on average, establishment of one plant per foot. In an effort to reduce potential soilborne pathogens and improve seedling establishment, we began experimenting with soil solarization in 2010. This project seeks to evaluate the effectiveness of reducing abundance of soil pathogenic fungi and bacteria at two sites in central Utah through the use of soil solarization.

Methods
Study sites were located at the USDA ARS Dry Land Research Farm in Nephi, Utah and the Utah Division of Wildlife Resources, Plant Materials Evaluation Farm in Fountain Green, Utah.

In 2010 trials, temperatures at or above our target of 140° Fahrenheit were achieved at the soil surface for 310 min. but that temperature was only reached for 10 min. at a depth of 3 inches. We questioned whether beneficial results were achieved with increasing depths. In 2011 we wanted to extend the duration of the solarization period by installing the plastic during the third week of June and leaving it in place through the end of August, the effective season for solarization in our climate. In 2011 we switched from 1 mil to a thicker 2 mil plastic to limit tearing during application. At the Nephi site, nursery beds were laid out perpendicular to the dominant wind pattern, resulting in plastic being blown off shortly after installation. On a few beds located immediately leeward of taller vegetation, plastic remained in place through the summer. At the Fountain Green site, beds were laid out parallel to the dominant wind patterns and a snow fence was installed on the leeward side. Here plastic retention was much better.

Five soil samples from each of three sampling depths, 0-2”, 2-4”, 4-6” in both control and solarized beds were homogenized. Soil dilutions were prepared for each site x treatment x depth combination by adding 5 g of soil plus sterile water to create a 50 ml solution. Further diluting resulted in a 10^{-1} dilution for treatment soils and 20^{-2} solution for control soils. 0.25 ml of solution were added to both PDA and water agar plates. Total colonies were counted at seven days.

At both sites solarization treatments resulted in dramatic reductions in total bacterial and fungal colony counts at all depths. The test of effectiveness will be whether this results in improved seedling establishment in 2012.



<u>Clipping effects on seed production of *Ipomopsis aggregata*</u>

Increase beds planted in 2010 will bolt in 2012 permitting continuation of this work. A five block randomized design study implementing a cut treatment prior to bolting and control on at least two different *Ipomopsis* sources will be conducted. Yields and seed quality will be evaluated.

<u>Seeds and Soils Study</u>

A five block greenhouse study was conducted to evaluate the influence of soil texture and seeding depth on germination of 18 species of forbs native to the Great Basin. Soils of clay loam, sandy loam, loam and loamy sand textures collected from wildland sites, and steam aerated at 60° C for 1 hour to reduce soil pathogen populations were transferred into flats to provide a 4-inch deep soil layer. The 18 species listed in the following tables were grouped based on the need for cold stratification. For each trial, nine species were sown on the surface and at depths of 1, 2, and 3 cm in a randomized design. Data is being analyzed.

Cold Stratification Group	
Heliomeris multiflora var. *nevadensis*	Nevada goldeneye
Crepis acuminata	tapertip hawksbeard
Crepis intermedia	limestone hawksbeard
Ipomopsis aggregata	scarlet gilia
Lomatium nudicaule	barestem biscuitroot
Balsamorhiza sagitatta	Arrowleaf balsamroot
Eriogonum heracleoides	Wyeth buckwheat
Penstemon speciosus	royal penstemon
Penstemon pachyphyllus	thickleaf beardtongue
Enceliopsis nudicaulis	nakedstem sunray

No Cold Stratification Group	
Sphaeralcea coccinea	scarlet globemallow
Sphaeralcea grossulariifolia	gooseberryleaf globemallow
Lupinus prunophilus	hairy bigleaf lupine
Lupinus sericeus	silky lupine
Lupinus arbustus	longspur lupine
Lupinus argenteus	silvery lupine
Agoseris grandiflora	bigflower agoseris
Agoseris heterophylla	annual agoseris
Cleome lutea	yellow spiderflower
Mentzelia albicaulis	whitestem blazingstar

Products:

Equipment development/modification - current projects

Budget realignment at the Missoula Technology and Development Center resulted in one of our projects being canceled and the need to acquire additional funding to proceed with the second.

Development of a specialized seed harvester for species with indeterminate ripening and seed shatter characteristics. We anticipate design work to begin in 2012. Several private seed production companies are interested in contributing ideas to the project.

Stock seed increase - plot installation 2011

Between two Utah farm sites, 39 sources of 16 species were planted into 47 increase beds or rows grouped by provisional seed zone.

Wildland seed collection 2011

28 collections, 16 species
29 new sites identified, 15 species

Awards

Nominated for Excellence in Botany Partnership Development, USFS National Botany Program, Washington, DC.

Workshop

Co-organized the Rangeland Technology Equipment Council Annual Workshop "Establishing Sagebrush in Semiarid Rangelands" held at the 66th Annual Society for Range Management Meeting.

Reference:

James, J.J.; Svejcar, T.J. 2010. Limitations to post-fire seedling establishment: The role of seeding technology, water availability, and invasive plant abundance. Rangeland Ecology and Management 63:491-495.

Publications:

Jensen, S.; Stanton, S.; Nielson, M.; Stettler, J.; Mathews, D.; Ersfeld, TJ.; Sample, C. 2011. Selecting and growing Great Basin natives. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 64-68. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Presentations:

Jensen, Scott. 2011. Selecting and growing Great Basin natives. Great Basin Native Plant Selection and Increase Project Annual Meeting, February 22-23, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Jensen, Scott. 2011. Applying provisional seed zones in the Great Basin. Native Plant Summit, Boise, ID.

Jensen, Scott. 2011. Great Basin provisional seed zones and applications to the Colorado Plateau. Colorado Plateau Native Plant Project Annual Meeting, Moab, UT.

Jensen, Scott. 2011. Current trends in plant materials development and the role of wildland collection. Utah Seed Council, Ephraim, UT.

Jensen, Scott. 2011. The development and use of forbs in restoration. Great Basin Science Delivery Project, Winnemucca, NV.

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

Project Location: USADA-NRCS Aberdeen Plant Materials Center, Aberdeen, Idaho

Principal Investigators and Contact Information:

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Project Description:

Plant Guides

The Aberdeen Plant Materials Center (PMC) is gathering information on significant/important/notable/selected plant species to create 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 potential uses, ethnobotanical significance, adaptation, pests and potential problems. In 2011 plant guides were completed or revised for fernleaf biscuitroot (*Lomatium dissectum*), Gray's biscuitroot (*L. grayi*), nineleaf biscuitroot (*L. triternatum*), hoary tansyaster (*Machaeranthera canescens*), and Douglas' dustymaiden (*Chaenactis douglasii*). In 2012, Aberdeen PMC will produce plant guides for gooseberryleaf globemallow (*Sphaeralcea grossularifolia*), blue penstemon (*Penstemon cyaneus*), yellow beeplant (*Cleome lutea*), and tapertip hawksbeard (*Crepis acuminata*). 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.

Douglas' dustymaiden

Fifteen accessions of Douglas' dustymaiden were evaluated at the Aberdeen PMC from 2009 to 2010. The accessions were evaluated for establishment, growth and seed production. Following evaluation, accession 9076577 was chosen for selected class release. Accession 9076577 was originally collected in Boise County, Idaho near Arrow Rock and Lucky Peak Reservoirs, approximately 0.5 miles west of the dam on Forest Road 268. The site is a mountain big sagebrush/bitterbrush community in coarse granitic soils at 3,150-ft elevation. Accession 9076577 ranked at or near the top for percent establishment, plant vigor, height, flower production and seed yield. In the fall of 2010, a 500 foot row of weed barrier fabric was planted to accession 9076577; however problems encountered during planting resulted in poor germination and establishment. In 2011, a 1,000-ft row of fabric was seeded. Release documentation is being developed and official release will occur once the Aberdeen PMC has produced a sufficient amount of early generation seed.

Hoary tansyaster

Nine accessions of hoary tansyaster were evaluated from 2009 through 2011 for establishment, plant growth and seed production. This accession had the best establishment and stands for 2009 and 2010, and the best rated vigor in 2010. This accession also had the tallest plants in the study. Although we were not able to evaluate seed production in 2010 due to wind storms, 9076670 was observed to be an excellent seed producer. The population for 9076670 is located near the St. Anthony Sand Dunes in Fremont County, Idaho at 5,000 ft elevation. The site has sandy soils and supports a bitterbrush, Indian ricegrass, rabbitbrush, scurfpea plant community. The location receives on average between 10 and 15 inches of mean annual precipitation. In 2010, the site was revisited to collect additional seed to use in a seed increase planting at the Aberdeen PMC. In 2010, a 500 foot row of weed barrier fabric was planted. An additional 1,000 foot row was planted in 2011. Next spring, we plan to establish an additional non-fabric field for seed increase. Release documentation is being developed and official release will occur once the PMC has produced a sufficient amount of early generation seed.

Propagation protocols

Seed production information obtained during collection evaluation and seed increase of native forb species was used to develop propagation protocols for Douglas' dustymaiden, hoary tansyaster, nineleaf biscuitroot, fernleaf biscuitroot, Gray's biscuitroot and Searls' prairie clover. These protocols provide information on seed collection, planting, management, harvest and cleaning. Propagation protocols are available at http://nativeplants.for.uidaho.edu.

Publications:

St. John, L.; Ogle, D. 2011. Cooperative work between the Great Basin Native Plant Selection and Increase Project and the Aberdeen Plant Materials Center. In: Great Basin Native Plant Selection and Increase Project 2010 Progress Report. p. 69-76. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

St. John, L.; Tilley, D.; Ogle, D.; Johnson, D.; Bushman, S. 2012. Propagation protocol for production of *Dalea searlsiae* (A. Gray) Barneby 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. Online: http://www.nativeplantnetwork.org

Tilley, D. 2011. Propagation protocol for production of *Machaeranthera canescens* (Pursh) A. Gray seeds. Aberdeen, ID: USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. In: Native Plant Network. URL: http://www.nativeplantnetwork.org. Moscow, ID: University of Idaho, College of Natural Resources, Forest Research Nursery. Online: http://nativeplants.for.uidaho.edu.

Tilley, D.; Ogle, D.; St. John, L. 2010. Plant guide for Doulas' dusty maiden (*Chaenactis douglasii*). Aberdeen, ID: USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. 4 p. Online: www.plants.usda.gov

Tilley, D.; Ogle, D.; St. John, L. 2010. Plant guide for Hoary tansyaster (*Machaeranthera canescens*). Aberdeen, ID: USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. 3 p. Online: www.plants.usda.gov

Tilley, D.; St. John, L.; Ogle, D.; Shaw, N. 2011. Plant guide for Gray's biscuitroot (*Lomatium grayi*). Aberdeen, ID: USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. 4 p. Online: www.plants.usda.gov

Tilley, D.; St. John, L.; Ogle, D.; Shaw, N. 2010. Plant guide for Nineleaf biscuitroot (*Lomatium triternatum*). Aberdeen, ID: USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. 4 p. Online: www.plants.usda.gov

Tilley, D.; St. John, L.; Ogle, D.; Shaw, N.; Cane, J. 2010. Plant guide for Fernleaf biscuitroot (*Lomatium dissectum*). Aberdeen, ID: USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. 6 p. Online: www.plants.usda.gov

Tilley, D.; St. John, Loren.; Ogle, D.; Shaw, N.; Cane, J. 2012. Propagation protocol for production of *Lomatium dissectum* (Nutt.) Mathias & Constance 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. Online: http://www.nativeplantnetwork.org

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

Tilley, D.; St. John, L.; Ogle, D.; Shaw, N.; Cane, J. 2012. Propagation protocol for production of *Lomatium triternatum* (Pursh) Coulter & Rose 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. Online: http://www.nativeplantnetwork.org

Presentations:

Tilley, D.; St. John, L.; Ogle, D. 2011. Aberdeen PMC Report of Activities, 2011. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 21-22, Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

St. John, L. 2011. Joint Fire Science seeding at Wildcat Hills, UT. Utah Section Society for Range Management Field Tour, 2011 June 2, Snowville, UT.

John, L. 2011. USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center demonstration area. Orchard Experimental Restoration Site Field Day, 2011 June 28, Boise, ID.

Management Applications and Seed Production Guidelines:
Douglas' dustymaiden and hoary tansyaster are feasible for commercial seed production. Douglas' dustymaiden establishes well using dormant fall 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 were completed for royal penstemon, hotrock penstemon, sharpleaf penstemon, fernleaf biscuitroot, nineleaf biscuitroot, Gray's biscuitroot, Douglas' dustymaiden, and hoary tansyaster.

Propagation Protocols were completed for Douglas' dustymaiden, hoary tansyaster, nineleaf biscuitroot, fernleaf biscuitroot, Gray's biscuitroot, and Searls' prairie clover.

Early generation Certified seed of hoary tansyaster and Douglas' dustymaiden 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: Identification of Herbicides for Use in Native Forb Seed Production

Project Location: Utah State University, Logan, Utah

Principal Investigator and Contact Information:

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Project Description:

Native forb seed is needed to restore the rangelands of the Intermountain West. Weed control is essential for the commercial production of native forb seed. Weeds compete with crop plants reducing establishment, vigor, and seed production. In addition, some weed seeds can contaminate the seed crop, reducing its value or introducing weeds to reclamation areas. Removal of weeds by hand or with cultivation is economically restrictive. The overall objective of this research project is to identify herbicides that can be used to control weeds in forb seed production with limited injury to the forbs. The forbs evaluated in this project include: Basalt milkvetch (*Astragalus filipes)*, Western prairie clover (*Dalea ornata*), and Searls' prairie clover (*Dalea searlsiae*).

Results for 2011

Field plots with 2,4-DB at Hermann Farms demonstrated little herbicide injury on established Basalt milkvetch, but also did not control perennial sowthistle.

In fall of 2010 and summer of 2011 basalt milkvetch and Western prairie clover trials were planted with seed at the Utah State University, Greenville Research Farm. Seed had been scarified and treated with fungicide by Hermann Farms. Basalt milkvetch seed was 'Dry River' germplasm and Western prairie clover was 'Aridlands' germplasm. The soil was a Millville silt loam. Planting was accomplished using a Hege cone-seeder to drill seeds 0.25 inches deep in four rows spaced 14 inches apart. Seed was planted at 8 lbs. PLS per acre. Herbicide applications were made with a CO_2-pressurized backpack sprayer calibrated to deliver 20 gpa at 30 psi. Plots were 5 by 30 feet and treatments were replicated 4 times.

Fall planted trials

Field trials of basalt milkvetch and Western prairie clover were planted November 18, 2010. In the spring of 2011, only basalt milkvetch had successfully established. Western prairie clover seedlings were observed emerging early, but appeared to have been killed by late spring freeze events. Post-emergence herbicide treatments were applied to the basalt milkvetch on June 21, 2011. Response to herbicide treatments was evaluated visually and by taking density counts at the time of application and 36 days after treatment. Bromoxynil and quinclorac caused significant injury to basalt milkvetch plants (Table 1). Treatments of 2,4-DB, bentazon, imazethapyr and imazamox resulted in only minimal injury. Combining 2,4-DB with bromoxynil or benatazon with imazamox caused only slight increases in plant injury. Regardless of treatment, basalt milkvetch densities decreased from 42 to 19%. Possible explanations for plant death may include nutritional deficiencies, improper soil water relations, or disease problems.

Table 1. Basalt milkvetch injury and density change in response to post-emergence herbicide application on June 21 to plants seeded the previous winter, 2011.

		Evaluations 36 DAT	
Treatment*	Rate	Injury	Density reduction
	lb ae/or ai/A	%	
Untreated	-	0	21
2,4-DB	0.25	1	29
2,4-DB	0.5	9	29
Bentazon + COC	0.5	8	29
Bromoxynil	0.25	30	36
2,4-DB + bromoxynil	0.25 + 0.125	14	37
Quinclorac + MSO	0.25	19	42
Imazethapyr + COC	0.047	8	19
Imazamox + COC	0.063	7	28
Imazamox + bentazon + COC	0.063 + 0.25	13	26
LSD (0.05)	-	14.7	NS

*COC = crop oil concentrate added at 1.0 pt/acre.

Summer planted trials for post-emergence treatments
Additional field trials of basalt milkvetch and Western prairie clover were planted June 15, 2011. These trials were planted as above but in rows spaced 7 inches apart. Only Western prairie clover effectively established at this planting time. Post-emergence herbicide treatments were applied to the Western prairie clover plants on August 19, 2011. While there appeared to be increased injury to prairie clover with combinations of 2,4-DB with bromoxynil, differences were not statistically different (Table 2). Plant densities increased from pre-treatment counts to those taken 22 days after treatment, suggesting additional plants germinated after treatment. Increases ranged from 3 to 31% and were not different among treatments. The number of flowers per plot also did not appear to be affected by herbicide treatment.

Fall Trial for Pre-emergence Herbicides
A trial was established to evaluate the effects of pre-emergence herbicides on Western prairie clover germination and establishment. The trial was planted August 26, 2011 and pre-emergence herbicide treatments were applied on August 27, 2011. Plant densities were determined by counting the number of plants in each plot on October 13, 2011. While injury symptoms were visible on small plants in plots treated with pendimethalin, dimthenamid-p and ethofumesate, small plant size prevented overall injury ratings. Plant densities were not affected by treatments and ranged from 137 to 200 plants per plot (Table 3). Spring evaluations will document if seedling injury from pre-emergence herbicides causes increased mortality over the winter.

Overall, trials demonstrated that basalt milkvetch and Western prairie clover are relatively tolerant to post-emergence herbicides and that some pre-emergence herbicides show promise for establishing Western prairie clover fields. Further testing is needed to determine possible herbicide effects on seed yields and viability and to verify crop safety.

Table 2. Western prairie clover injury, plant density increase, and number of flowering plants on September 10, 2011 in response to post-emergence herbicide application to plants seeded in June 2011 and treated in August 2011.

Treatment*	Rate	Evaluations 22 DAT Injury	Density increase	Flowers
	lb ae/or ai/A	———%	———	no/plot
Untreated	-	0	22	169
2,4-DB	0.25	5	22	188
Bentazon + COC	0.5	11	31	200
Bromoxynil	0.25	10	15	136
2,4-DB + bromoxynil	0.25 + 0.125	18	14	148
Imazethapyr + COC	0.047	6	14	173
Imazamox + COC	0.063	4	3	162
Imazamox + bentazon + COC	0.063 + 0.25	9	21	185
LSD (0.05)	-	NS	NS	NS

*COC = crop oil concentrate added at 1.0 pt/acre.

Table 3. Western prairie clover plant densities on October 13, 2011 in response to pre-emergence herbicides applied the day after planting on August 26, 2011.

Treatment	Rate lb ai/A	Plant density No./plot
Untreated	-	137
Pendimathalin	0.5	181
Pendimathalin	1.0	182
Pendimathalin	1.5	172
Pendimathalin	1.0	173
Pendimathalin	1.0	200
Pendimathalin	1.0	188
Dimethenamid-p	0.75	171
Ethofumesate	1.0	179
LSD (0.05)	-	NS

Direction for 2012

While this is the end of this cooperative agreement, there is continued need to develop herbicides for use in native forb seed production. The commercial quantities of seed of many native forb species that are now available would make additional field research more easily accomplished.

Publications:

Ransom, C.V. 2011. Evaluation of imazapic rates and forb planting times on native forb establishment. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 87-90. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Ransom, C.V.; Edvarchuk, K. 2011. Identification of herbicides for use in native forb seed production. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 91-92. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Roerig, K. C.; Ransom, C. V. 2010. Searls' Prairie clover (*Dalea searlsie*) tolerance to post-emergence herbicide applications. Western Society of Weed Science Research Progress. Report. p 74.

Presentations:

Ransom, C.V.; Israilsen, K. Grass and forb seed production: Weed control and herbicide effects. Utah Crop Improvement Association, Seed School. 2008 February 19, Brigham City, Utah. 60 attendees.

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

Ransom, C.V. 2011. Forb response to herbicides for seed production and rangeland restoration. Great Basin Native Plant Selection and Increase Project Annual Meeting. 2011 February 22-23, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Management Applications:

This research has demonstrated potential for safe use of herbicides in basalt milkvetch and Western prairie clover seed production. It has also added to the knowledge base concerning the importance of different times of planting for these two species to improve establishment success. Before herbicides can be used in production fields, they need to be registered and labeled for such use by the EPA.

Project Title: Seed Production of Great Basin Native Forbs
Subsurface Drip Irrigation:
2006 – 2011 Results
2011 New Plantings
Seeding Practices
Legume Seed Scarification

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

Principal Investigators and Contact Information:

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Nancy Shaw
USFS, Rocky Mountain Research Station
Boise, ID

Doug Johnson and **Shaun Bushman**
USDA-ARS, Forage & Range Research Laboratory
Logan, UT

Project Description:

1a. Irrigation: 2006 – 2011 results

Native wildflower seed is needed to restore rangelands of the Intermountain West. Commercial seed production is necessary to provide the quantity of seed needed for restoration efforts. A major limitation to economically viable commercial production of native wildflower (forb) seed is stable and consistent seed productivity over years.

In natural rangelands, the natural variations in spring rainfall and soil moisture result in highly unpredictable water stress at flowering, seed set, and seed development, which for other seed crops is known to compromise seed yield and quality.

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

Materials and Methods

Plant Establishment

Seed of the seven Intermountain West forb species (the first seven species in Table 1) was received in late November in 2004 from the Rocky Mountain Research Station (Boise, ID). The plan was to plant the seed in the fall of 2004, but due to excessive rainfall in October, the ground preparation was not completed and planting was postponed to early 2005. To try to ensure germination the seed was submitted to cold stratification. The seed was soaked overnight in distilled water on January 26, 2005, after which the water was drained and the seed 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* had started to sprout.

In late February 2005 drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth between 2 30-inch rows of a Nyssa silt loam with a pH of 8.3 and 1.1 percent organic matter. The drip tape was buried in alternating inter-row spaces (5 ft apart). The flow rate for the drip tape was 0.34 gal/min/100 ft at 8 psi with emitters spaced 16 inches apart, resulting in a water application rate of 0.066 inch/hour.

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

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

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

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

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

Irrigation for Seed Production

In April 2006 each strip of each forb species was divided into plots 30 ft long. Each plot contained four rows of each species. The experimental designs were randomized complete blocks with four replicates. The three irrigation treatments were a non-irrigated check, 1 inch per irrigation, and 2 inches per irrigation. Each treatment received 4 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; the amount was measured by a water meter and recorded after each irrigation to ensure correct water applications. Irrigations were controlled with a controller and solenoid valves.

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

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

Soil volumetric water content was measured by neutron probe. The neutron probe was calibrated by taking soil samples and probe readings at 8-, 20-, and 32-inch depths during installation of the access tubes. The soil water content was determined volumetrically from the soil samples and regressed against the neutron probe readings, separately for each soil depth. 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 result in reliable seed yield estimates. Replanting of *P. deustus* in the fall of 2006 did not result in adequate plant stand in the spring of 2007.

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

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

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

Cultural Practices in 2006

On October 27, 2006, 50 lb phosphorus (P)/acre and 2 lb zinc (Zn)/acre were injected through the drip tape to all plots of *Eriogonum umbellatum*, *Penstemon* spp., and *Lomatium* spp. On November 11, 100 lb 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 on May 14 and 29 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. All plots of the three *Sphaeralcea* species were flailed on November 8, 2007.

Cultural Practices in 2008

On November 9, 2007 and on April 15, 2008, Prowl at 1 lb ai/acre was broadcast on all plots for weed control. Capture® 2EC at 0.1 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 through the drip irrigation system to the three *Lomatium* species.

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 timing, 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 dissectum*, *Lomatium triternatum*, and *Lomatium grayi* plots as urea injected through the drip tape. The flowering, irrigation timing, and harvest timing varied by species (Table 2). Harvesting and seed cleaning methods for each species are listed in Table 3.

Table 2. Native forb flowering, irrigation, and seed harvest dates by species in 2006, 2007, and 2008.

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

Table 2 (continued). Native forb flowering, irrigation, and seed harvest dates by species in 2009, 2010, and 2011.

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

Table 3. Native forb seed harvest and cleaning by species.

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 and 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

The soil volumetric water content in the various species in 2011 responded to the irrigation treatments on each species (Figs. 3-7) and remained fairly moist due to winter snow pack, heavy spring rainfall, and the late distribution of precipitation (Fig. 2).

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

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, Fig. 8). 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, Fig. 1) and wet weather (Fig. 2). The accumulated precipitation in April through June of 2010 and 2011 was the highest 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, resulting in lower yields. Averaged over 6 years, seed yield of *E. umbellatum* increased with increasing water applied up to 8 inches, the highest amount tested (Fig. 3). The quadratic seed yield responses most years suggests that additional irrigation above 8 inches would not be beneficial.

Penstemon acuminatus. There was no significant difference in seed yield between irrigation treatments for *Penstemon 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 (Fig. 9). 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 percent of stand loss was 51.3, 63.9, and 88.5 for the 0-, 4-, and 8-inch irrigation treatments, respectively. The trial area was disked out in 2010. Following the 2005 planting, seed yields were substantial in 2006 and moderate in 2008. *P. acuminatus* is a short-lived perennial.

Penstemon speciosus. In 2006-2009 seed yield of *Penstemon speciosus* showed a quadratic response to irrigation rate (Fig. 10, 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 and 2011, 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.

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.

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, 2009, 2010, and 2011 seed yields of *L. triternatum* showed a quadratic response to irrigation rate (Fig. 11). 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. Averaged over 5 years, seed yield of *L. triternatum* was estimated to be maximized by 5.1 inches of applied water. Irrigation requirements were less in 2011.

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 (Fig. 12). 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 was again not responsive to irrigation. The spring of 2011 was unusually cool and wet. Averaged over 5 years, seed yield of *L. grayi* was estimated to be maximized by 5.1 inches of applied water. More appropriately, irrigation probably should be variable according to precipitation.

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 (Fig. 13). Seed yield with the 4-inch irrigation rate was significantly higher than with the non-irrigated check, but the 8-inch irrigation rate did not result in a significant increase above the 4-inch rate. In 2010 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. Averaged over the 3 years, seed yield showed a quadratic response to irrigation rate and was estimated to be maximized by 5.6 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.

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).

Dalea ornata and *D. searlsiae*. Emergence for the two *Dalea* species was poor, and plots had poor and uneven stands. In 2007, there was no significant difference in seed yield among irrigation treatments for the two *Dalea* species, with *D. ornata* having the higher seed yield. The stand of the two *Dalea* species declined and was too poor for seed harvest in 2008. The two *Dalea* species were replanted in the fall of 2008, but emergence was again poor and stands were not adequate for seed harvest in 2009 and the planting was destroyed.

Conclusions

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

Due to the arid environment, supplemental irrigation may 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.

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

	Precipitation (inches)		Growing degree-days (50 - 86°F)
Year	January - June	April - June	January - 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
66-year average	5.8	2.7	1042[a]

[a]25-year average.

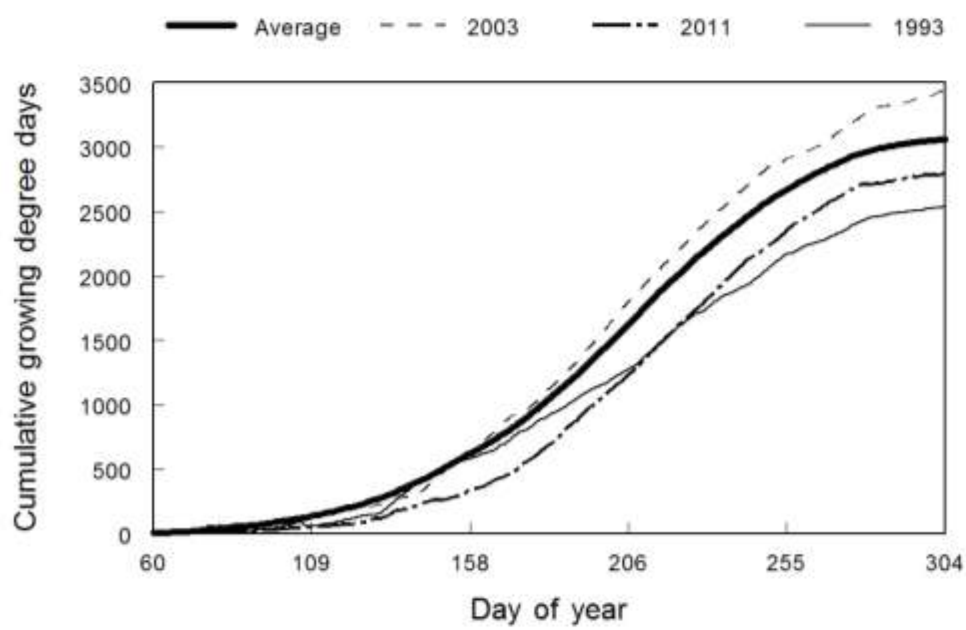

Figure 1. Cumulative annual and 21-year average growing degree-days at the Malheur Experiment Station, Oregon State University, Ontario, OR.

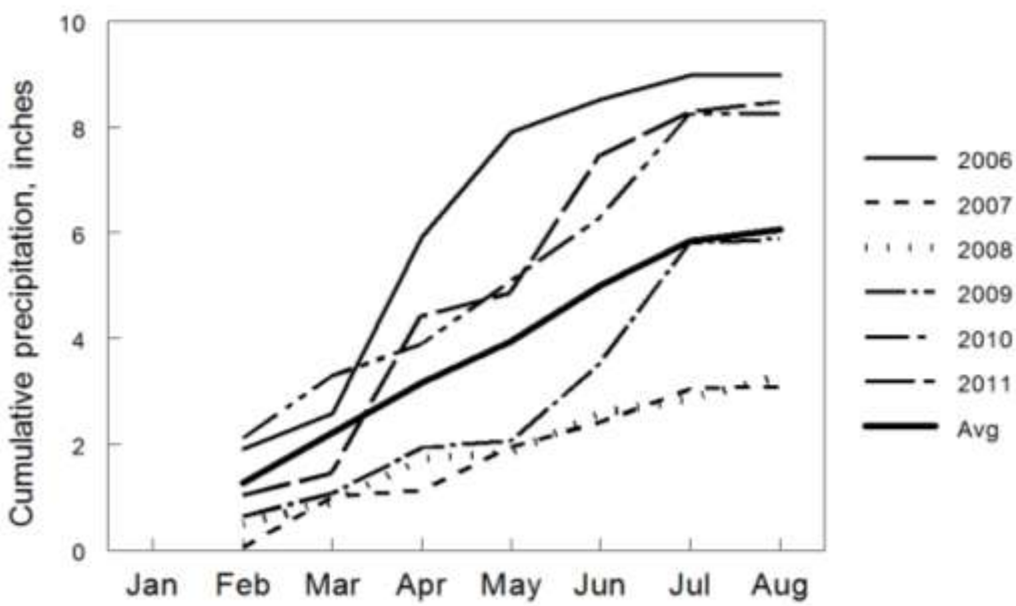

Figure 2. Cumulative annual and 66-year average precipitation from January through July at the Malheur Experiment Station, Oregon State University, Ontario, OR

Table 5. Native forb seed yield response to irrigation rate (inches/season) in 2006, 2007, and 2008.

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

[a] Planted March, 2005, areas of low stand replanted by hand in October 2005.

[b] LSD (0.10).

[c] Planted March, 2005, areas of low stand replanted by hand in October 2005 and whole area replanted in October 2006. Yields in 2006 are based on small areas 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, and 2- to 6-year averages.

Species	2009				2010				2011			
	0 inches	4 inches	8 inches	LSD (0.05)	0 inches	4 inches	8 inches	LSD (0.05)	0 inches	4 inches	8 inches	LSD (0.05)
	lb/acre											
Eriogonum umbellatum[a]	132.3	223	240.1	67.4	252.9	260.3	208.8	NS	248.7	136.9	121.0	90.9
Penstemon acuminatus[a]	20.7	12.5	11.6	NS	-- Stand disked out --							
Penstemon speciosus[a]	6.8	16.1	9	6.0b	147.2	74.3	69.7	NS	371.1	328.2	348.6	NS
Lomatium dissectum[d]	50.6	320.5	327.8	196.4b	265.8	543.8	499.6	199.6	567.5	1342.8	1113.8	180.9
Lomatium triternatum[d]	181.6	780.1	676.1	177	1637.2	2829.6	3194.6	309.4	1982.9	2624.5	2028.1	502.3[f]
Lomatium grayi[d]	359.9	579.8	686.5	208.4	1035.7	1143.5	704.8	NS	570.3	572.7	347.6	NS
Sphaeralcea parvifolia[e]	285.9	406.1	433.3	NS	245.3	327.3	257.3	NS	81.6	142.5	141.2	NS
Sphaeralcea grossulariifolia[e]	270.7	298.9	327	NS	310.5	351	346.6	NS	224.0	261.9	148.1	NS
Sphaeralcea coccinea[e]	332.2	172.1	263.3	NS	385.7	282.6	372.5	NS	89.6	199.6	60.5	NS

Species	2- to 6-year averages			
	0 inches	4 inches	8 inches	LSD (0.05)
Eriogonum umbellatum[a]	173.4	200.7	224.8	34.5
Penstemon acuminatus[a]	163.8	204.8	189.9	NS
Penstemon speciosus[a]	131.8	179.8	153.5	NS
Lomatium dissectum[d]	294.6	691.0	647.1	195.7
Lomatium triternatum[d]	799.8	1462.5	1462.5	200.9
Lomatium grayi[d]	479.0	734.3	663.1	160.7[b]
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 March, 2005, areas of low stand replanted by hand in October 2005.
[b] LSD (0.10).
[c] Planted March, 2005, areas of low stand replanted by hand in October 2005 and whole area replanted in October 2006. Yields in 2006 were based on small areas with adequate stand. Yields in 2007 were based on whole area of very poor and uneven stand.
[d] Planted March, 2005, whole area replanted in October 2005.
[e] Planted spring 2006, whole area replanted in November 2006.

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.

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	6+
Penstemon acuminatus	no response	1	3
Penstemon speciosus	0 in wet years, 4 in dry years	1	3
Lomatium dissectum	6	4	6+
Lomatium triternatum	4 to 8 depending on precipitation	2	6+
Lomatium grayi	0 in wet years, 7 to 8 in dry years	2	6+
Sphaeralcea parvifolia	no response	1	5+
Sphaeralcea grossulariifolia	no response	1	5+
Sphaeralcea coccinea	no response	1	5+

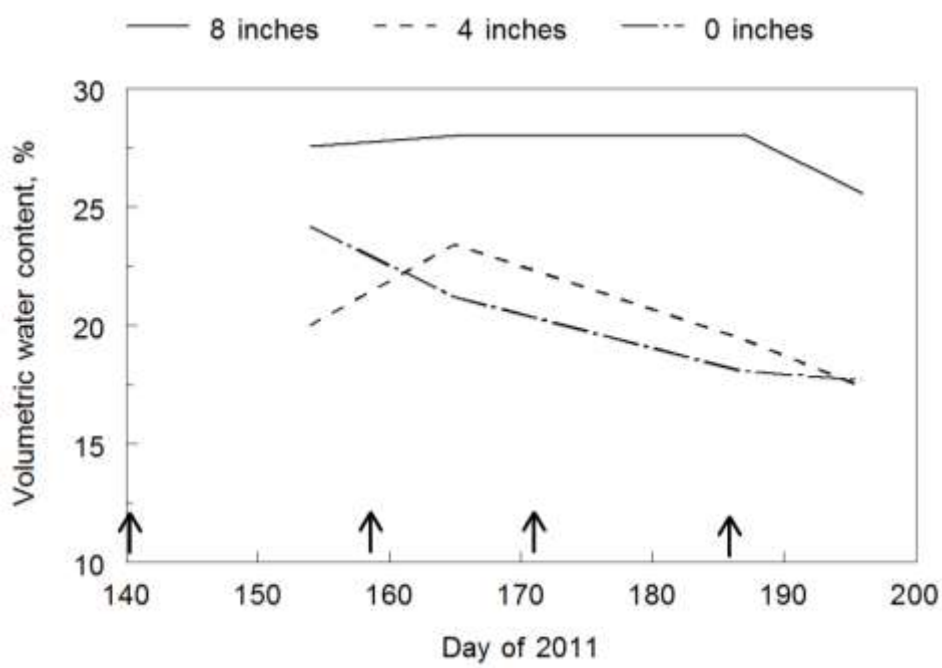

Figure 3. Soil volumetric water content for *Eriogonum umbellatum* over time in 2011. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 20 and ended on July 5. Arrows denote irrigations. *E. umbellatum* was harvested on August 1 (day 213).

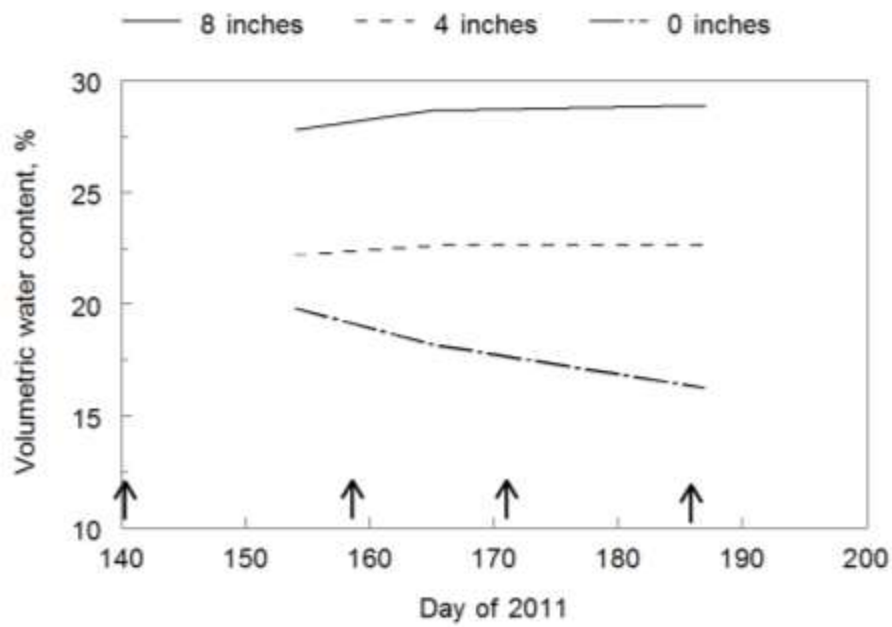

Figure 4. Soil volumetric water content for *Penstemon speciosus* over time in 2011. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 20 and ended on July 5. Arrows denote irrigations. *P. speciosus* was harvested on July 29 (day 210).

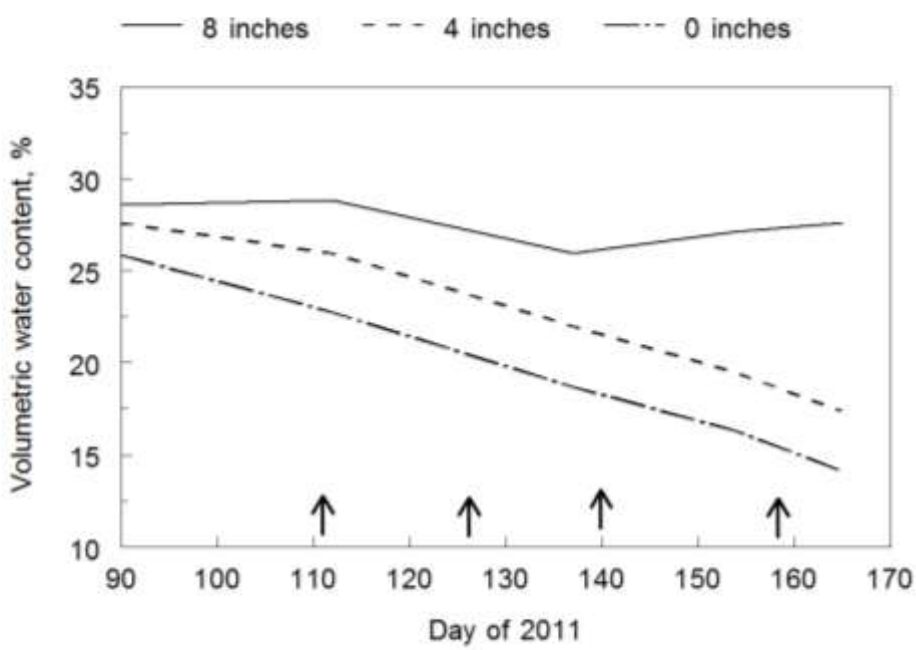

Figure 5. Soil volumetric water content for *Lomatium triternatum* over time in 2011. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 21 and ended on June 7. Arrows denote irrigations. *L. triternatum* was harvested on July 26 (day 207).

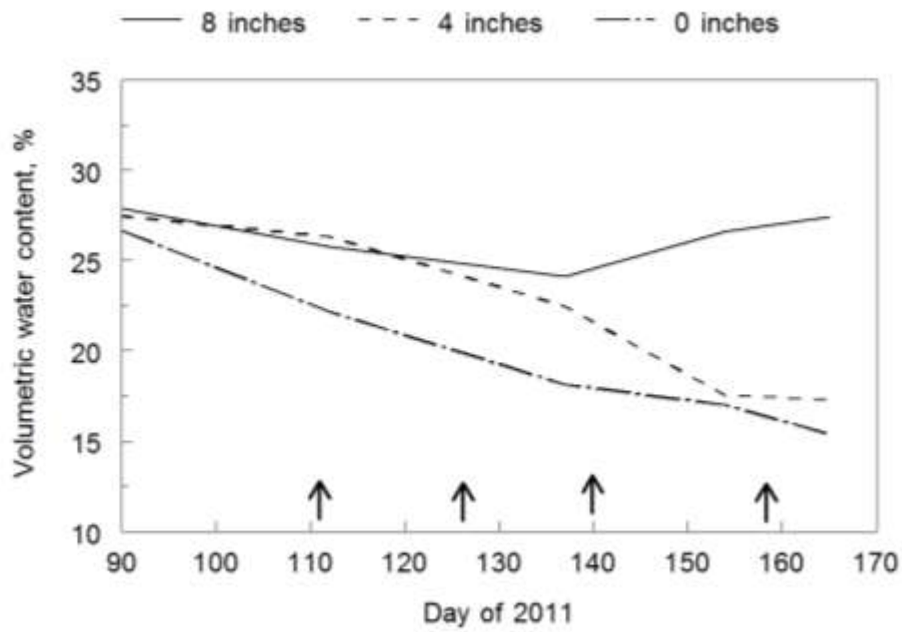

Figure 6. Soil volumetric water content for *Lomatium grayi* over time in 2011. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 21 and ended on June 7. Arrows denote irrigations. L. grayi was harvested on June 22 (day 173).

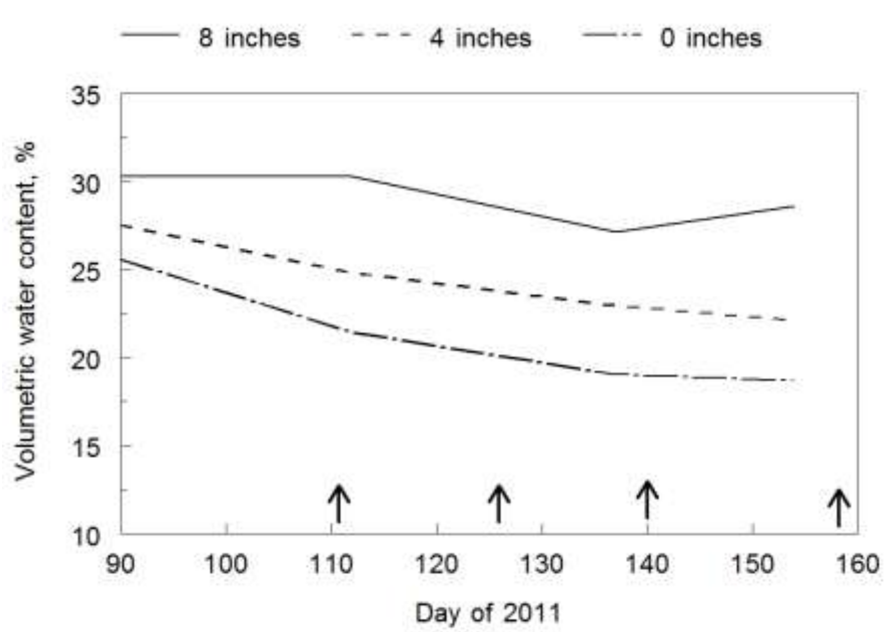

Figure 7. Soil volumetric water content for *Lomatium dissectum* over time in 2011. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 21 and ended on June 7. Arrows denote irrigations. *L. dissectum* was harvested on June 20 (day 171).

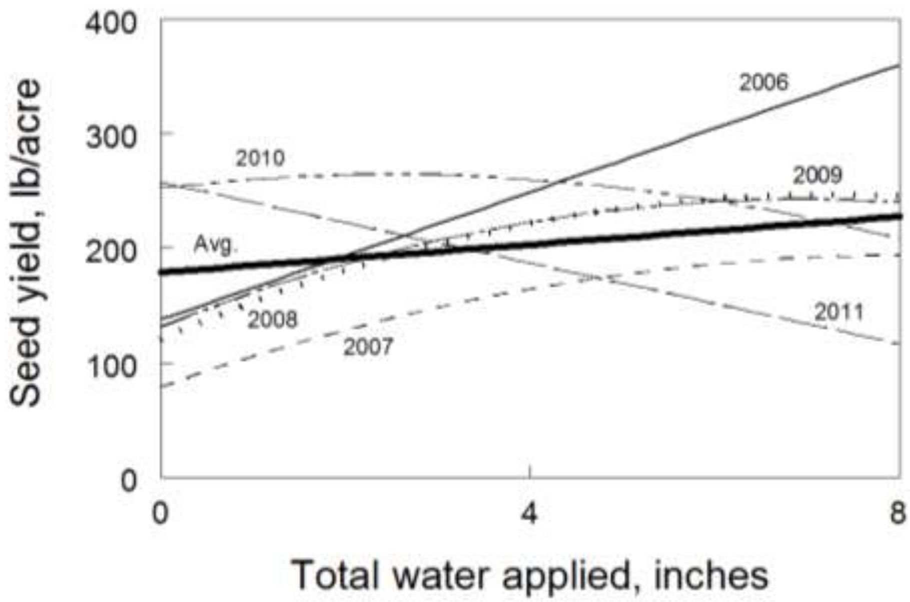

Figure 8. Average annual *Eriogonum umbellatum* seed yield response to irrigation water applied in 6 years and averaged over 6 years.
Regression equations: *2006*, Y = 137.9 + 27.8X, R^2 = 0.68, P = 0.01;
2007, Y = 79.6 + 28.3X – 1.75X^2, R^2 = 0.69, P = 0.05; *2008*, Y = 121.3 + 34.6X – 2.4X^2, R^2 = 0.73, P = 0.01;
2009, Y = 132.3 + 31.9X – 2.3X^2, R^2 = 0.60, P = .05; *2010*, Y = 252.9 + 9.21X – 1.8X^2, R^2 = 0.08, P = NS;
2011, Y = 232.7 – 16.0X, R^2 = 0.58, P = 0.01; *6-year average*, Y = 173.9 + 6.43X, R^2 = 0.49, P = 0.05

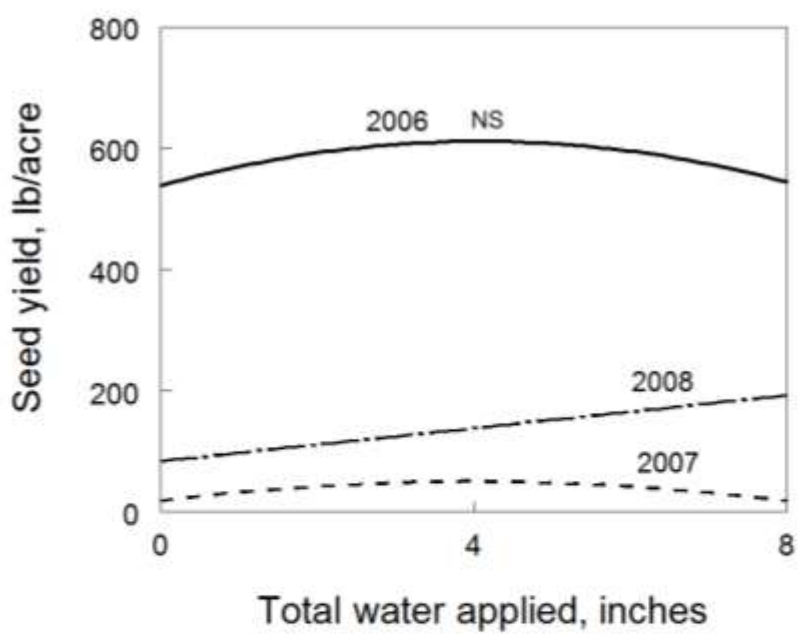

Figure 9. Annual *Penstemon acuminatus* seed yield response to irrigation water.
Regression equations: *2006*, Y = 538.4 + 35.6X – 4.4X^2, R^2 = 0.03, P = NS;
2007, Y = 19.3 + 15.4X – 1.9X^2, R^2 = 0.44, P = 0.10; *2008*, Y = 84.5 + 13.6X, R^2 = 0.49, P = 0.05

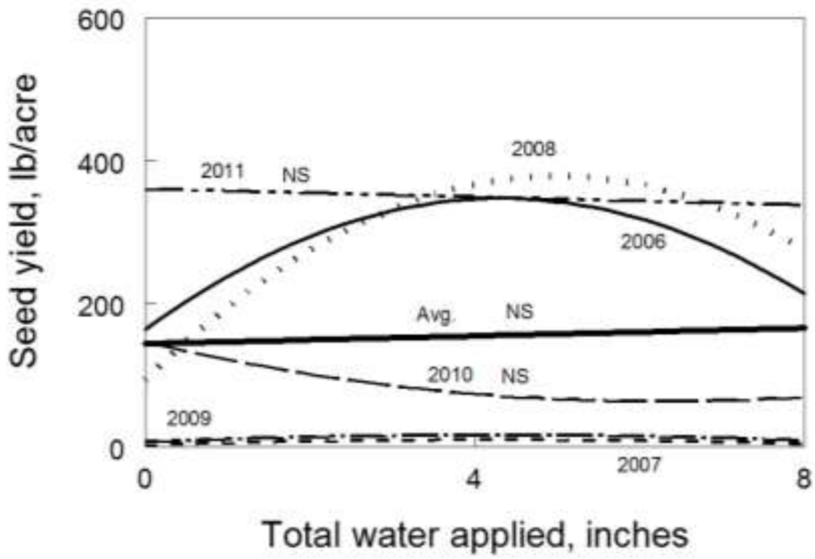

Figure 10. Annual and 6-year average *Penstemon speciosus* seed yield response to irrigation water.
Regression equations: *2006*, $Y = 163.5 + 85.1X – 9.9X^2$, $R^2 = 0.66$, $P = 0.05$;
2007, $Y = 2.5 + 3.2X – 0.38X^2$, $R^2 = 0.48$, $P = 0.10$; *2008*, $Y = 94.1 + 113.7X – 11.4X^2$, $R^2 = 0.56$, $P = 0.05$;
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; *6-year average*, $Y = 144.2 + 2.72X$, $R^2 = 0.06$, P = NS

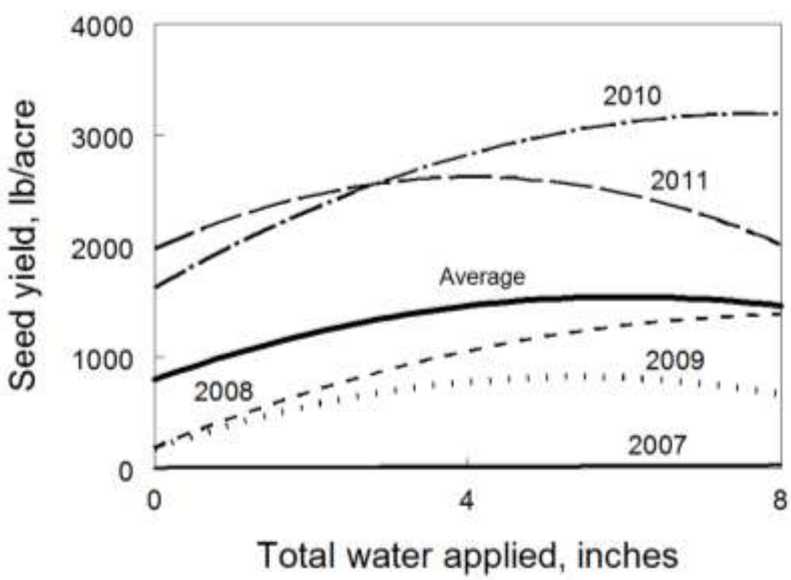

Figure 11. Annual and 5-year average *Lomatium triternatum* seed yield response to irrigation water applied.
Regression equations: *2007*, $Y = 3.26 + 3.06X$, $R^2 = 0.52$, $P = 0.01$;
2008, $Y = 195.3 + 283.9X – 16.9X^2$, $R^2 = 0.77$, $P = 0.01$;
2009, $Y = 181.6 + 237.4X – 22.0X^2$, $R^2 = 0.83$, $P = 0.001$;
2010, $Y = 1637.2 + 401.5X – 25.9X^2$, $R^2 = 0.83$, $P = 0.001$;
2011, $Y = 1982.932 + 315.1X – 38.7X^2$, $R^2 = 0.45$, $P = 0.10$;
6-year average, $Y = 799.8 + 248.5X – 20.7X^2$, $R^2 = 0.81$, $P = 0.001$

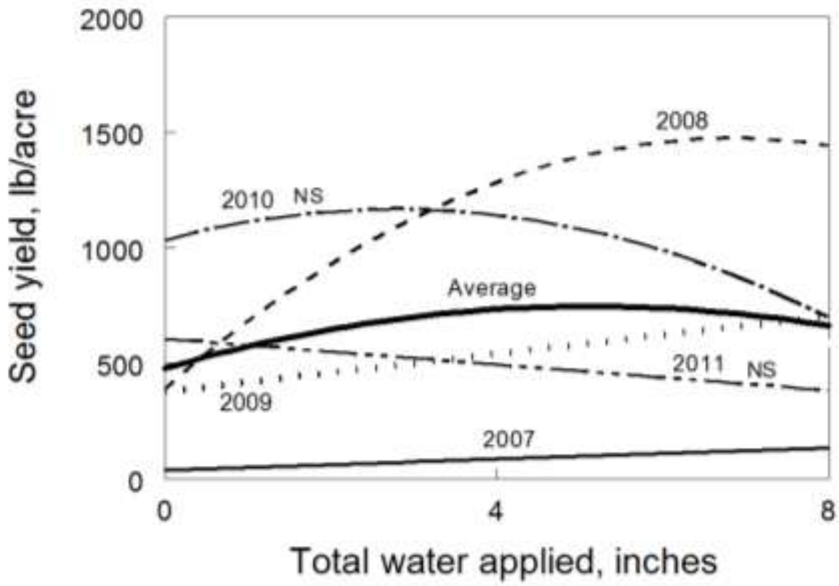

Figure 12. Annual and 5-year average *Lomatium grayi* seed yield response to irrigation water applied.

Regression equations: *2007*, Y = 37.5 + 12.0X, R^2 = 0.26, P = 0.10;
2008, Y = 393.3 + 315.4X – 23.0X^2, R^2 = 0.93, P = 0.001; *2009*, Y = 378.7 + 40.8X, R^2 = 0.38, P = 0.05;
2010, Y = 1035.7 + 95.3X – 17.1X^2, R^2 = 0.22, P = NS; *2011*, Y = 608.2 – 27.8X, R^2 = 0.07, P = NS;
6-year average, Y = 479.0 + 104.6X – 10.2X^2, R^2 = 0.46, P = 0.10

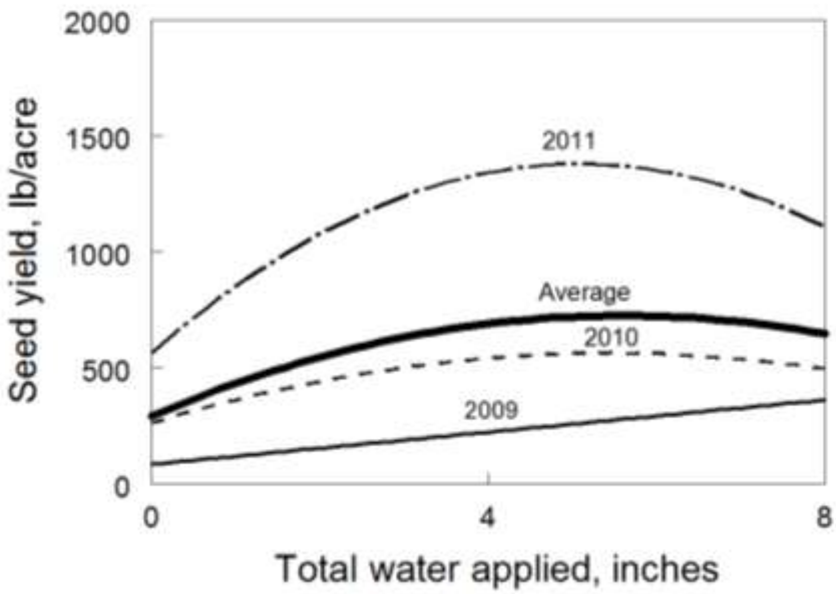

Figure 13. Annual and 3-year average *Lomatium dissectum* seed yield response to irrigation water.

Regression equations: *2009*, Y = 86.4 + 34.6X, R^2 = 0.31, P = 0.10;
2010, Y = 265.8 + 109.8X – 10.1X^2, R^2 = 0.68, P = 0.01;
2011, Y = 567.5 + 319.3X – 31.4X^2, R^2 = 0.86, P = 0.001;
6-year average, Y = 294.7 + 154.1X – 13.8X^2, R^2 = 0.72, P = 0.01

1b. Irrigation: 2011 New Plantings

The trials reported here tested the effects of three low rates of irrigation on the seed yield of 10 native forb species planted in 2009.

Materials and Methods

Plant Establishment

In November 2009, drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth between 2 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 all species was planted in 30-inch rows using a custom-made 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 63801) covered four rows (two beds) and was applied with a mechanical plastic mulch layer. The field was irrigated for 24 hours on December 2 due to very dry soil conditions.

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% sawdust and 50% hydro seeding mulch (Hydrostraw LLC, Manteno, IL) by volume. The mulch mixture was sprayed with water using a backpack sprayer.

Table 1. Forb species planted in the drip irrigation trials in 2009 at the Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Common names
Penstemon deustus	Scabland penstemon, hot-rock penstemon
Penstemon cyaneus	Blue penstemon
Penstemon pachyphyllus	Thickleaf beardtongue
Eriogonum heracleoides	Parsnip-flowered buckwheat
Dalea searlsiae	Searls' prairie clover
Dalea ornata	Western prairie clover
Astragalus filipes	Basalt milkvetch
Cleome serrulata	Rocky mountain beeplant
Lomatium nudicaule	Bare-stem desert parsley, Barestem lomatium
Cymopterus bipinnatus	Hayden's cymopterus

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 blocks with four replicates. The three irrigation treatments were a nonirrigated check, 1 inch per irrigation, and 2 inches per irrigation. Each treatment received 4 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; the amount was measured by a water meter and recorded after each irrigation to ensure correct water applications. Irrigations were controlled with a controller and solenoid valves.

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* and *Cymopterus bipinnatus* have not flowered as of 2011. Irrigation treatments were not applied to *Lomatium nudicaule* and *Cymopterus bipinnatus.*

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 during the season into volumetric soil water content.

Table 2. Native forb flowering, irrigation, and seed harvest dates by species in 2011.

Species	Flowering			Irrigation		Harvest
	start	peak	end	start	end	
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 ---					

<u>Results and Discussion</u>

The spring of 2011 followed considerable snowpack and had higher than average precipitation and lower than average growing degree days (Figures 1 and 2).

The soil volumetric water content in the various species in 2011 responded to the irrigation treatments on each species (Figs. 3-7) and remained fairly moist due to winter precipitation and the continued precipitation in 2011. The soil moisture content remained above 20 percent until mid June for all species and irrigation treatments.

Seed Yields

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 8 to 13). 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. *Cleome serrulata* started flowering in late June and peaked in August, when precipitation was lower. Seed yields of *Penstemon cyaneus* and *Penstemon pachyphyllus* did not respond to irrigation, but the results might be compromised by the poor stand in many plots.

Table 3. Native forb seed yield response to irrigation rate (inches/season) in 2011.

Species	0 inches	4 inches	8 inches	LSD (0.05)
	----------- lb/acre ----------			
Penstemon cyaneus[a]	857.2	821.4	909.4	NS
Penstemon pachyphyllus[a]	569.9	337.6	482.2	NS
Penstemon deustus	637.6	477.8	452.6	NS
Eriogonum heracleoides	55.2	71.6	49.0	NS
Dalea searlsiae	262.7	231.2	196.3	50.1
Dalea ornata	451.9	410.8	351.7	NS
Astragalus filipes	87.0	98.4	74.0	NS
Cleome serrulata	446.5	499.3	593.6	100.9[b]

[a]poor stand
[b]LSD (0.10)

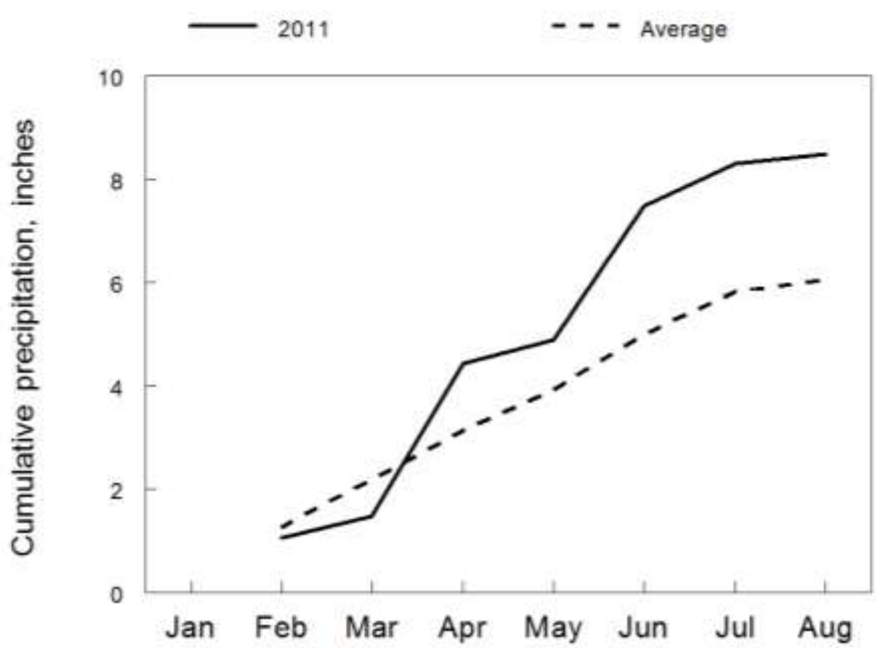

Figure 1. Cumulative annual and 66-year average precipitation from January through July at the Malheur Experiment Station, Oregon State University, Ontario, OR.

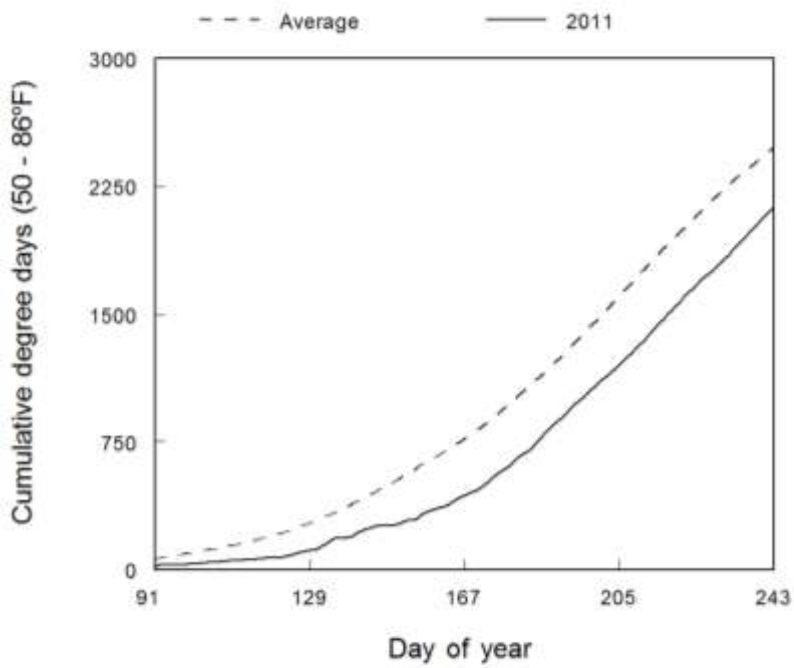

Figure 2. Cumulative 2011 and 20-year average growing degree-days at the Malheur Experiment Station, Oregon State University, Ontario, OR.

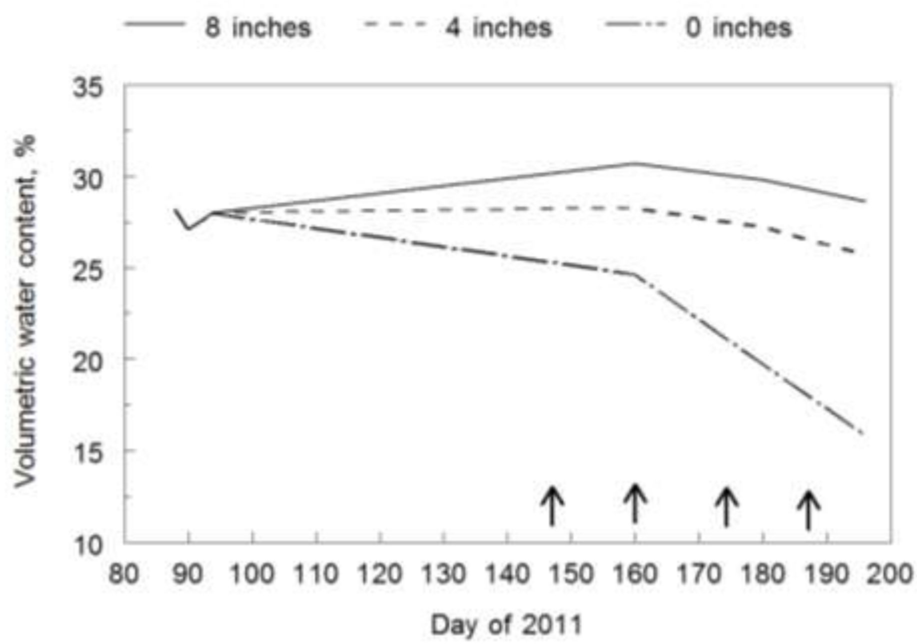

Figure 3. Soil volumetric water content for *Eriogonum heracleoides* over time in 2011. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 27 and ended on July 6. Arrows denote irrigations. *E. heracleoides* was harvested on August 1 (day 213).

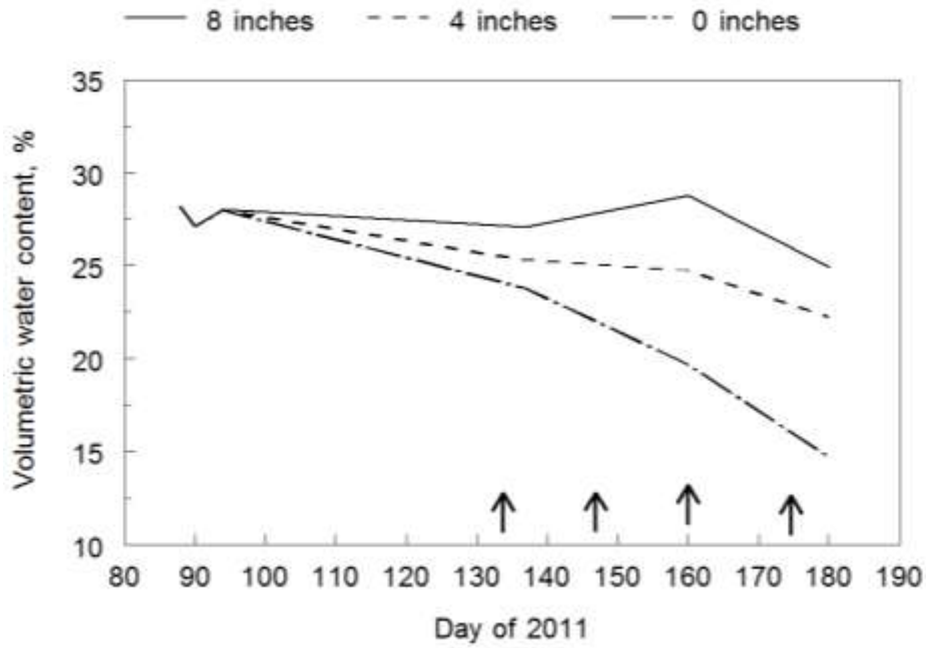

Figure 4. Soil volumetric water content for *Penstemon deustus* over time in 2011. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 13 and ended on June 23. Arrows denote irrigations. *P. deustus* was harvested on August 16 (day 228).

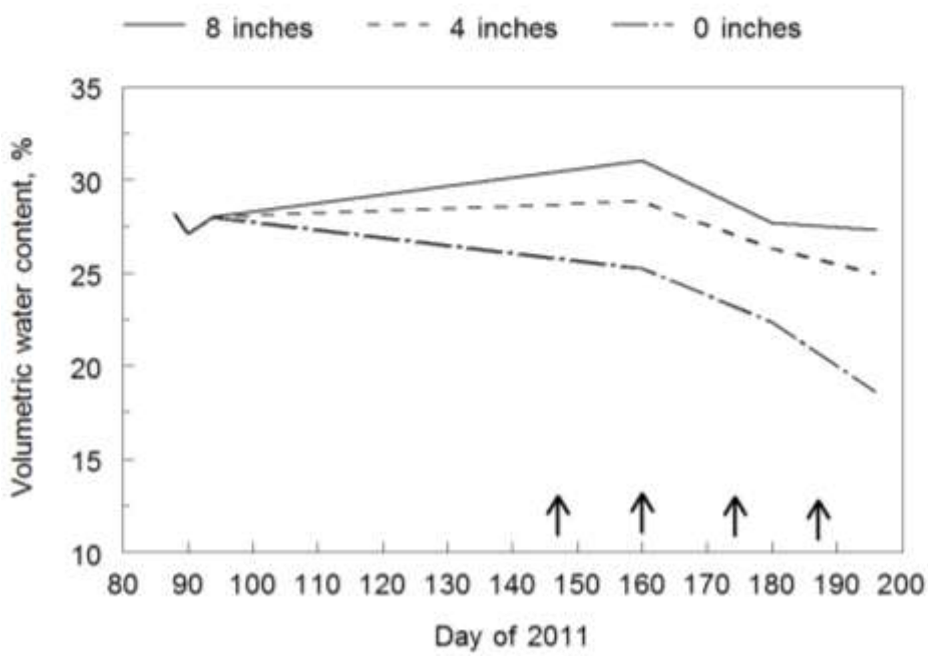

Figure 5. Soil volumetric water content for *Dalea searlsiae* over time in 2011. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 27 and ended on July 6. Arrows denote irrigations. *D. searlsiae* was harvested on July 21 (day 202).

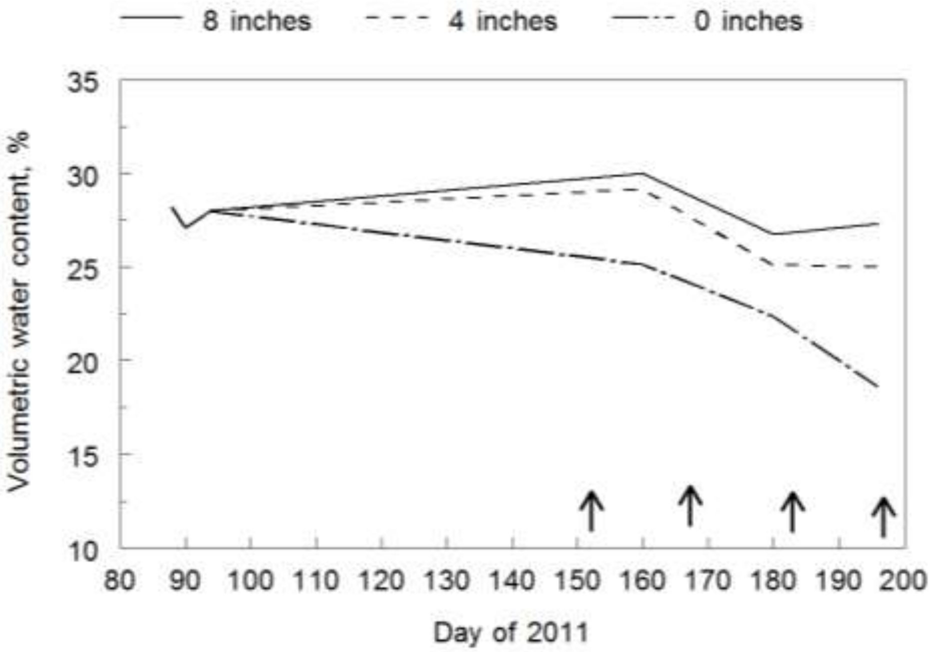

Figure 6. Soil volumetric water content for *Dalea ornata* over time in 2011. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 27 and ended on July 6. Arrows denote irrigations. *D. ornata* was harvested on July 22 (day 203).

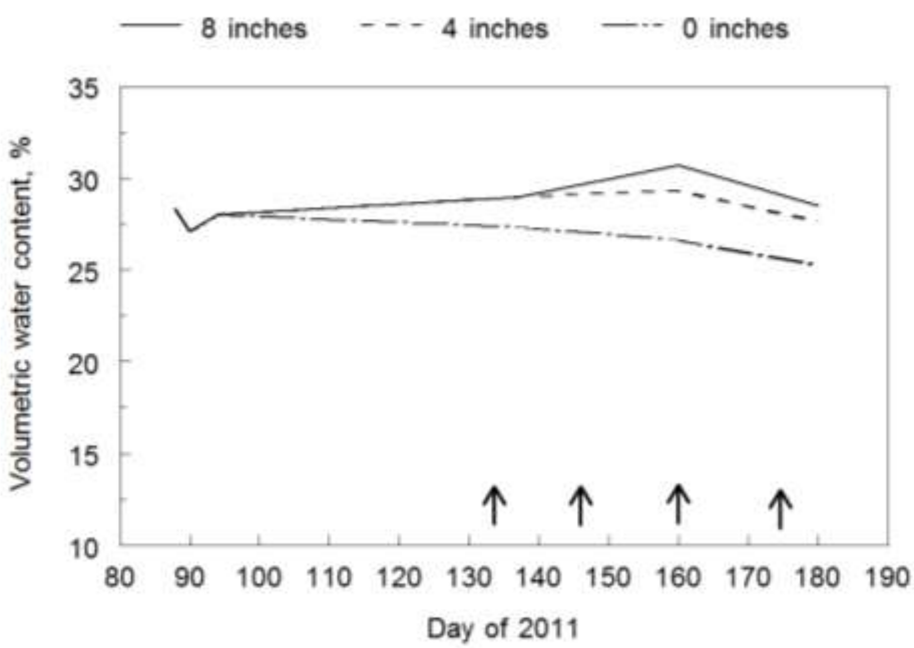

Figure 7. Soil volumetric water content for *Astragalus filipes* over time in 2011. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 13 and ended on June 23. Arrows denote irrigations. *A. filipes* was harvested on July 18 (day 199).

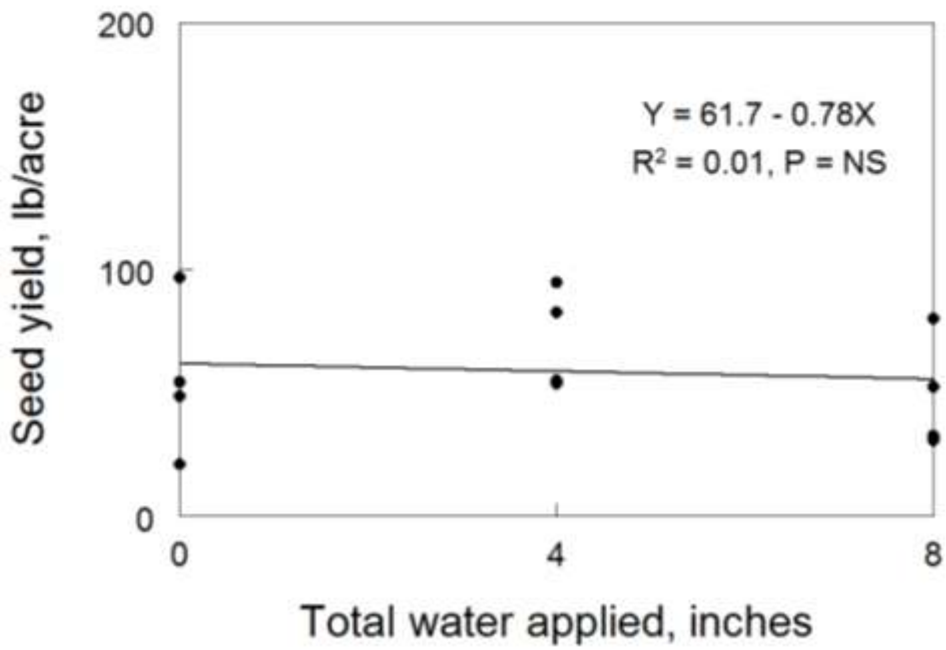

Figure 8. *Eriogonum heracleoides* seed yield response to irrigation water applied in 2011.

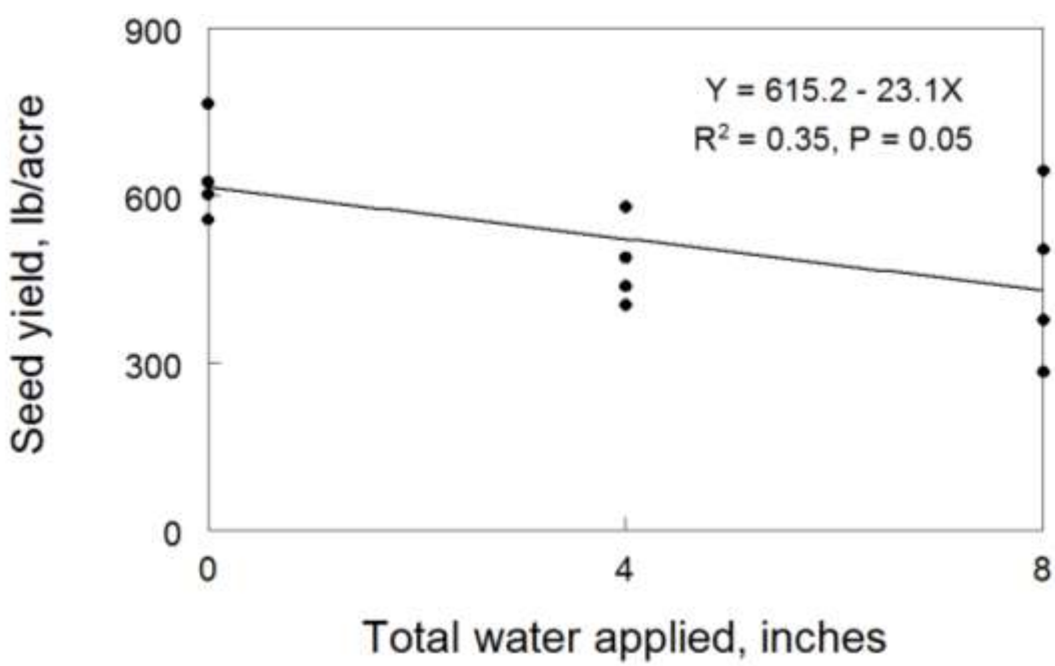

Figure 9. *Penstemon deustus* seed yield response to irrigation water applied in 2011.

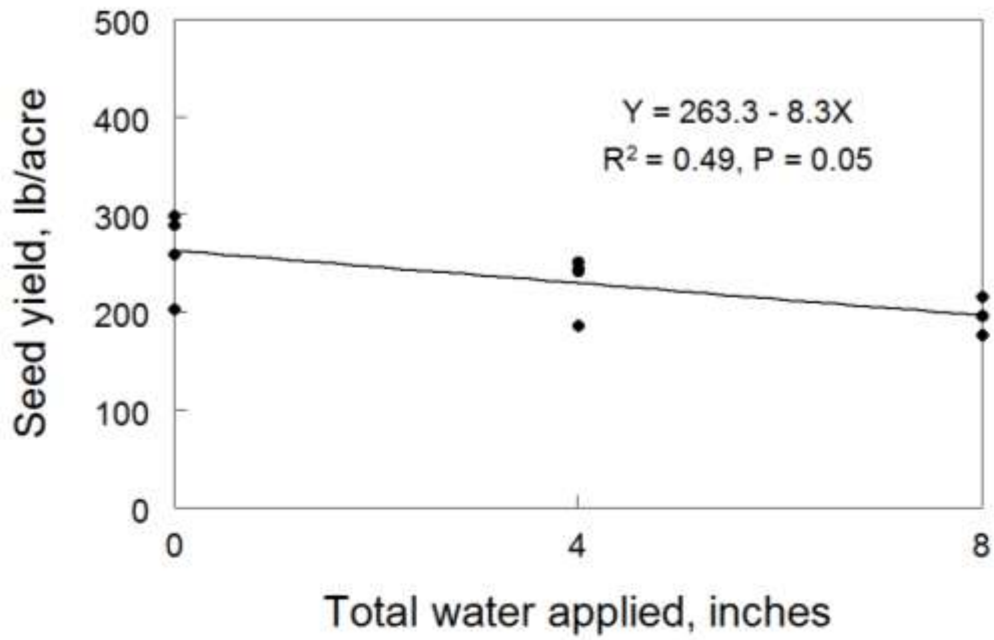

Figure 10. *Dalea searlsiae* seed yield response to irrigation water applied in 2011.

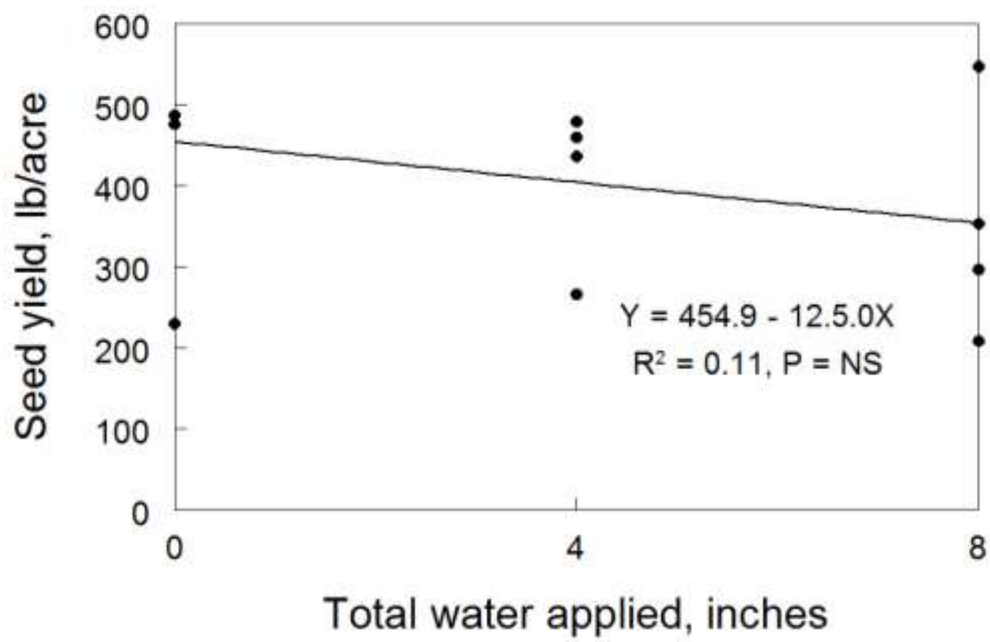

Figure 11. *Dalea ornata* seed yield response to irrigation water applied in 2011.

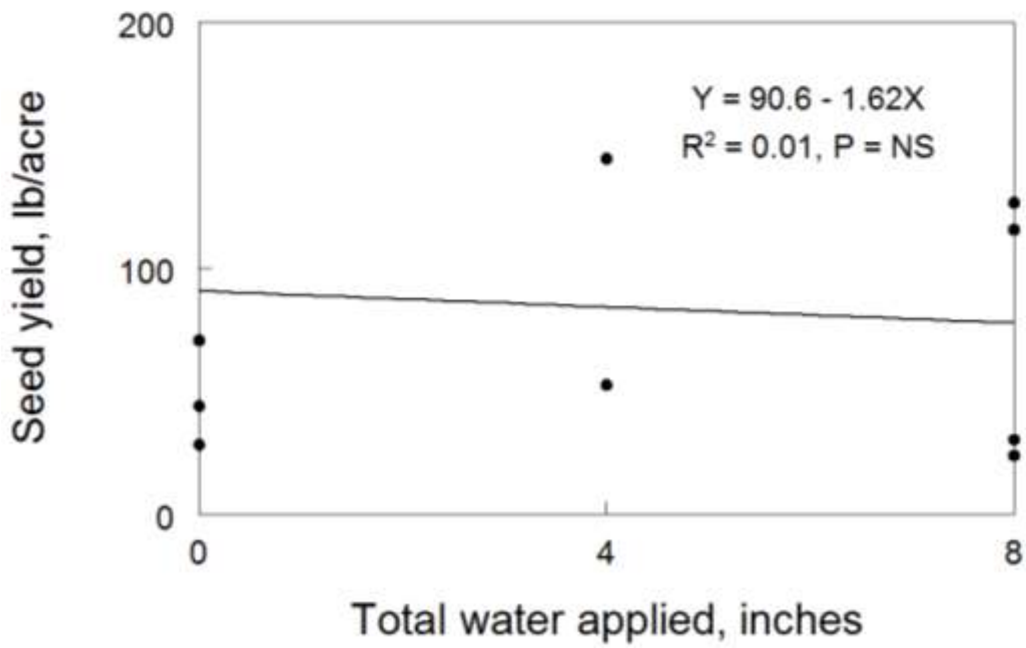

Figure 12. *Astragalus filipes* seed yield response to irrigation water applied in 2011.

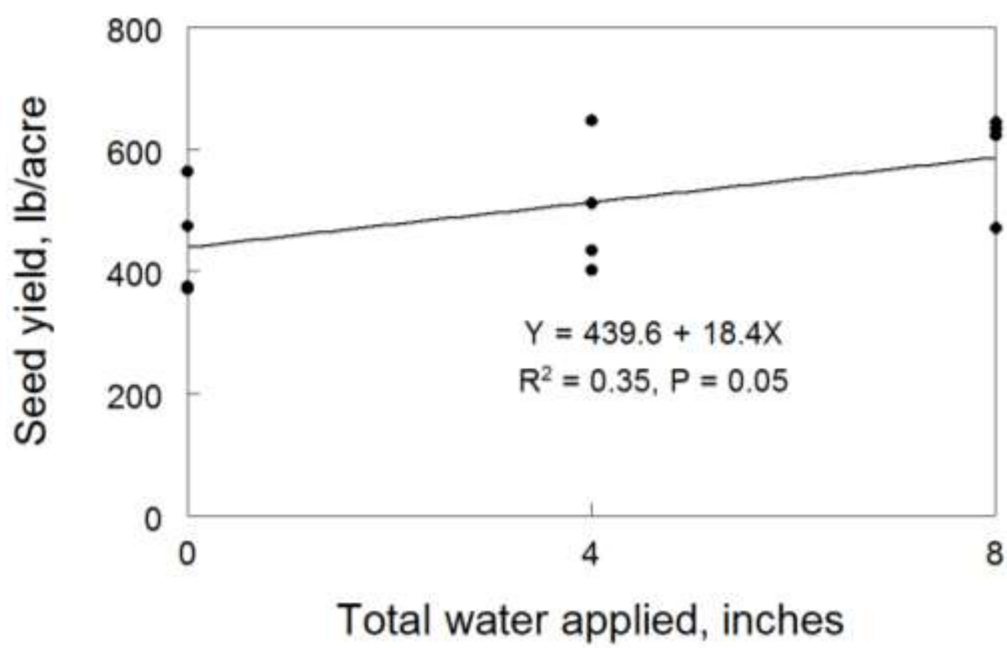

Figure 13. *Cleome serrulata* seed yield response to irrigation water applied in 2011.

2. Seeding Practices

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

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

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

#	Row cover	Seed treatment*	Sawdust	Sand	Mulch
1	yes	yes	yes	no	no
2	yes	yes	no	no	no
3	yes	no	yes	no	no
4	no	yes	yes	no	no
5	yes	yes	yes	yes	no
6	no	yes	no	no	yes
7	no	no	no	no	no

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

Materials and Methods

Five species for which stand establishment has been problematic were chosen. A sixth species (*Penstemon acuminatus*) was chosen as a check, because it has reliably produced good stands at Ontario. Seed of *Dalea ornata* was scarified by immersion for 5 min in 98 percent sulfuric acid. Seed weights for all species were determined. A portion of the seed was treated with a liquid mix of the fungicides Ridomil MZ58 and Captan (100 g Ridomil, 100 g Captan in 1 liter of water). Seed weights of the treated seeds were determined after treatment and untreated and treated seed were used to make seed packets containing approximately 300 seeds each. Seed packets were assigned to one of seven treatments (Table 1). The trial was planted manually on November 3, 2010. The experimental design was a randomized complete block with six replicates. Plots were one 30-in wide bed by 5 ft long. Two seed rows were planted on each bed.

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

Table 2. Seed weights and tetrazolium test (seed viability) for native plants submitted to emergence treatments in the fall of 2010.

Species	Common name	Untreated seed weight	Tetrazolium test
		seeds/g	%
Achnatherum thurberianum	Thurber's needlegrass	352.4	72
Dalea ornata	Blue mountain prairie clover	276.4	89
Dalea searlsiae	Searls' prairie clover	321.4	84
Penstemon acuminatus	Sharpleaf penstemon	1119.4	73
Penstemon deustus	Hotrock or scabland penstemon	6164.4	70
Heliomeris multiflora	Showy goldeneye	1821.9	88
Balsamorhiza sagittata	Arrowleaf balsamroot	138.6	77
Astragalus filipes	Basalt milkvetch	236.6	94

After planting, the sawdust was applied in a narrow band over the seed row at 0.26 oz/ft of row (558 lb/acre). For treatments receiving both sawdust and sand, the sand was applied at 0.65 oz/ft of row (1,404 lb/acre) as a narrow band over the sawdust. Following planting and sawdust and sand applications, some beds were covered with row cover. The row cover (N-sulate, DeWitt Co., Inc., Sikeston, MO 63801) covered four rows (two beds) and was applied with a mechanical plastic mulch layer. For the hydroseeding mulch treatments, hydroseeding mulch (Hydrostraw LLC, Manteno, IL) was applied dry at 7.5 g/foot of row in a 3 cm band over the seed row. The applied dry mulch was sprayed with water using a backpack sprayer to simulate hydroseeding.

On March 23, 2011, the row cover was removed and emergence counts were made in each plot. Emergence counts were again taken on May 13. Seed of *Dalea ornata*, *Penstemon acuminatus*, and *Heliomeris multiflora* was harvested by hand in August. *H. multiflora* continued to flower and seed was again harvested in November.

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

<u>Results and Discussion</u>

By the first emergence count on March 23, 2011, all species had started emerging. On March 23 and May 13, row cover with sawdust and seed treatment resulted in higher emergence than no row cover (bare ground) with sawdust and seed treatment for *Achnatherum thurberianum*, *Penstemon acuminatus*, *P. deustus*, *Heliomeris multiflora*, and *Balsamorhiza sagittata* (Table 3). On March 23, adding sawdust to row cover and seed treatment did not improve emergence of any species, but reduced emergence of *P. deustus.* On May 13, adding sawdust to row cover and seed treatment improved emergence of *A. thurberianum*, but reduced emergence of *P. deustus.*

On March 23, adding seed treatment to sawdust and row cover improved emergence of *Penstemon acuminatus*. On May 13, adding seed treatment to sawdust and row cover improved emergence of *A. thurberianum, P. acuminatus,* and *P. deustus.* Adding sand to sawdust, seed treatment, and row cover increased emergence for *B. sagittata* and *P. acuminatus* on May 13. There was no difference in emergence between treatments for *Dalea ornata* on either date.

Emergence with hydroseed mulch and seed treatment was lower than with row cover and seed treatment for all species on both dates, except for *Balsamorhiza sagittata* on May 13.

Analysis of the five treatments tested in 2010 and 2011 on the 6 species, shows that over the 2 years, row cover with seed treatment and sawdust improved emergence compared to no row cover with seed treatment and sawdust for *A. thurberianum, P. deustus*, *H. multiflora,* and *B. sagittata* (Table 4). Row cover with seed treatment and sawdust had lower emergence than row cover and seed treatment without sawdust for *P. deustus.* The effect of systems with and without seed treatment on emergence differed by year. Adding seed treatment to row cover and sawdust did not improve emergence for any species and reduced emergence for 3 species in 2010. In 2011, adding seed treatment to row cover and sawdust improved emergence for 3 species. March precipitation, when emergence starts, was higher in 2011 (3 in) than in 2010 (0.6 in). Adding sand to row cover, seed treatment and sawdust did not improve emergence of any species.

<u>Conclusions</u>

The above results describe practices that can be immediately implemented by seed growers. Averaged over two years:

- Row cover with seed treatment and sawdust improved emergence over no row cover with seed treatment and sawdust for all species except *Penstemon acuminatus*.
- Row cover with sawdust and seed treatment did not improve emergence over row cover without sawdust and with seed treatment and reduced emergence for *Penstemon desutus*.
- The effect of systems with and without seed treatment on emergence differed by year. In a drier year (2010), adding seed treatment to row cover and sawdust did not improve emergence for any species and reduced emergence for three species in 2010. In 2011 (wetter year), adding seed treatment to row cover and sawdust improved emergence for three species.
- Adding sand to row cover, seed treatment and sawdust did not improve emergence of any species.

Reference:

Shock, C.C., E.B.G. Feibert, L.D. Saunders, and N. Shaw. 2010. Emergence of native plant seeds in response to seed pelleting, planting depth, scarification, and soil anti-crusting treatment. Oregon State University Malheur Experiment Station Annual Report 2009:218-222.

Table 3. Emergence of seven native plant species on March 23 and May 13, 2011 in response to seven treatments applied at planting in the fall of 2010. Emergence for each species was corrected to the percent emergence of viable seed. *Dalea ornata* seed was acid scarified.

March 23

#	Row cover	Seed treatment	Sawdust	Sand	Mulch	*Balsamorhiza sagittata*	*Achnatherum thurberianum*	*Dalea ornata*	*Penstemon acuminatus*	*Penstemon deustus*	*Heliomeris multiflora*	Average
						% emergence						
1	yes	yes	yes	no	no	80.3	45.7	4.9	46.9	30.5	35.4	40.6
2	yes	yes	no	no	no	78.9	47.8	10.7	47.5	55.3	34.0	45.7
3	yes	no	yes	no	no	84.1	56.6	1.5	29.2	18.1	37.6	37.8
4	no	yes	yes	no	no	46.8	5.9	0.0	21.4	0.0	12.5	14.4
5	yes	yes	yes	yes	no	94.0	44.1	3.0	58.7	37.9	49.0	47.8
6	no	yes	no	no	yes	44.2	0.0	0.0	10.9	0.0	6.9	10.3
7	no	no	no	no	no	44.7	5.4	0.0	14.6	11.7	8.6	14.2
Average						67.6	29.4	2.9	32.7	21.9	26.3	30.1
LSD (0.05) Treatment												5.3
LSD (0.05) Species												6.2
LSD (0.05) Treatment X Species												16.5

May 13

#	Row cover	Seed treatment	Sawdust	Sand	Mulch	*Balsamorhiza sagittata*	*Achnatherum thurberianum*	*Dalea ornata*	*Penstemon acuminatus*	*Penstemon deustus*	*Heliomeris multiflora*	Average
						% emergence						
1	yes	yes	yes	no	no	57.5	48.2	1.6	38.3	32.1	35.5	35.5
2	yes	yes	no	no	no	57.7	36.6	0.7	38.8	46.5	30.5	35.1
3	yes	no	yes	no	no	63.9	36.0	0.0	24.1	15.3	31.6	28.5
4	no	yes	yes	no	no	37.9	26.0	0.8	26.4	14.7	17.6	20.6
5	yes	yes	yes	yes	no	69.6	42.1	0.1	48.8	31.3	43.6	39.3
6	no	yes	no	no	yes	48.6	27.9	1.1	19.5	20.0	22.3	23.2
7	no	no	no	no	no	33.7	24.1	1.6	17.7	5.7	9.6	15.4
Average						52.7	34.4	0.9	30.5	23.7	27.2	28.2
LSD (0.05) Treatment												3.8
LSD (0.05) Species												3.6
LSD (0.05) Treatment X Species												9.6

Table 4. Plant stands of six native plant species on April 9, 2010 and May 13, 2011 in response to five treatments applied at planting in the fall of 2009 and 2010. Plant stands for each species was corrected to the percent of viable seed. *Dalea ornata* seed was acid scarified.

#	Row cover	Seed treatment	Sawdust	Sand	*Balsamorhiza sagittata*	*Achnatherum thurberianum*	*Dalea ornata*	*Penstemon acuminatus*	*Penstemon deustus*	*Heliomeris multiflora*	Average
					% emergence						
					2010						
1	yes	yes	yes	no	60.0	44.3	9.6	19.6	32.3	26.0	35.5
2	yes	yes	no	no	49.6	41.9	9.8	18.8	49.1	23.4	34.8
3	yes	no	yes	no	66.7	54.3	3.2	26.4	43.8	39.2	44.4
4	no	yes	yes	no	25.5	41.2	5.0	18.1	17.1	10.9	20.7
5	yes	yes	yes	yes	59.3	47.2	13.9	22.5	29.8	22.3	37.4
Average					52.2	45.8	8.3	21.1	34.4	24.4	34.6
					2011						
1	yes	yes	yes	no	57.5	48.2	1.6	38.3	32.1	35.5	35.5
2	yes	yes	no	no	57.7	36.6	0.7	38.8	46.5	30.5	35.1
3	yes	no	yes	no	63.9	36.0	0.0	24.1	15.3	31.6	28.5
4	no	yes	yes	no	37.9	26.0	0.8	26.4	14.7	17.6	20.6
5	yes	yes	yes	yes	69.6	42.1	0.1	48.8	31.3	43.6	39.3
Average					52.7	34.4	0.9	30.5	23.7	27.2	31.8
					Average						
1	yes	yes	yes	no	58.8	46.3	5.6	29.0	32.2	30.7	35.5
2	yes	yes	no	no	53.7	39.2	5.2	28.8	47.8	26.9	34.9
3	yes	no	yes	no	65.3	45.1	1.6	25.3	29.6	35.4	37.1
4	no	yes	yes	no	31.7	33.6	2.9	22.3	15.9	14.2	20.6
5	yes	yes	yes	yes	64.4	44.7	7.0	35.6	30.6	33.0	38.2
Average					52.5	39.1	4.0	26.6	28.2	26.0	33.3
LSD (0.05)											
Treatment				4.1							
Species				3.2							
Treatment X Species				7.2							
Treatment X Year				3.5							
Treatment X Species X Year				8.5							

3. Legume Seed Scarification

Legumes can provide important roles 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, but especially for certain species. Rangeland legumes have been extremely difficult to establish.

In established native perennial fields at the Malheur Experiment Station and in rangelands we have observed prolific natural emergence from seed that falls on the soil surface and is covered by thin layers of organic debris. Seed of some legumes has a hard seed coat that slows germination. Scarification of the seed coat might improve water penetration and improve emergence. This trial tested the effect of seed scarification, row cover, and hydroseed mulch on germination of surface planted seed of three legume species that are native to Malheur County and surrounding rangelands (Table 1). Row cover can be a protective barrier against soil desiccation and bird damage. Hydroseeding mulch could be a low cost replacement for row cover.

Materials and Methods

Three species for which stand establishment has been problematic were chosen (Table 1). Seed of each species was scarified by immersion for 5 min in 98 percent sulfuric acid. All seed was treated with a liquid mix of the fungicides Ridomil MZ58 and Captan (100 g Ridomil, 100 g Captan in 1 liter of water). Seed weights of the scarified and non scarified seeds were determined after treatment. The seed weights were used to make seed packets containing approximately 300 seeds each. The seed packets were assigned to one of two treatments (Table 2). The trial was planted manually on November 3, 2010. The experimental design was a randomized complete block with six replicates. Plots were one 30-inch wide bed by 5 ft long. Two seed rows were planted on each bed.

Table 1. Seed weights for three native legume species submitted to emergence treatments in the fall of 2010.

Species and scarification	seeds/g
Dalea ornata (scarified)	273.2
Dalea ornata (non-scarified)	272.2
Astragalus filipes (scarified)	236.6
Astragalus filipes (non-scarified)	248.3
Dalea searlsiae (scarified)	321.4
Dalea searlsiae (non-scarified)	311.4

After planting, some of the beds were covered with row cover. The row cover (N-sulate, DeWitt Co., Inc., Sikeston, MO 63801) covered four rows (two beds) and was applied with a mechanical plastic mulch layer. For the hydroseeding mulch treatments, Hydroseeding mulch (Hydrostraw LLC, Manteno, IL) was applied dry at 7.5 g/foot of row in a 3 cm band over the seed row. The applied dry mulch was sprayed with water using a backpack sprayer to simulate hydroseeding.

On March 23, 2011, the row cover was removed and emergence counts were made in each plot. Emergence counts were again taken on May 13.

Tetrazolium tests were conducted to determine seed viability of each species. Seed viability was 89 percent for *Dalea ornata*, 84 percent for *Dalea searlsiae,* and 94 percent for *Astragalus filipes*. The tetrazolium results were used to correct the emergence data to emergence of viable seed.

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

Results and Discussion

Emergence for *Dalea ornata* was low for all treatments on both count dates (Tables 2 and 3). Averaged over treatments, non scarified *Dalea ornata* seed had higher stands than scarified seed on May 13. For *Dalea searlsiae* on March 23, the highest emergence resulted from planting non scarified seed with row cover. For *Dalea searlsiae* on May 13, the highest stands resulted from planting non scarified seed. *Dalea* spp. might establish better with scarified seed in a spring planting. This option was not tested. For *Astragalus filipes* on March 23, the highest emergence resulted from planting scarified seed with row cover. For *Astragalus filipes* on May 13, the highest stands resulted from planting scarified seed.

On March 23, for *Dalea searlsiae* and *Astragalus filipes*, row cover resulted in higher emergence than hydroseed mulch. The trend was the same for *Dalea ornata*, but differences were not statistically different. By May 13, there was no statistically significant difference in stand between the row cover and hydroseed mulch.

Conclusions

- For *Dalea ornata* and *Dalea searlsiae,* seed scarification reduced emergence.
- For *Astragalus filipes,* seed scarification increased emergence.

Table 2. Emergence of three native legume species on March 23, 2011 in response to seed scarification and two treatments applied at planting in the fall of 2010. Emergence for each species was corrected to the percent emergence of viable seed.

	Dalea ornata			*Astragalus filipes*			*Dalea searlsiae*			Average		Avg.
Treatment	scarified	non scarified	avg.	scarified	non scarified	avg.	scarified	non scarified	avg.	scarified	non scarified	
	% emergence											
Row cover	5.1	7.1	6.1	88.3	25.5	56.9	8.4	18.3	13.3	33.9	16.9	25.4
Hydroseed mulch	0.0	0.0	0.0	43.2	13.8	28.5	0.0	1.0	0.5	14.4	4.9	9.7
Average	2.6	3.5	3.0	65.7	19.6	42.7	4.2	9.6	6.9	24.2	10.9	17.5
LSD (0.05)												
Treatment		5.1										
Species		4.8										
Scarification		2.5										
Treatment X Species		6.8										
Species X Scarification		4.4										
Trt X Species X Scarif.		6.2										

Table 3. Stand of three native legume species on May 13, 2011 in response to seed scarification and two treatments applied at planting in the fall of 2010. The stand for each species was corrected to the percent stand of viable seed.

	Dalea ornata			*Astragalus filipes*			*Dalea searlsiae*			Average		Avg.
Treatment	scarified	non scarified	avg.	scarified	non scarified	avg.	scarified	non scarified	avg.	scarified	non scarified	
	% stand											
Row cover	0.6	6.4	3.5	55.6	17.2	36.4	0.4	8.3	4.3	18.8	10.6	14.7
Hydroseed mulch	0.5	6.8	3.7	40.0	12.2	26.1	0.5	6.0	3.3	13.7	8.4	11.0
Average	0.6	6.6	3.6	47.8	14.7	31.3	0.4	7.2	3.8	16.3	9.5	12.9
LSD (0.05)												
Treatment		NS										
Species		5.4										
Scarification		3.2										
Treatment X Species		NS										
Species X Scarification		5.5										
Trt X Species X Scarif.		NS										

Publications:

Feibert, E.; Shock, C.C.; Saunders, L.; Parris, C.; Shaw, N. 2011. Challenges for Intermountain West native wildflower seed production and establishment. HortScience 46(9) (Supplement) 2011 ASHS Annual Conference, September 25- 28.

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http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Feibert, E. 2011. Oregon State University, Malheur Experiment Station Update. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22-23, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Native Perennial Research Field Day, OSU Malheur Experiment Station. 12 May 2011. Ontario, OR.

Summer Farm Festival and Annual Field Day, OSU Malheur Experiment Station. 13 July 2011. Ontario, OR.

Management Applications and Seed Production Guidelines:

Sub-surface Drip Irrigation for Native Forb Seed Production

2006 – 2011 Results

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

Species	Optimum amount of irrigation	Years to first seed set	Life span
	inches/season	from fall planting	years
Eriogonum umbellatum	0 in wet years, 7 to 8 in dry years	1	6+
Penstemon acuminatus	no response	1	3
Penstemon speciosus	0 in wet years, 4 in dry years	1	3
Lomatium dissectum	6	4	6+
Lomatium triternatum	4 to 8 depending on precipitation	2	6+
Lomatium grayi	0 in wet years, 7 to 8 in dry years	2	6+
Sphaeralcea parvifolia	no response	1	5+
S. grossulariifolia	no response	1	5+
Sphaeralcea coccinea	no response	1	5+

2011 New Plantings

Amount of irrigation water for maximum native wildflower seed yield

Species	Optimum amount of irrigation
	(inches/season)
Penstemon cyaneus[a]	no response
Penstemon pachyphyllus[a]	no response
Eriogonum heracleoides	no response
Dalea ornata	no response
Astragalus filipes	no response
Dalea searlsiae	0
Penstemon deustus	0
Cleome serrulata	8

[a] poor stand

Seeding Practices

Conclusions for fall planted seed of *Balsamorhiza sagittata*, *Achnatherum thurberianum*, *Dalea ornata*, *Penstemon acuminatus*, *Penstemon deustus*, *Heliomeris multiflora*:

- Row cover with seed treatment and sawdust improved emergence over no row cover with seed treatment and sawdust for all species except *Penstemon acuminatus*.
- Row cover with sawdust and seed treatment did not improve emergence over row cover without sawdust and with seed treatment for any species and reduced emergence for *Penstemon deustus*.
- The effect of systems with and without seed treatment on emergence differed by year. In 2010, a drier year, adding seed treatment to row cover and sawdust did not improve emergence for any species and reduced emergence for three species (*A. thurberianum, P., H. multiflora)*. In 2011, a wetter year, adding seed treatment to row cover and sawdust improved emergence for three species (*A. thurberianum, Penstemon acuminatus, Penstemon deustus)*.
- Adding sand to row cover, seed treatment and sawdust did not improve emergence for any species.

Legume Seed Scarification

Conclusions for fall planted seed:

- For *Dalea ornata* and *Dalea searlsiae*, seed scarification reduced emergence.
- For *Astragalus filipes*, seed scarification increased emergence.

Products:

- Seed produced from these planting was used to establish commercial seed production fields.
- A field tour for growers was conducted in May 2011.
- A tour of the seed production trials was incorporated into the annual Malheur Experiment Station Field Day activities in July of 2011.
- Three research reports on seed production of native perennials were published in Annual Experiment Station Bulletin.

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

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

Principal Investigators and Contact Information:

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Project Description:

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

Significance:

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

Project status

Several diseases (leaf spots, blights, rusts, wilts and powdery mildews) were recorded on forbs (Table 1). Arid conditions prevailing in the Pacific Northwest are favorable for powdery mildew disease cycle.

Publications:

Sampangi, R.; Mohan, K.; Shock, C. 2011. Etiology, epidemiology and management of diseases of native wildflower seed production. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 129-130.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Presentations:

Sampangi, R.; Mohan, K.; Shock, C. 2011. Diseases of native plants. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22-23, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Sampangi, R. 2011. Diseases of native plants. Oregon State University Maheur Agricultural Experiment Station: Native Plant Seed Production Field Day, 2011 May 12, Ontario, OR.

Table 1. Native flowering plants and associated diseases observed in Idaho and Oregon.

Host	Diseases		
Globemallows			
Sphaeralcea grossularifolia	Powdery mildew	Rust	
S. parviflora	*Leveillula taurica*	*Puccinia sherardiana*	
S. coccinea			
Biscuitroot	Powdery mildew	Rust	Leaf spot
Lomatium dissectum	*Leveillula taurica*	*Puccinia jonesii*	*Alternaria* spp.
L. grayi	Bacterial blight - *Pseudomonas syringae PV.*		
L. triternatum			
Penstemon	Powdery mildew	Rust	Leaf spot
Penstemon acuminatus	*Leveillula taurica*	*Puccinia* spp.	*Phoma* spp.
P. deustus			
P. pachphyllus	Downy mildew	Red ring and leaf	Cuc mosaic
P. speciosus	*Peronospora* spp.	spot disease (virus)	Virus
P. cyaneus			
Blue flax and Lewis flax	Rust		
Linum perenne	*Melampsora lini*		
L. lewisii			
Arrowleaf balsamroot	Rust		
Balsamorhiza sagittata	*Puccinia balsamorhizae*		
Basalt milkvetch	Powdery mildew		
Astralagus filipes	*Leveillula taurica*		
Bee plant	Powdery mildew	Wilt	
Cleome lutea	*Leveillula taurica*	*Fusarium* spp.	
C. serrulata			
Sulfur-flower buckwheat	Powdery mildew	Rust	
Eriogonum umbellatum	*Leveillula taurica*	*Uromyces* spp.	
Eriogonum heracleiodes			
Prairie clover	Powdery mildew		
Dalea searlsiae	*Leveillula taurica*		
Dalea ornata			
Corn lily	Leaf spot and blight		
Veratrum californicum	*Phyllosticta* spp.		
Thurber's needlegrass	Wilt		
Achnatherum thurberianum	*Fusarium* spp.		

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

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

Principle Investigators and Contact Information:

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

A synopsis of the Stock Seed Buy-Back Program follows, applicable to the period Jan. 1, 2011-Dec. 31, 2011.

This program encourages and allows seed growers to benefit economically in a timely manner as an incentive to participate in the UCIA Stock Seed Buy-back Program. The program helps accelerate the increase in stock seed supplies and ultimately increase seed supplies on the open market for commercial revegetation use.

The objectives of the UCIA Stock Seed Buy-back Program, funded through the GBNPSIP, is to: a) facilitate development of a seed market for specific germplasm accessions, pooled accessions, and/or formal germplasm releases developed through GBNPSIP; b) reward initial seed growers financially for the risks they have assumed to participate in the program; c) document germplasm identity through the seed increase process by utilizing seed certification protocols; and d) increase stock seed available for potential secondary seed growers. This program is administered through the Utah Crop Improvement Association, 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 (see Appendix 1). 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. and Bouck, M. 2011. Stock seed production of native plants for the Great Basin. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 131-135. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Presentations:

Young, S. 2011. Striking a balance of diversity and practicality for germplasm increase. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011, February 22-23, Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Young, S. and Payne, R. 2011. Seed testing and controls. ASTA-NRCS Conservation Seed Workshop, 2011, April 5, Washington, DC.

Young, S. 2011. Knowing what you have by understanding seed labels: Genetic identity and mechanical quality of reclamation seeds. Native Seed Production for Restoration, Hedgerow, and Cover Crops within Southern California Ecoregions, NRCS-USDA-FS, 2011, September 20-21, Redlands, CA.

Young, S. 2011. History and utility of AOSCA seed certification programs for varieties and pre-variety germplasm. Native Seed Production for Restoration, Hedgerow, and Cover Crops within Southern California Ecoregions, NRCS-USDA-FS, 2011, September 20-21, Redlands, CA.

Management Applications:

For most of the species being studied by GBNPSIP cooperators, wildland seed collection is insufficient to provide for reclamation planting needs. Thus, accessions consisting of limited quantities of seed obtained from defined wildland stands, or pooled from defined geographic areas, must be increased in commercial fields or nurseries in order to be available in the marketplace in sufficient quantities to supply reclamation projects of the scope called for in the Great Basin.

The UCIA Buy-Back project provides a bridge between small-quantity initial accessions and commercial marketplace production, by working with specialized growers who are willing to provide land, time, and expertise to produce increased amounts of stock seed from the former, and with UCIA facilitation, makes it available for the latter.

This 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 6 grasses and 28 forbs that have been forwarded to growers under the auspices of the GBNPSIP, 2002-2011, are summarized in Table 1. Seed market production of each entry over the 10-year period is categorized in increments from 0 to 100,000+ lb. This table is instructive of the success of the GBNPSIP in seed market impact. Grasses are easier to produce, and are generally used in greater quantities than forbs in reclamation plantings. Many of the forbs have been more recently developed and made available to growers, and are thus in less supply in the marketplace.

Table 1. Seed market production of the Great Basin Native Plant Selection and Increase Project 2002-2011

Scientific Name	Common Name	Germplasm ID	Level III Ecoregion Source[1]	Development Status SI, S, T, V[2]	Pooled (P) Single (S)	Official Release Yes or No	Seed Market Production 10 year total lb.	Notes
GRASSES								
Achnatherum thuberianum	Thurber's needlegrass	Orchard	SRP	SI	S	No	100-1,000	Low seed producer – establishment difficult. Out of production.
Elymus elymoides	Bottlebrush squirreltail	Little Sahara	CBR	SI	S	No	10,000-100,000[3]	Commercially available
Elymus elymoides	Bottlebrush squirreltail	Toe Jam Creek	NBR	S	S	Yes	10,000-100,000	Commercially available
Elymus elymoides	Bottlebrush squirreltail	Fish Creek	NBR	S	S	Yes	10,000-100,000	Commercially available
Leymus cinereus	Basin wildrye	UDWR Intermountain Tetra	CBR/NBR	S	P	No	1,000-10,000	Commercially available
Poa secunda	Sandberg bluegrass	Mountain Home	SRP	S	S	Yes	10,000-100,000+	Commercially available
Pseudoroegneria spicata	Bluebunch wheatgrass	Anatone	CP	S	S	Yes	10,000-100,000+	Commercially available
FORBS								
Achillea millefolium occidentalis	Western yarrow	Eagle	SRP	S	S	Yes	10,000-100,000	Commercially available
Astragalus filipes	Basalt milkvetch	NBR 1	NBR	S	P	Yes	1-100	In production - 2011
Chaenactis douglasii	Douglas' dustymaiden	CHDO-NBR1-P01-RMRS	NBR	SI	S	No	1-100	In production - 2011
Dalea ornata	Western prairie clover	John Day	BM	SI	S	No	100-1,000	In production - 2009
Dalea ornata	Western prairie clover	Spectrum	NBR	S	S	Yes	1-100	In production - 2011
Dalea ornata	Western prairie clover	Majestic	NBR	S	S	Yes	1-100	In production - 2011
Dalea searlsiae	Searls' prairie clover	EK	CBR	SI	S	No	1-100	In production - 2011
Eriogonum heracleiodes	Wyeth's buckwheat	ERHE2-BP-NGB1-10	NBR/SRP	SI	P	No	1,000-10,000	Commercially available
Eriogonum umbellatum	Sulphur-flower buckwheat	ERUM-NGB-P01-RMRS	NBR/SRP	SI	P	No	1-100	In production - 2013
Eriogonum umbellatum	Sulphur-flower buckwheat	ERUM-NBR-P01-RMRS	NBR	SI	P	No	1-100	In production - 2012
Eriogonum umbellatum	Sulphur-flower buckwheat	ERUM-NBR-P02-RMRS	NBR	SI	P	No	0	In production - 2013
Hedysarum boreale	Utah sweetvetch	Timp	WUM	S	S	Yes	1,000-10,000	Commercially available
Linum lewsii	Lewis flax	Maple Grove	CBR/WUM	S	S	Yes	10,000-100,000	Commercially available
Linum lewisii	Lewis flax	Columbia	CP	SI	S	No	1,000-10,000	In production - 2010
Lomatium dissectum	Fernleaf biscuitroot	LODI-NBR	NBR	SI	P	No	1-100	In production - 2011
Lomatium grayi	Gray's biscuitroot	LOGR-Weiser-RMRS	SRP	SI	S	No	0	In production - 2012
Lomatium nudicaule	Barestem biscuitroot	LONU2-NBR-P01-RMRS	NBR	SI	P	No	0	In production - 2013
Lomatium triternatum	Nineleaf biscuitroot	LOTR2-NBR/BM-P01-RMRS	NBR/BM	SI	P	No	0	In production - 2012 or 2013
Lomatium triternatum	Nineleaf biscuitroot	LOTR2-Lakeview-RMRS	NBR/ECSF	SI	S	No	0	In production - 2012
Machaeranthera canescens	Hoary tansyaster	MACA-NGB-P01-RMRS	NBR/SRP	SI	P	No	1-100	In production - 2011
Penstemon acuminatus	Sharpleaf penstemon	PEAC-SRP-P01-RMRS	SRP	SI	P	No	0	In production - 2012
Penstemon cyaneus	Blue penstemon	PECY3-Little Wood-RMRS	SRP	SI	S	No	1,000-10,000	In production - 2006
Penstemon deustus	Scabland penstemon	PEDE4-Banks	IB	SI	S	No	100-1,000	In production - 2006
Penstemon speciosus	Royal penstemon	PESP-SRP-P01-RMRS	SRP	SI	P	No	1-100	In production - 2011
Penstemon speciosus	Royal penstemon	PESP-NBR-P01-RMRS	NBR	SI	P	No	1-100	In production - 2011
Sphaeralcea coccineae	Scarlet globemallow	SPCO-Bonnevile Basin	CBR	SI	S	No	1-100	In production - 2011
Sphaeralcea grossulariifolia	Gooseberryleaf globemallow	SPGR2-Pioche	CBR	SI	P	No	100-1,000	In production - 2011
Sphaeralcea munroana	Munro's globemallow	SPMU2-Sand Hollow-RMRS	SRP	SI	S	No	1-100	In production - 2011

[1] CBR = Central Basin and Range, CP = Columbia Plateau, BM = Blue Mountains, ECSF = Eastern Cascades Slopes and Foothills, IB = Idaho Batholith, NBR = Northern Basin and Range, SRP = Snake River Plain, WUM = Wasatch/Uintah Mountains

[2] SI = source identified, S = selected, T = tested, V = variety

[3] Approximately 900 lbs. field produced, other seed wild collected

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

Project Location: Eastern Oregon Stewardship Services, Prineville, Oregon

Principal Investigator and Contact Information:

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Project Description:

Objectives

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

Methods

Native seed farms growing forbs for the GBNPSIP in the Columbia Basin were visited and fields were monitored. If needed seed stocks from the Great Basin were not immediately available, we spent the 2011 field season collecting larger quantities of seed to transfer to growers. We collected research seed for the GBNPSIP and ARS in Pullman.

Results

Three native seed farms in the Columbia Basin of Washington were visited in 2011. Fields at L&H were not yet planted with species provide by GBNPSIP in 2010. Growers were concerned about finding markets for the forb species they were already growing. Only Benson farm was interested in expanding forb fields. Twenty-seven seed lots from 13 species were collected by EOSS for GBNPSIP growers (Table 1). Thirty-two research collections from three species were made for ARS in Pullman (Table 2).

Publications:

Tischew, S.; Youtie, B.; Kirmer, A.; Shaw, N.L. 2011. Farming for restoration: Building bridges for native seed. Ecological Restoration. 29:219-222. http://www.treesearch.fs.fed.us/pubs/39204

Youtie, B. 2011. Coordination of GBNPSIP plant materials development, seed increase and use. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 136-140. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Presentations:
Youtie, Berta. Coordination of GBNPSIP plant materials development, seed increase and use. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22- 23, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Youtie, Berta. A seed collector's odyssey. Oregon State University, Malheur Experiment Station, Native Plant Seed Production Field Day, 2011 May 12, Ontario, OR.

Management Applications:
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.

Products:
Table 1. Forb species collected in 2011 for GBNPSIP

Scientific name	*Common name*
Grayia spinosa	spiny hopsage
Cleome lutea	yellow beeplant
Dalea ornata	Western prairie clover
Eriophylum lanatum	Oregon sunshine
Lomatium dissectum	fernleaf biscuitroot
Lomatium triternatum	nineleaf desert parsley
Machaeranthera canescens	hoary aster
Mentzelia albicaulis	blazing star
Penstemon speciosus	royal penstemon
Phacelia hastata	silverleaf phacelia
Phacelia linearis	threadleaf phacelia
Sporobolus cryptandrus	Sand dropseed
Sphaeralcea munroana	Munro globemallow

Table 2. Research collections (R) and bulk seed lots collected in the 2011 field season by Eastern Oregon Stewardship Services.

Site Number	*Site Details*	*Collection Date*	*No. of Plants*
CHDO1BY11-R	Burnt River Canyon	7/3/11	30
CHDO1BY11M-R	Pueblo Slough, Denio	6/16/11	38
CHDO1BY11S-R	Crowley Rd	7/6/11	29

Site Number	*Site Details*	*Collection Date*	*No. of Plants*
CHDO2BY11M-R	Hwy 140, NV	6/17/11	30
CHDO2BY11-R	Hells Canyon, Idaho	7/4/11	35
CHDO3BY11-R	Hwy 26 Rock Ck, Grant Co.	7/6/11	45
CHDO3BY11S-R	Owyhee Dam	7/11/11	30
CHDO4BY11-R	Silvies Valley	7/28/11	60
CHDO4BY11S-R	Dry Creek Crowley	7/24/11	29
CHDO5BY11-R	Between Shaniko & Antelope	8/7/11	30
CHDO6BY11S-R	Pine Cr RD, Boise Co., Idaho	9/18/11	30
CHDO2BY11S-R	Snake River RD near Huntington	7/10/11	26
CLLU1BY10	S. of Adrian, Malheur Co.	6/29&7/23/11	300
CLLU2BY10	Mikey Hot Springs, Harney Co.	8/8/11	60
DAOR1BY11	Adrian	7/17/11	40
GRSP1BY11S	Overstreet	6/30/11	50
GRSP2BY11S	Crowley RD	7/6/11	50
ERLA1BY11S	Crowley Rd	7/24/11	50
ERUM1BY11S-R	Snake River Rd out of Huntington	8/15/11	29
ERUM2BY11-R	Hells Canyon, Idaho	8/15/11	30
ERUM3BY11-R	Fields Peak, Grant Co.	8/22/11	29
ERUM4BY11-R	Shevlin Park, Bend	8/24/11	29
ERUM5BY11-R	Hwy 20 Glass Buttes MP81-82	8/24/11	29
ERUM6BY11-R	Hwy 26 between Redmond & Sisters	8/25/11	35
ERUM7BY11-R	Hwy 26 Ochoco NF	8/30/11	29
ERUM8BY11-R	Malheur NF Long Ck	8/31/11	29
ERUM9BY11-R	Hwy 395 Silvies Valley	8/31/11	30
ERUM10BY11-R	Steens Mt Summit Trailhead	9/1/11	29
ERUM3BY11S-R	Jack's Corral east of McDermitt	9/3/11	30
ERUM4BY11S-R	Castle Rock	9/6/11	30
ERUM5BY11S-R	Hwy 21 below Wilderness Ranch Idaho	9/17/11	29
ERUM6BY11S-R	Pine Creek RD, Boise Co., Idaho	9/18/11	29
LODI1BY11	Owyhee Dam	6/17/11	100
LODI2BY11	Holliday Road, Vale	6/22/11	400
LODI3BY11	Burnt River Canyon	7/3/11	25
LOTR1BY11S	Crowley Road	7/2&6/11	1000
MACA1ABY09	Wrights Point, Harney Co.	10/9/11	100

Site Number	*Site Details*	*Collection Date*	*No. of Plants*
MACA1BY11-R	Hwy 20 East of Glass Buttes	9/9/11	29
MACA2BY11-R	Hwy 27 3.5 mi north of Hwy 20	9/9/11	35
MACA3BY11-R	Prineville	9/17/11	29
MACA1BY10-R	Walgreen's Ontario	10/13/11	29
MACA1BY10	Walgreen's Ontario	10/13&15/11	250
MACA2BY11S-R	Adrian	10/7/11	29
MACA2BY11S	Adrian	10/14&15/11	500
MACA4BY11S-R	Pine Creek Ranch	10/2/11	29
MEAL1BY11S	Chukar Park below Beulah Reservoir	9/16/11	50
PESP1BY08	Wright's Point	8/22/11	50
PESP1BY11S	Hwy 20 west. of Harper	7/24/11	25
PESP2BY11S	Crowley RD	7/24/11	200
PSSP3BY11S	Owyhee Dam Rd	7/23/11	60
PHHA1BY10	Owyhee Dam	7/10/11	200
PHHA2BY10	Leslie Gulch	7/17/11	100
PHHA4BY10	Hwy 20 MP156	7/20/11	50
PHHA5BY10	Drewsey, Otis Valley	7/20/11	50
PHLI4BY10	Exclosure powerline Harney Co.	7/30/11	150
SPCR1BY11S	Owyhee Dam RD	7/3/11	250
SPMU1BY10	Overstreet	7/9/11	300
SPMU2BY10	Owyhee Dam Rd	7/11/11	50
SPMU3BY10	Succor Creek Road near 201	7/3-5/11	1000

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

Project Location: Brigham Young University, Provo, Utah
USFS Rocky Mountain Research Station, Shrub Science Laboratory, Provo, Utah

Principle Investigator and Contact Information:

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Project Description:
Seed harvesting has become an important aspect of restoration of public lands and increasing seed production of native shrubs would be beneficial. There is a crucial need for large volumes of sagebrush seed of higher quality for use in rehabilitation projects (Beetle and Young 1965). By removing neighboring plants, there is less competition for water for the remaining stand (Armstrong 2007). This study is designed to expand previous research by determining if thinning stands can improve seed yields in established native populations of Wyoming big sagebrush. The specific objective of this research is to determine if treated areas can increase seed yield over natural stands of sagebrush. Removal of competition between stands has been the best application for increasing seed yield. 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 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 (50 acres or larger), sagebrush stand uniformity, and sagebrush density. Both sites are in Utah; the first site is approximately 10 miles south of Scipio along the I-15 corridor. The second site is approximately 10 miles 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; 3) mechanical kill in 10-foot strips; 4) general chemical thinning; and 5) chemical kill in 10-foot strips. All treatments were established during the summer of 2010. Mechanical thinning and killing was accomplished with a Dixie harrow. General mechanical thinning was accomplished by pulling the Dixie harrow across the plot area (150 X 700 ft) once to thin the sagebrush. Ten-foot kill strips were created by pulling the Dixie harrow across the 10-foot strips three times. Each time the Dixie harrow was pulled in the opposite direction of the previous pass. Chemical thinning and kill treatments were accomplished with a foliar application of 2,4-D. General thinning was accomplished with a lower application rate and no oil adjuvants to increase chemical uptake. Ten-foot killing strips were treated with a higher rate of 2,4-D and an adjuvant oil was added. Control areas were left untouched. Seed production in the 2010 treatment areas was minimal due to the chemical and mechanical disturbances that occurred from the treatments; therefore data for 2010 was not analyzed.

2011 Results

Individual sagebrush, or portions of a sagebrush, which survived the treatments in 2010 produced seed during 2011. At the site near Scipio, there were significant differences (P=0.05) among treatments. Mechanically killing 10-foot strips significantly increased the amount of seed over general mechanical thinning, general chemical thinning, and chemical killing in strips (Fig. 1). Yields, however, were not significantly different than the control, which means it may not be worth the effort to eliminate the competing sagebrush if seed yields are not significantly increased. At Sahara, there were no significant differences among treatments. General mechanical thinning tended to have the highest seed yield while mechanical killing in strips tended to be the lowest. Observation of the treatment plots would have suggested otherwise, but in the end there is no difference from the control, which would suggest the effort and resources to eliminate the competing sagebrush may not be worth while for seed increase.

In our efforts to eliminate competition, we had hoped to thin (kill) 60-70% of the sagebrush. We were able to achieve this level with the general mechanical thinning, 75% at Scipio and 77% at Sahara (Fig. 2). However, the kill resulting from general chemical thinning was much lower than anticipated at 48% at both locations. Mechanically killed strips at Scipio had the highest levels of killed sagebrush at 93%. These high kill rates may have influenced the level of seed production since the competition was almost eliminated. Mechanically killed strips at Sahara were much lower than anticipated at 71%, the chemical kill strips were also lower than anticipated at 80% for Scipio and 62% for Sahara. It is possible that the height of sagebrush, which forced us to raise the spray boom to approximately 4 feet, made it difficult for the spray to penetrate down and adequately cover all of the brush.

Plant understory was evaluated during 2011 and approximately 39 different species were identified. Those with the highest populations were cheatgrass (*Bromus tectorum*), bottlebrush squirreltail (*Elymus elymoides*), bulbous bluegrass (*Poa bulbosa*), Sandberg bluegrass (*Poa secunda*), western wheatgrass (*Pascopyrum smithii*), slender wheatgrass (*Elymus trachycaulus*), crested wheatgrass (*Agropyron cristatum*), *Lomatium*, prickly lettuce (*Lactuca serriola*), and longleaf phlox (*Phlox longifolia*). Cheatgrass had the highest frequency of all understory species at both locations. The cheatgrass populations in the disturbed areas where the treatments were applied were greater than in the control treatment. It might be recommended that areas treated to eliminate sagebrush be seeded with another plant(s) to minimize cheatgrass growth.

This is the first year that data could be collected. These two research sites need to be evaluated for several years because the elimination of competition and subsequent availability of resources, particularly water, is likely to manifest itself over time. It is anticipated that data will be collected at the Scipio and Sahara sites for several years and a better understanding of competition elimination and seed production will be gained.

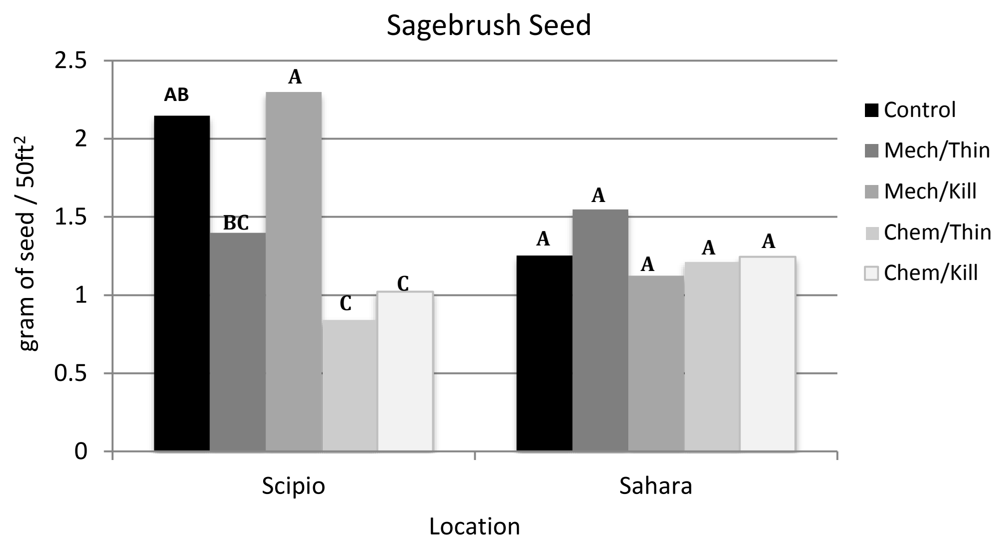

Figure 1. Seed produced in a 50 square foot plot for all treatments at Scipio and Sahara in 2011.

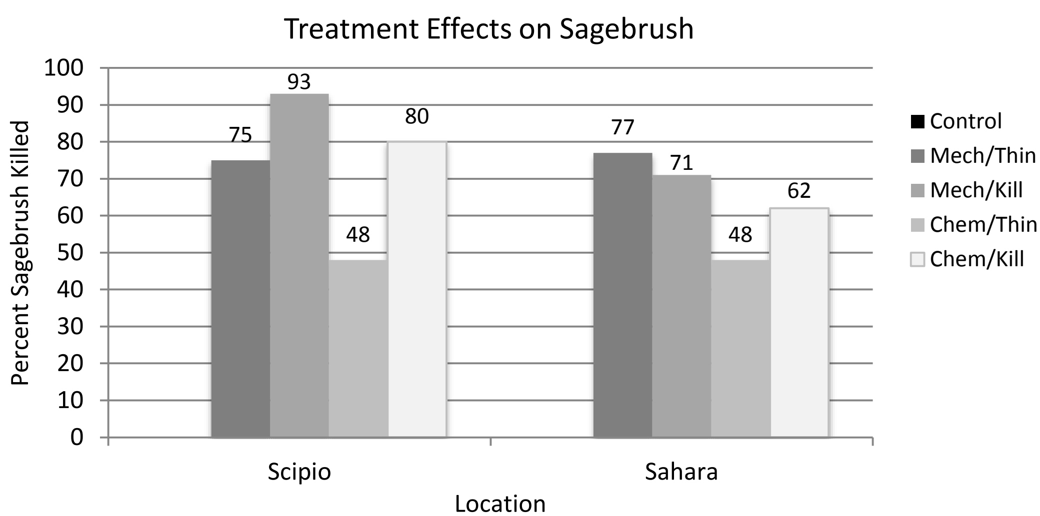

Figure 2. Percent kill of sagebrush for all treatments at Scipio and Sahara in 2011.

References:

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

Armstrong, J. 2007. Improving sustainable seed yield in Wyoming big sagebrush. Provo, UT: Brigham Young University. Thesis. 39 p.

Publications:

Geary, B. 2011. Cultural thinning of native sagebrush stands to increase seed yields. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 85-86. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Project Title: Insect Pests of Grass and Forb Seed Production

Project Location: Colorado State University Extension, Grand Junction, Colorado

Principal Investigator and Contact Information:

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Presentations:

Hammon, B. 2011. Stink Bugs: A seed production pest. Great Basin Native Plant Selection and Increase Project Annual meeting, 2011 February 22-23, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Hammon, R. 2011. Management of insects in seed production fields. Oregon State University Malheur Agricultural Experiment Station: Native Plant Seed Production Field Day, 2011 May 12, Ontario, OR.

Publications:

Hammon, R.; Franklin, M. (in prep). Insects affecting Fourwing saltbush. Colorado State University Technical Note. Grand Junction, CO: Colorado State University, Tri-River Area Extension.

Hammon, R.; Franklin, M. (in prep). Pests of Utah sweetvetch. Colorado State University Technical Note. Grand Junction, CO: Colorado State University, Tri-River Area Extension.

Hammon, R.; Franklin, M. (in prep). Insects affecting Mountain mahogany. Colorado State University Technical Note. Grand Junction, CO: Colorado State University, Tri-River Area Extension.

Hammon, R.; Franklin, M. (in prep). Insects affecting Penstemon seed production. Colorado State University Technical Note. Grand Junction, CO: Colorado State University, Tri-River Area Extension.

Hammon, R.; Franklin, M. (in prep). Managing Lygus in forb seed production. Colorado State University Technical Note. Grand Junction, CO: Colorado State University, Tri-River Area Extension.

Hammon, R.; Franklin, M. (in prep). Insects affecting Globemallow seed production. Colorado State University Technical Note. Grand Junction, CO: Colorado State University, Tri-River Area Extension.

Management Applications and Seed Production Guidelines:

Fact sheets will provide a guide for growers to monitor and manage pests affecting seed production of several forb and shrub species.

Project Title: Adaptation of Roundleaf Buffaloberry (*Shepherdia rotundifolia*) to Urban Landscapes

Project Location: University of Nevada Cooperative Extension, Reno, Nevada

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Project Description:
We study variation and diversity among intermountain western native plant species 1) to assure their stability and performance in home and commercial landscapes and 2) to assess their useful range for growers to establish a market for their stock. *Shepherdia rotundifolia* (roundleaf buffaloberry [Elaeagnaceae] is a Colorado Plateau endemic native to southern Utah and the Grand Canyon region of northern Arizona. The species is extremely drought tolerant and shows ornamental traits that make it an attractive candidate for use in urban home and commercial landscapes. The species attracts a variety of pollinators and other beneficial insects and is of value to wildlife as it provides food and cover for quail and small mammals. However, the species is difficult to keep alive in culture and is known to be short-lived in irrigated ornamental landscapes. *Shepherdia argentea* (silver buffaloberry) is widely distributed in riparian areas throughout the West and is common in naturalized designed landscapes in the Great Basin region. Its rangy appearance and thorny nature, however, render it less common for general ornamental use. With this project we characterize the natural habitat of *S. rotundifolia* in an effort to better understand its cultural requirements and report results of efforts to cross-hybridize with *S. argentea,* in hopes of creating an acceptable taxon for use in irrigated urban settings.

Objective
To characterize the natural habitat of *Shepherdia rotundifolia* and study its behavior in an irrigated setting to better understand its cultural requirements.

Methods

We characterized the edaphic, elevation, and light conditions experienced by *S. rotundifolia* at six representative sites in southern Utah. We also report 30-year historical weather patterns at the locations. We conducted common garden studies of *S. rotundifolia* using plants grown from seed collected at these sites to determine their physiological response to growth under irrigated landscape conditions. Finally, we performed reciprocal crosses of *S. rotundifolia* in the wild with its riparian relative, *S. argentea*, in an attempt to capture the aesthetic characters of *S. rotundifolia* and the tolerance to wet soils of *S. argentea*.

Results and Discussion

Elevation at the six sites ranges from 1500 to 2500 meters, and although the species tolerates drought, it can be found in areas with annual precipitation ranging from 200 to over 400 mm (Table 1). Once thought to be shade intolerant, we also found that plants in the highest elevation populations were mostly found beneath the canopy of ponderosa pine, the leaf litter of which also lowered the pH of the soils and increased their organic matter content (data not shown).

Cultural trials of *S. rotundifolia* grown from seed in pots and common garden studies of the transplants showed that the species does not acclimate easily to conventional horticultural conditions and develops chlorosis of older leaves after one year of growth. This could be due to irrigation or soil conditions of the managed landscape setting or it could be a result of nutrient excess or deficiencies. The potassium content of soils beneath the canopies of the species in its natural habitat was higher than that of typical urban soils (data not shown). The leaf symptoms of cultured plants were consistent with potassium deficiency, although this was not confirmed. Roundleaf buffaloberry is a nitrogen-fixing species and thrives in low-nitrogen environments; it is also possible that nitrogen levels of the soils in our common garden study were too high, which would discourage association of plant roots with symbiotic soil bacteria and potentially weaken plants.

Table 1. Site conditions characterizing *S. rotundifolia* populations studied. Average precipitation, maximum and minimum temperatures over a 30-year record at each site were obtained from existing weather stations closest to the sites.

		Average over 30 years (1981-2010)			
Population	Elevation (m)	Precipitation (mm/year)	Tmax °C	Tmin °C	Relative Light Intensity (%)
Tor-2500	2507	285	17	3	31
Tor-2300	2295	285	17	3	98
Tor-1600	1642	210	19	6	100
Natural Bridges	1342	327	17	4	99
Bluff	1342	199	17	4	94
Springdale	1188	409	25	9	88

We performed reciprocal crosses of *S. rotundifolia* with *S. argentea* and obtained a successful hybrid with intermediate leaf characters (Table 2). Hybrid plants grown from seed were transplanted in a common garden setting at Greenville Farm in North Logan, UT. Plant physiological response (stomatal conductance and photosynthetic light response) indicated that the hybrid exhibits a physiological response more similar to *S. argentea*, a riparian species, than to *S. rotundifolia*. These data suggest that, while the hybrid retains some of the aesthetic appeal of *S. rotundifolia*, it may demonstrate a greater tolerance to regularly irrigated soils, a condition common in ornamental landscapes. Further study of physiological responses of the hybrid to drought conditions will better characterize optimal cultural requirements in managed settings.

Table 2. Leaf morphological characteristics of *Shepherdia rotundifolia*, *S. rotundifolia x argentea*, and *S. argentea* grown from seed in pots (N=2).

	Species		
Morphology	*S. rotundifolia*	*S. rotundifolia x argentea*	*S. argentea*
Petiole length (mm)	5.3	10.5	7.0
Leaf length (mm)	24.0	39.3	42.5
Leaf width (mm)	23.0	24.5	12.7
Leaf length/width (mm)	1.0	1.6	3.4

<u>Conclusion</u>
The interspecific hybrid between *S. rotundifolia* and *S. argentea* may be better adapted to and more acceptable in urban landscapes than either species alone.

Publications:

Kratsch, H.; Sriladda, C. 2011. Morphological and genetic variation among common Utah globemallows. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 28-31.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Sriladda, C. 2011. Ecophysiology and genetic variation in domestication of *Sphaeralcea* and *Shepherdia* species for the Intermountain West. Logan, UT: Utah State University. Dissertation.
http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=2027&context=etd

Presentations:

Kratsch, H.; Sriladda, C. 2011. Morphological and genetic variation among common Utah globemallows. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22- 23, Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Kratsch, H.; Sriladda, C.; Kjelgren, R. 2011. *Shepherdia rotundifolia*: Preserving the species through urban landscape use. WERA1013: Intermountain Regional Evaluation and Introduction of Native Plants. 2011 October 8, Fort Collins, CO.

Management Applications:
A better understanding of the ecophysiology of *Shepherdia rotundifolia* will enable greater adoption of native plants in urban landscapes and will diversify such landscapes and provide pollinator and wildlife habitat. Anecdotally, this species also appears to be declining in its native habitat; preserving its genetic resources by adapting it for urban landscape use may be of benefit for its long-term survival.

Products:

- A list of intermountain regional native plant growers has been revised and sent to the WERA 1013 Intermountain Regional Evaluation and Introduction of Native Plants. http://www.uwyo.edu/wera1013/

- Kratsch, H. 2011. Some good native plants for Great Basin landscapes. University of Nevada Cooperative Extension Special Publication 11-13. http://www.unce.unr.edu/publications/files/ho/2011/sp1113.pdf

- A Master Gardener Native Plants Club has been established at the University of Nevada Cooperative Extension, including 30 Master Gardener volunteers from three counties in the Western Region of Nevada. Their goals are to select candidate species and to propagate and grow them for demonstration gardens around the region. Two gardens are currently in progress, one in Reno and one in Gardnerville. Fact sheet development and public education events are also goals of this group.

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

Project Location: University of Nevada, Reno, Nevada
USDA Agricultural Research Service, Reno, Nevada

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Project Description:

<u>Background</u>

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 *Bromus tectorum.* Greater restoration success may be achieved with seed mixes that mimic natural succession in Great Basin systems, which includes native annuals as a key component of the post-disturbance community. 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.

<u>Objectives</u>

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

Methods

In greenhouse and field experiments, seedlings of the native perennial grass, *Elymus multisetus*, were grown individually with native annual forbs (*Amsinckia tessellata*, *A. intermedia*, *Mentzelia veatchiana*, *Blepharipappus scaber,* and *Descurania pinnata*) or an annual forb mix (*A. tessellata*, *M. veatcheana*, *Cryptantha pterocarya*, and *Eriastrum sparsiflorum*). Half of the replicates were grown with competition from *B. tectorum.* We recorded the number of green leaves on *E. multisetus* plants at three separate times after planting to assess treatment effects on growth rate, and measured aboveground biomass of *E. multisetus* and competitors after one growing season. Additionally, *B. tectorum* was grown with native annuals in the greenhouse and field to determine the effect of native annual forbs on *B. tectorum* biomass and seed production. Structural equation modeling (SEM) was also used to examine the direct and indirect effects of native annual forbs on *E. multisetus* performance under greenhouse and field conditions.

Results

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

We used SEM to differentiate the role of direct and indirect effects of native annual forbs on *E. multisetus* performance. The direction and magnitude of these effects depended upon the annual forb and performance measure examined, and mirrored those observed in both the greenhouse and field experiments. With the exception of *A. intermedia*, both direct and indirect effects of native annual forbs on *E. multisetus* growth rate were positive, whereas effects on biomass were mostly negative. Thus, despite our prediction that the presence of native annual forbs would provide strong indirect facilitation, high variability in response among the different forb species and small sample sizes resulted in non-significant models.

Conclusions

The results of our greenhouse and field experiments support the idea that the presence of certain native annual forbs can enhance the establishment of *E. multisetus* in *B. tectorum* invaded rangelands. Native annual forbs are often overlooked as restoration materials, in part because they are weedy, ruderal species. However, these same characteristics are what may result in pre-emption of space and resources that result in reduced recruitment of exotic species like *B. tectorum*. 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. Unlike introduced annuals, native annual forbs are only a step in the successional pathway and 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 further native annual forbs so that recommendations can be made to seed growers and land managers regarding which species to invest in.

Publications:

A manuscript entitled 'Native annual forbs reduce *Bromus tectorum* biomass and indirectly facilitate establishment of a native perennial grass' has been submitted to Ecological Applications.

Leger, E.; Goergen, E.; Espeland, E. 2011. Evolution of native plants in cheatgrass invaded systems. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 144-146. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Forbis, T.; Leger, E.; Goergen, E. 2011. The role of native annual forbs in the restoration of invaded rangelands. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 141-143. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Presentations:

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

Goergen, E.; Leger, E.A.; Forbis, T. 2011. The role of native annual forbs in the restoration of invaded rangelands. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22- 23, Salt Lake City, UT http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Goergen, E.; Leger, E.A.; Forbis, T. 2011. Restoration of invaded rangelands. "Chin-wagging and Wine Discussion Series" sponsored by the Galena Creek Visitor Center.

Goergen, E.; Leger, E.A.; Forbis, T. 2011. The role of native annual forbs in the restoration of invaded rangelands. Intermountain Native Plant Symposium, Boise State University, Boise, ID.

Goergen, E.; Leger, E.A.; Forbis, T. 2011. The role of native annual forbs in the restoration of invaded rangelands. 10th Biennial Conference of Research on the Colorado Plateau, Flagstaff, AZ.

Management Applications and Seed Production Guidelines:

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

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

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

Project Location: University of Nevada Cooperative Extension, Elko, Nevada

Principle Investigator and Contact Information:

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Project Description:

Objectives of this research include:

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

<u>Methods</u>

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

Crested Wheatgrass Control and Revegetation Treatments

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

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

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

Treatment Implementation

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

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 ®); (3) glyphosate (Roundup ®) full rate; (4) glyphosate half-rate; and (5) 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.

Preliminary Results

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

2009

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

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

2010

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

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

2011

Data analysis is currently in progress for data collected in 2011. We noted an obvious increase in exotic annual forbs during the 2011 growing season, especially tansy mustard (*Sisymbrium altissimum*).

<u>Plans for 2012</u>

During 2012, we will continue to collect vegetation data, as described above, for both treatment trials (fourth-year data for first trial, second-year data for second trial). Data will be analyzed using mixed model analysis, with blocks and years considered random and other treatments considered fixed.

Publications:

McAdoo, J.K. 2011. Evaluating strategies for increasing plant diversity in crested wheatgrass seedings. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 147-152.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Presentations:

McAdoo, K.; Swanson, J.; Shaw, N. 2011. Facilitated succession to diversify crested wheatgrass seedings in Northeastern Nevada. Winter Meeting, Nevada Chapter of the Wildlife Society, 2011 January, Reno, NV.

McAdoo, K.; Swanson, J.; Shaw, N. 2011. Diversifying crested wheatgrass seedings in Northern Nevada. Society for Range Management Annual Meeting, 2011 January, Billings, MT.

McAdoo, K.; Swanson, J. 2011. Increasing plant diversity in Northern Nevada crested wheatgrass seedings. Great Basin Native Plant Selection and Increase Project Annual Meeting, February 22-23, Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Management Applications:
The relative success and/or failure of revegetation strategies and methodologies used in this research will be communicated in appropriate venues for the benefit of both public and private land managers and resource users. This research will add to the body of knowledge regarding the rehabilitation, functionality, and restoration of Great Basin rangelands.

Products:
Field Tour - We conducted a field tour on July 7, 2011 to look at results of applying crested wheatgrass reduction methodologies and seeding native species.

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

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

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

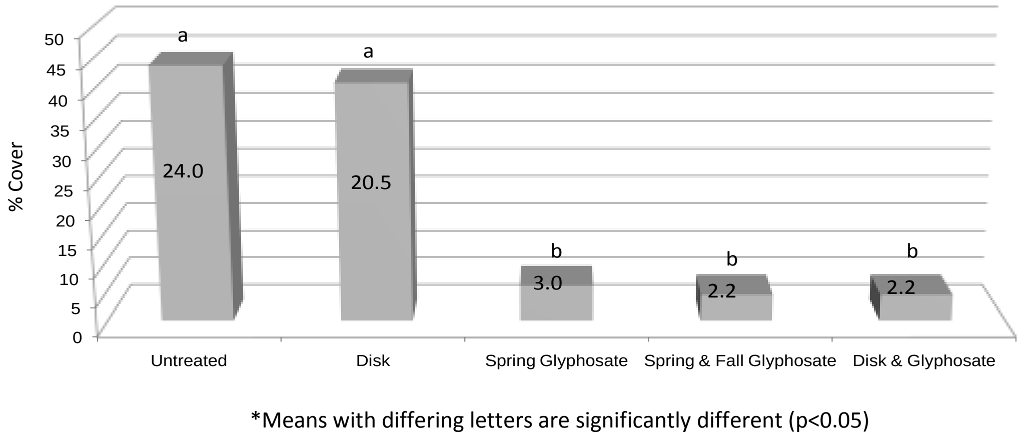


Figure 1. Effects of treatments on crested wheatgrass cover, 2009. *

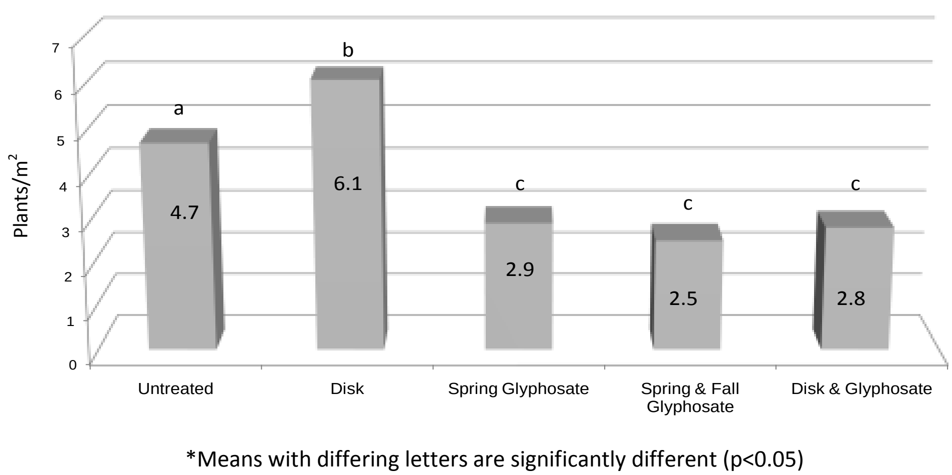


Figure 2. Effects of treatments on crested wheatgrass density, 2009. *

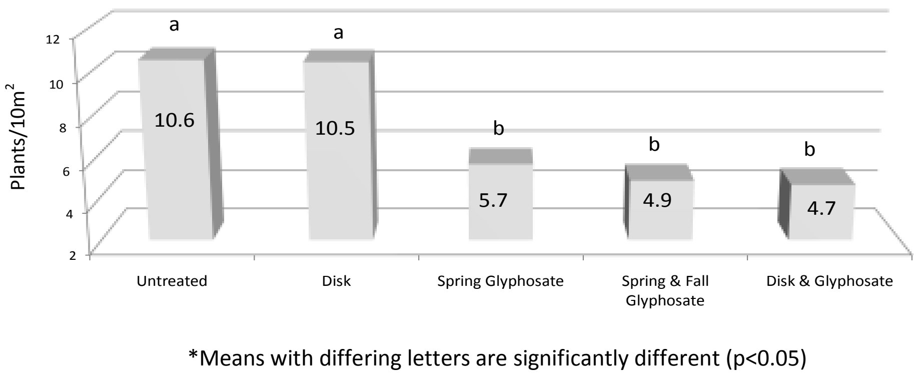


Figure 3. Effects of treatments on crested wheatgrass density, 2010. *

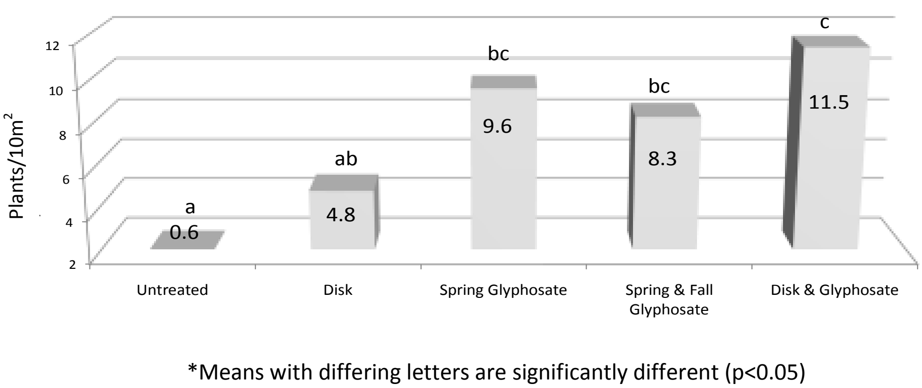
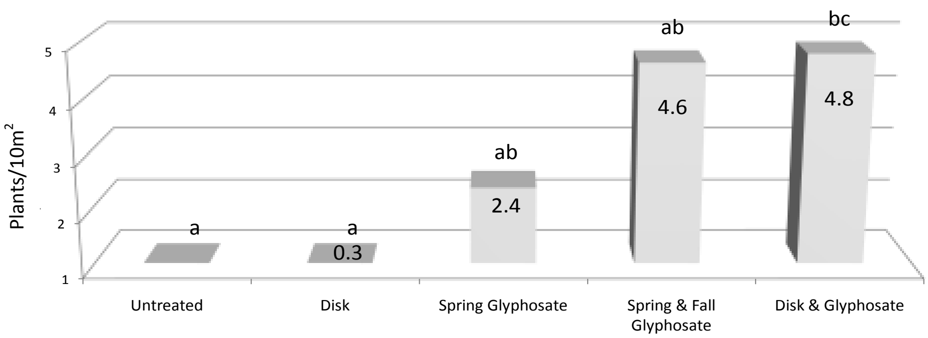
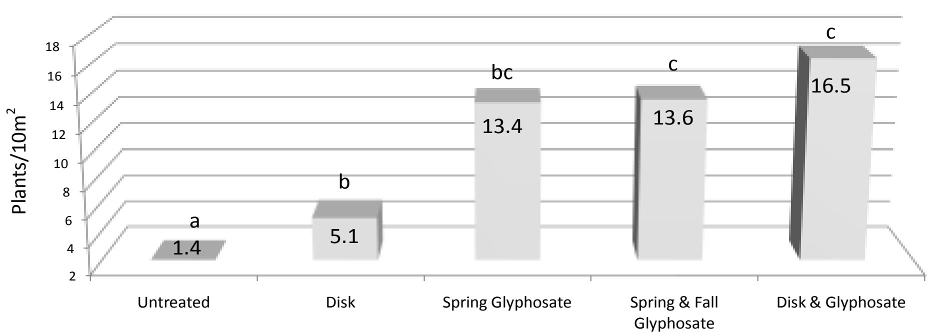


Figure 4. Effects of treatments on density of seeded native grasses, 2010. *



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

Figure 5. Effects of treatments on seeded forb densities, 2010. *



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

Figure 6. Effects of treatments on density of all seeded species, 2010. *

Project Title: The Ecology of Native Forb Establishment in Crested Wheatgrass Stands: A holistic approach

Project Location: USDA-ARS, Eastern Oregon Agricultural Research Center, Burns, Oregon

Principal Investigator and Contact Information:

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Project Description:

Objectives

Forbs are a critical functional component of sage steppe. However, forb seed can be expensive and previously funded research by GBNPSIP has shown that forb establishment rates are very low. While competition from crested wheatgrass and cheatgrass 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 control treatments can produce over a two-fold variation in crested wheatgrass density and cover, variation in crested wheatgrass abundance did not appear to influence forb establishment. The level of crested wheatgrass control and type of disturbance applied can influence cheatgrass invasion which, in turn, can influence forb establishment and survival. However a number of other factors, including planting depth, abiotic stress, safe site availability and seeding rate also may contribute to forb seeding failures. A holistic approach that examines multiple processes is needed to make large strides in improving forb restoration programs. Such an approach allows determination of the relative importance of multiple ecological processes for forb establishment. This information, in turn, can provide the scientific basis for improving native forb restoration programs and allocating limited restoration resources. The broad objective of this project is to identify the relative importance of biotic and abiotic controls on forb establishment.

Methods

This project involves two phases. The first phase was to assess general patterns of survival for seed of native grasses and forbs. The second phase 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 BLM seeded across four fire sites in eastern Oregon. 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.

The second phase, examining the ecological processes and conditions limiting forb establishment, was originally designed with a budget that would support manipulations at one site. However, with recent procurement of a larger NIFA funded project that examines in more detail the ecology of grass seedling establishment, this second phase has been modified to leverage this infrastructure and include more sites and conditions for the examination of forb recruitment. The core aspects of the initially proposed study design remain the same and include manipulation of cheatgrass and crested wheatgrass competition (two levels), disturbance (two levels) and seeding rate (four levels) in plots where monocultures of *Linum lewisii, Crepis* sp. and *Sphaeralcea munroana* are sown. Seeds will be sown in 2-m x 2-m plots in fall 2012 with five replications per treatment combination at two high and two low precipitation sites in Oregon. Germination bags will be pulled monthly through the fall, winter and spring to document timing, rate and magnitude of germination and plots will be monitored bi-weekly for emergence and survival during the first spring and then monthly through the second growing season.

2011 Results

Results for the first phase of this study show that across the four fire sites seeded by BLM, 60 to 80% of the forb and grass seed sown germinated, but at all four sites only 5 to 10% of the germinated seed emerged (Fig. 1). As a consequence of death during germination and prior to emergence, about 90% of the sown individuals died before emerging from the soil surface. Once seedlings of grasses and forbs emerged, survival probabilities through the first growing season and summer dry season were greater than 0.5. Because of the high initial mortality, however, final seedling establishment was low and less than 5 plants m^{-2} at two of the sites.

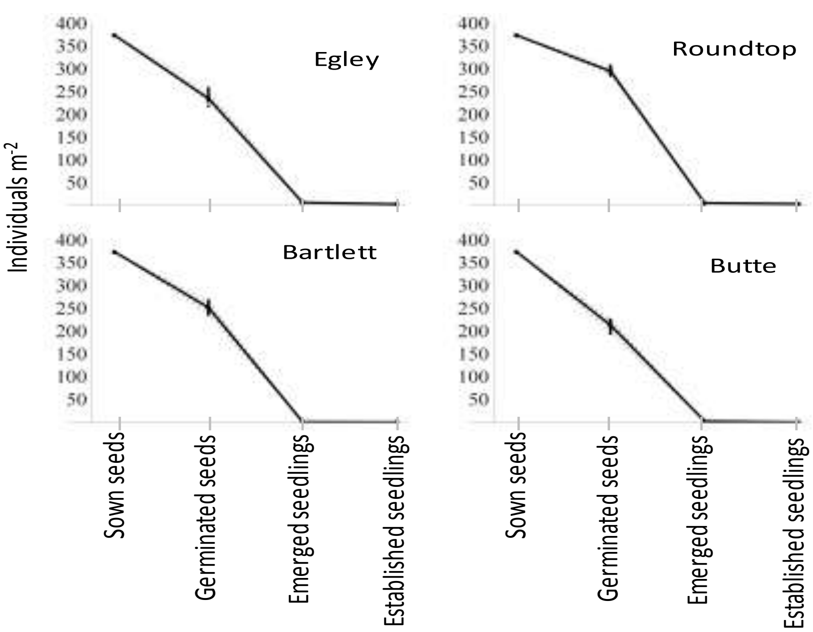

Figure 1. Numbers of seeded individuals surviving to various growth stages for forb and grass species mixtures sown by BLM following wildfires at four sites in eastern Oregon. Seeding rates were 376 seeds m^{-2}.

Future Plans

Phase two of this project, which includes the additional three sites leveraged off of the NIFA grass seedling grant, will be implemented at the same time the NIFA grass seedling study is initiated allowing statistical comparisons of demographic performance among both grasses and forbs. Sites have been selected and permitted through BLM. Sites will be fenced spring 2012 and seeded fall 2012. These plots will be followed at least 3 years, the duration of the NIFA grant.

Publications:

James, J.J.; Svejcar, T.; Rinella, M.J. 2011. Demographic processes limiting seedling recruitment in arid grassland restoration. Journal of Applied Ecology 48:961-969.

James, J.J.; Drenovsky, R.E.; Monaco, T.M.; Rinella, M.J. 2011. Managing soil nitrogen to restore annual grass-infested plant communities: Effective strategy or incomplete framework? Ecological Applications 21:490-502.

James, J.J.; Smith, B.S.; Vasquez, E.A.; Sheley, R.L. 2010. Principles for ecologically based invasive plant management. Invasive Plant Science and Management 3:229-239.

James, J.J.; Svejcar, T.J. 2010. Limitations to post-fire seedling establishment: The role of seeding technology, water availability, and invasive plant abundance. Rangeland Ecology and Management 63:491-495.

Presentations:

James, J.J. Managing demographic processes in rangeland restoration. Society for Ecological Restoration, 2011 August 21- 25, Mèrida, Mexico. (Invited)

James, J.J. Grass seedling demography and restoration. Oregon State University, Department of Forest Ecosystems and Society, 2011, Corvallis, OR. (Invited seminar)

James, J.J. The role of soil pathogens and soil physical properties in grassland restoration. Montana State University, 2011, Bozeman, MT. (Invited seminar)

Management Applications and Seed Production Guidelines:

Recruitment failures in rangeland restoration have been widely blamed on mortality during spring and summer drought or competition from weeds. These initial results strongly suggest most mortality may be concentrated very early in the life cycle of seedling development. Thus, management of ecological conditions during this time period may result in the greatest increase in seeded species establishment. Potential management strategies may include sowing seeds in winter or early spring if conditions allow and identifying and selecting plant materials with greater emergence probability. At the minimum these data suggests the relative importance of weeds and summer drought might be very low compared to other factors like winter time freeze thaw events and soil pathogens.

Products:

- Results from this project have provided some of the material for annual week-long workshops held through the USDA-ARS Area-wide program.
- Results provided some of the basis and rationale for the NIFA project (2011-38415-31158).
- Results also were used to organize a symposium at the 2010 SRM meeting in Billings, MT on seedling establishment.

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

Project Location: USDA Agricultural Research Service, Burns, Oregon

Principal Investigators and Contact Information:
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Project Description:

Objectives

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

Methods

In 1998, experimental plots were set up with known, even densities of crested wheatgrass and seven native perennial bunchgrasses. Since 1998, no management activities have occurred on these experimental plots. In 2011, we counted total density of perennial bunchgrasses by species in nine 312.5 m^2 plots. These plots are more than 8-fold larger than the plots we sampled in 2010 for preliminary analysis.

Results

Over a period of 13 years, crested wheatgrass density increased 12-fold and native grass densities for the most part either remained the same or decreased (Fig 1). Idaho fescue showed slight evidence of being able to increase when co-seeded with crested wheatgrass with a 1.5-fold increase ($p = 0.07$). Sampling a greater area reduced the apparent increase of crested wheatgrass relative to data collected in 2010 (where we saw a 40-fold increase). Three additional bunchgrass species were also able to recruit in very low numbers into the community.
The results of this study suggest that, when seeded together, crested wheatgrass is much better at recruiting new individuals into the plant community, and that while a few native perennial bunchgrasses are able to maintain presence, crested wheatgrass may be displacing most of the others. This suggests that, in the long term, even if crested wheatgrass stands are suppressed enough that native perennial bunchgrasses are able to establish, native bunchgrass species will not increase and crested wheatgrass will rapidly recover. However, this study did not address changes in forb and shrub composition over time and it is possible that reestablishment of shrubs and forbs may be more successful. The results of this study suggest caution when co-planting crested wheatgrass with native bunchgrass species if the expectation is that crested wheatgrass will serve as a bridge species to eliminate annual weeds while native bunchgrasses establish.

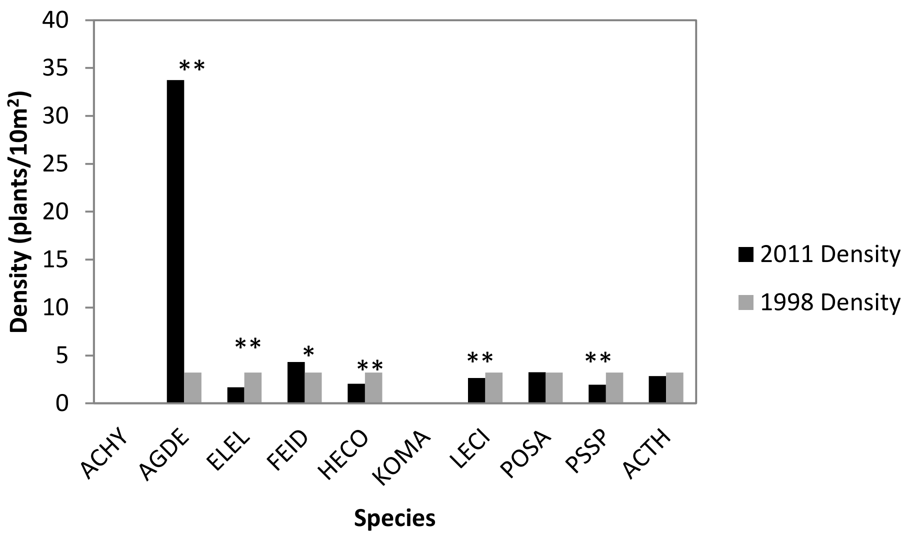

Figure 1. Density per 10 m^2 of crested wheatgrass (AGDE = crested wheatgrass) and each of seven planted native perennial bunchgrass species (PSSP = bluebunch wheatgrass; LECI = basin wildrye; FEID = Idaho fescue; ELEL = bottlebrush squirreltail; HECO = needle-and-thread grass; POSE = Sandberg bluegrass; ACTH = Thurber's needlegrass) and 2 perennial bunchgrass species that were able to recruit into the community (ACHY = Indian ricegrass, KOMA = Junegrass) **Indicates statistical difference at $P \leq 0.01$, *indicates statistical difference at $P < 0.1$.

Future Plans

In 2012 we will begin sampling 100 crested wheatgrass plant communities across the northern Great Basin to determine what factors promote native plant recruitment in crested wheatgrass plant communities. We have contacted private and public land managers to locate crested wheatgrass plant communities. Site, environmental, and management characteristics will be collected to determine their relationships with native plant recruitment into crested wheatgrass communities. A Ph.D. graduate student has been hired and we are recruiting four summer technicians to help her collect this data.

Publications:

Davies, K.; Nafus, A. 2011. Recruitment of native vegetation into crested wheatgrass seedings and the influence of crested wheatgrass on native vegetation. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 159-160. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Management Applications:

Results are still preliminary, but they do suggest that crested wheatgrass is better able to recruit new individuals into the plant community than native bunchgrasses. The ability of crested wheatgrass to increase, while native bunchgrasses densities remained the same or decreased should be considered before co-planting crested wheatgrass and native bunchgrasses or seeding crested wheatgrass into a native plant community.

Project Title: Revegetation Equipment Catalog Website Maintenance

Project Location: Texas Tech University, Lubbock, Texas

Principal Investigator and Contact Information:

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Texas Tech University
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Robert.Cox@ttu.edu

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" through "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 website will be fully transferred to Texas Tech, and the mirroring site at Texas A&M will be removed.

Publications:
Cox, Robert. 2011. Revegetation Equipment Catalog. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 161.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Shaw, N.; Cox, R.; Fisk, M.; Denney, E.; Gurr, J. 2011. Native plant selection, seed biology and seeding equipment and technology. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 173-183.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

The Revegetation Equipment Catalog may be accessed at:
http://reveg-catalog.tamu.edu/ or http://www.rw.ttu.edu/reveg-catalog/

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 they might use to implement 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 Location: Utah State University, Logan, Utah

Principal Investigator and Contact Information:

Corey Ransom, Assistant Professor
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Department of Plants, Soils, and Climate
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Logan, Utah 84322-4820
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corey.ransom@usu.edu

Project Description:

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

Materials and Methods

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

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

Nephi	
Basalt milkvetch	*Astragalus filipes*
Prairie clover	*Dalea ornata*
Searl's prairie clover	*Dalea searlsiae*
Sulfur flower buckwheat	*Eriogonum umbellatum*
Nevada goldeneye	*Heliomeris multiflorum* var. *nevadensis*
Silky lupine	*Lupinus sericeus*
Big blue penstemon	*Penstemon cyaneus*
Globemallow	*Sphaeralcea*
Big bluegrass ('Sherman")	*Poa secunda*
Bluebunch wheatgrass ('Anatone')	*Pseudoroegneria spicata*
Cache Junction	
Slender wheatgrass ('First Strike')	*Elymus trachycaulus*
Basin wildrye ('Magnar')	*Leymus cinereus*
Big bluegrass ('Sherman')	*Poa secunda*
Bluebunch wheatgrass (Anatone selected germplasm)	*Pseudoroegneria spicata*

Table 2. Herbicide rates.

Herbicide	Rate
	lb ai/A
Untreated	-
Plateau	0.0156
Plateau	0.0313
Plateau	0.0625
Plateau	0.094
Plateau	0.125
Plateau	0.156
Plateau	0.188
Olympus	0.0534
Outrider	0.047
Matrix	0.039
Oust	0.0703
LSD (0.05)	-

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

Results for 2011

In 2011, few plants remained at the Nephi research location and plots at that location were abandoned.

Additional efforts to establish *Astragalus filipes* and *Dalea ornata* in the greenhouse trials were unsuccessful. Based on field trials it appears that scarification and stratification will be required to achieve uniform *Astragalus filipes* germination, while scarification alone appears to greatly improve *Dalea ornata* germination.

Preliminary trials evaluating annual grass germination and growth in response to imazapic in petri-dish assays compared to trials conducted with soil filled pots shows that responses differ significantly between the two systems and that petri-dish assays will not likely be useful in predicting forb response to imazapic in the field.

<u>Direction for 2012</u>
In 2012, a new research location will be established near Logan, Utah and core treatments will be applied in the spring and the fall. Species will be planted in fall of 2012 at much higher rates than in previous trials and row covers will be utilized to increase plant establishment. It is noted that these conditions would not be present in most reclamation situations, but that failure to establish plants makes evaluation of their response to herbicides impossible. Work will continue with species in greenhouse trials. Soil sampling will be delayed until it can be done at the new site.

Publications:

Ransom, C.V. 2011. Evaluation of imazapic rates and forb planting times on native forb establishment. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 87-90.
http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Roerig, K. C.; Ransom, C. V. 2010. Searls' Prairie clover (*Dalea searlsie*) tolerance to post-emergence herbicide applications. Western Society of Weed Science Research Progress. Report. p 74.

Presentations:

Ransom, C.V.; Israilsen, K. Grass and forb seed production: Weed control and herbicide effects. Utah Crop Improvement Association, Seed School. 2008 February 19, Brigham City, Utah. 60 attendees.

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

Ransom, C.V. 2011. Forb response to herbicides for seed production and rangeland restoration. Great Basin Native Plant Selection and Increase Project Annual Meeting. 2011 February 22-23, Salt Lake City, UT.
http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

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

Project Location: Texas Tech University, Lubbock, Texas

Principal Investigator and Contact Information:

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Robert.Cox@ttu.edu

Project Description:
The first step is to conduct a wide screening for all known smoke effects through as many species as possible. The second step is to further test 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.

Publications:

Cox, R. 2011. Revegetation Equipment Catalog. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 161. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Shaw, N.; Cox, R.; Fisk, M.; Denney, E.; Gurr, J. 2011. Native Plant Selection, Seed Biology and Seeding Equipment and Technology. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 173-183. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

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. Re-establishing populations and seedbanks of these species will contribute to natural recovery following wildfire or other disturbance, provide bloom for pollinators, and reduce progress of exotic invasions.

Project Title: Pollination and Breeding Biology Studies

Project Location: USDA-ARS Bee Biology and Systematics Lab, Logan, Utah

Principal Investigator and Contact Information:

James H. Cane, Research Entomologist
USDA - ARS Bee Biology and Systematics Lab
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(435)797.3879, Fax (435)797.0461
Jim.Cane@ars.usda.gov

Project Description:

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

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

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

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

<u>Status Report</u>

Many ground-nesting wild bees are present and populous in the years after wildfires where the pre-existing flora was in good shape. My graduate student is moving into his analyses of our systematically sampled floral guilds of native bees, quantified bloom and wildflower communities taken from matched pairs of burned and neighboring unburned plots across a 15-year chronosequence of large (> 1000 acre) wildfires in sagebrush steppe and juniper woodlands in five states of the northern Great Basin and Columbia Plateau. We added the last sites this year from Elko County Nevada and adjacent Idaho. We have now sampled bees and flora in 33 site pairs in a chronosequence representing a span of from 1-15 years since the last large fire (>1000 acres). We focused on 3 species of *Balsamorhiza,* but also some *Lomatium*, *Sphaeralcea*, *Astraglus filipes*, and *Penstemon speciosus*. At *A. filipes*, for instance, we now have 32 quantitative surveys of bees from five states. Most all are ground-nesters and non-social. The forb communities are generally more plentiful and slightly more diverse in most of the fires than in the control sites.

For one case study, we netted bees at surviving sunflowers along gravel roadways traversing the 450 sq mile Long Butte fire west of Twin Falls, ID. Just 3 weeks after the fire, we found the same bee fauna at the same densities 3-7 miles into the burn as we found around the perimeter, all of them collecting pollen, indicative of continued active nesting by ground-nesting populations over which the fire had burned. The vast isolation distance precludes the possibility that the foraging bees were commuting from beyond the fire perimeter. It seems that what blooms the year after wildfire will be critical for feeding the diverse bee communities that survive wildfire in the sage-steppe and juniper woodlands.

Comparing methods to estimate forb densities.
At the Scooby Fire in ne Utah, we compared the measure for plant density that we adopted for our bee surveys in fires (an ordered distance measure) with a more traditional method using random small quadrats (data provided by collaborator Nancy Shaw). Basically, our method (developed by Morisita) took the distance from each of a series of random points along a transect line to the third nearest flowering forb. We used two forbs, globemallow and yarrow, that were seeded into the site after burning. We counted just flowering individuals, which were generally sparse. The Morisita method consistently calculated greater plant densities than did the quadrats, probably because of the sparsity of forbs in the plots for which the quadrats registered zeroes but Morisita always registered presence at some distance. I feel that the Morisita method is more realistic for more spaced plants, but the quadrats are perfect for densely growing items (such as grasses). Nested quadrats, though perhaps best, take vastly more time to implement.

Pollinators and breeding biologies of the forb Dusty Maiden, Chaenactis douglasii.
This is a widespread if inconspicuous short-lived perennial forb that flowers late in spring from the foothills to upper montane areas throughout the Intermountain West. It is proving practical to grow for seed and is expected to be used for western rangeland rehabilitation.

We manually pollinated some 4,000 flowers on plants seeded in our common garden, collected the achenes, and x-rayed them to check our visual scoring of endosperm fill as a measure of fertility. This plant grew well in cultivation, blooming the first year. This ability bodes well for adding it to seed mixes where it can feed resident bee communities in the year after a fire (as can *Helianthus, Eriophyllum* and even *Sphaeralcea*). Nearly every flower (avg. 46 per flower head) sets an achene (97%), but some of these lack endosperm.

Through manual pollination experiments, the species was found to be only weakly self-fertile. It is primarily xenogamous, with 57% of outcrossed flowers producing achenes filled with endosperm; every flower head yielded some fertile seeds. In contrast, only 15% of flowers yielded filled achenes resulting from our manual pollination with self-pollen or on flower heads left to autopollinate. Freely-visited flowers from a wild population produced 91% fertile achenes, indicating that seed production was not pollinator limited.

Most nests of the solitary cavity-nesting bee *Osmia californica* released at this sage-steppe site were provisioned with white composite pollen resembling *Chaenactis* pollen. The bee is a composite specialist known to pollinate and provision *Balsamorhiza* pollen and, from our 2 years of study with the NRCS-PMC in Corvallis, cultivated *Eriophyllum* too. Floral visitors systematically sampled at four wild sites consisted entirely of wild bees (three populations sampled in Utah and Idaho) that were typically sparse (one bee per 14 plants). Most individuals represented bee species that are floral generalists; the rest are broadly specialized on the Asteraceae. Museum specimens from *C. douglasii* at the Logan lab (taken mostly from southern Utah) comprise 175 native bee species representing 39 genera and all six North American bee families, none of them apparent specialists on *Chaenactis* alone.

Publications:

Cane, J.H. 2011. Meeting wild bees' needs on rangelands. Rangelands 33:27-32.

Cane, J.H. 2011. Pollinator and seed predator studies. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p 77-80. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

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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. (in press)

Swoboda, K.A.; Cane, J.H. 2011. Breeding biology and incremental benefits of outcrossing for the restoration wildflower, *Hedysarum boreale* Nutt. (Fabaceae). Plant Species Biology doi: 10.1111/j.1442-1984.2011.00339.x

Watrous, K.; Cane, J.H. 2011. Breeding biology of the threadstalk milkvetch, *Astragalus filipes* (Fabaceae), with a review of the genus. American Midland Naturalist 165:225-240.

Presentations:

Cane, J. Native wildflowers for native bees. Utah Native Plant Society, 2011 February 21, Richfield, UT. (Invited)

Cane, J. Bee communities and wildfire: thermal tolerances, soil heat conduction and nesting depths. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22-23, Salt Lake City, UT. (Invited) http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.shtml

Cane, J. On-farm needs and post-fire fates of bees that pollinate our restoration forbs. 2011 March 28-31, Boise, ID. (Invited)

Cane, J. Post-fire fates and on-farm use of wild bees for native forb seed production. 11th Biennial Conference on Research on the Colorado Plateau, 2011 October 23-27, Flagstaff, AZ. (Invited)

Management Applications:
Growers of *Chaenactis* for seed who do not plan for pollination will have poor seed production with a large yield of empty achenes that may be challenging to separate from good seed. Excellent seed sets are possible with bees. The native bees *Osmia california and O. montana* are suitable pollinators for the crop and are bees that we manage now. A number of unmanaged generalist bees appear to be suitable too, and at the Aberdeen PMC, honey bees were avidly visiting its flowers and should be effective pollinators.

Our bee samples at remnant bloom in the weeks after wildfire provide further evidence that wild bee faunas of the sage-steppe survive the heat and combustion of wildfire. The management question therefore changes from: “What will pollinate seeded perennial wildflowers far into a burn?” to “How do we provide suitable floral resources for bee communities in the year after fire, populations that will then pollinate perennials that flower in later years?”

Products:
Two *Osmia* bee species that effectively pollinate *Hedysarum* and *Astragalus* are increasing well for us, but we are having to explore new paper sources or paper coatings for their nesting tubes, as manufacturers are running out of the Sweetheart straw paper with no plans for replacement. We have begun testing these managed bees in several other climates (e.g. western Oregon, southwest Colorado, central California) where the species exists but climates are different. Our production of *O. sanrafaelae* for pollination of *Hedysarum* in western Wyoming was set back by a record late, cold wet spring; we now have less than the estimated 17000 individuals deployed. Another pair of species, *O. montana* and *O. californica*, pollinate balsamroots, *Eriophyllum* and *Chaenactis.* We manage them easily now, and they are available in the thousands as by-catch from businesses that are trap-nesting blue orchard bees from the wild. With a year’s advance notice, they can be provided to growers as needed.

Project Title: Development of Seeding Equipment for Establishing Diverse Native Communities

Project Location: Truax Company, Inc, New Hope, Minnesota

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Project Description:

The evolution of the Roughrider continued during 2011 and additional developments will evolve in the future. During the last year, effort was focused primarily on three areas: durability, shock absorption, and variable planting depth.

The Truax Roughrider drill frames have experienced premature failure when used on extremely rough sites and therefore effort has been put forward to reduce or prevent this breakdown. The weight, or mass, of the equipment is transferred to the planter units through a series of elastomer torsion knuckles that act as a shock absorber as the unit moves across rough sites. The individual torsion knuckles have a built in stroke control so as the drill moves the stroke control will limit the amount of rotation around the rock shaft and hence the vertical travel of the individual planter assemblies. Once the rock shaft was rotated by the hydraulic cylinder to the full down position the stroke control prevents the locked-in-place planters from coming up, without lifting the entire machine. This lack of free movement, in turn, resulted in frame failure. Research and design changes have shown that by changing the stroke control configuration it is possible to provide down forces on the planter assemblies, while at the same time allowing individual planters to flex upward without having to lift the entire machine mass.

A second area of consideration during the 2011 planting season was to investigate whether by changing the depth of seed placement there was a corresponding change in percent of germination or establishment success. The depth control gage wheels were removed from a Roughrider when planting several plots outside Mountain Home, ID in the late fall of 2010 which allowed the seed furrow to be increased to 1-1/2” to 2” compared to the 1/2” to 1” with the gage wheels installed. Observation early in the spring of 2011 showed a lower apparent germination, which is generally the result of the seed being buried too deep. Follow up should determine whether these results carry through to the spring of 2012.

Publications:

Truax, J. 2011. Development of seeding equipment for establishing diverse native communities. In: Great Basin Native Plant Selection and Increase Project FY2010 Progress Report. p. 165-166. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2010_ProgressReport.pdf

Presentations:

Shaw, N.; Fisk, M.; Denney, E.; Truax, J. 2011. Post-fire seeding strategies and native plant materials for the northern Great Basin. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22-23, Salt Lake City, UT. http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2011.pdf

Project Title: Influence of Post-fire Treatments on Exotic, Native Residual and Seeded Species Production at the Scooby Wildfire Site in Northern Utah, 2010

Project Location: University of Wyoming, Laramie, Wyoming

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Project Description:

Introduction

Wildfire revegetation efforts employ a variety of mechanical and cultural methods to establish plant cover and diversity and to limit establishment of exotic plant species following a wildfire event. Yet, although cover establishment will limit soil loss from these sites, we know little about the relative impact of drill type, seed mixture or seeding technique on the productivity of exotics. Throughout the Western states, exotic annuals such as the cool season annual grass, cheatgrass (*Bromus tectorum*) and warm season forb species such as halogeton (*Halogeton glomeratus*) and Russian thistle (*Salsola kali*), often gain dominance on semi arid shrubland sites following wildfire. This study was conducted to understand the productivity of these three annual exotic species relative to a variety of seeding treatments using rangeland and minimum till drills. Our goal was to understand trade offs between the productivity of seeded desired grasses and forbs and their exotic competitors.

Halogeton is a warm season (C4) succulent annual forb native to southeastern Russia and northwestern China. First documented near Wells, Nevada in 1934, the species has since spread throughout the Rocky Mountain states and Great Basin. Consumption of halogeton results in the accumulation of toxic oxalates in tissues which has caused devastating livestock losses, especially among sheep. This invasive species is currently listed as a noxious weed in the Pacific Northwest, Intermountain West, California, Hawaii, and New Mexico (Pavek 1992). The entry of exotic annuals such as cheatgrass and halogeton into semi-desert shrublands reduces the return of native species following wildfire and diminishes habitat quality and forage availability for both wildlife and domestic livestock. This project examines post-wildfire revegetation strategies for semi-desert shrubland systems in the Great Salt Lake area (MLRA 028A) for their influence on cheatgrass, an exotic annual cool-season grass, and halogeton and Russian thistle, annual exotic warm-season forbs and associated soils. We compare seeding treatments for their impact on the presence of cheatgrass, Russian thistle, and halogeton and other exotics and examine the relationship of soil mycorrhizae with seeded and exotic species.

The Utah portion of the study was conducted on the Scooby Fire site in Wildcat Hills, southwest of Snowville, UT in the Great Salt Lake Area (MLRA 028A). The fire burned approximately 120 ha of native sagebrush in August 2008, and several rehabilitation seeding treatments were installed at the site in November 2008 using both the standard rangeland drill and a minimum-till drill. Plots were either drilled with no seed, drill seeded and machine broadcast immediately following drilling (some with varying amounts of Wyoming big sagebrush, *Artemisia tridentata* ssp. *wyomingensis*), drill seeded and hand broadcast (either simultaneously or in January), or designated as a control. Intensive documentation of the treatments (gap intercept, line point intercept, species density, and shrub and forb belt) has been conducted since summer 2009 (see Shaw et al., this volume). However, little data on invasive species impacts on productivity of the seeded species has been recorded. By adding an intensive study of invaders on the site, we address the role of seeding treatments associated with common invasive species establishment. In this report, we compare biomass production of seeded species to the presence of exotics (primarily cheatgrass, halogeton, and Russian thistle) and residual native species.

Halogeton is known to alter the soil chemistry by increasing pH, exchangeable sodium, electrical conductivity, and surface soil salt content (Duda et al. 2003). However, its influence on soil microbiology remains largely undocumented. Halogeton does not form mycorrhizal associations even when inoculum is present in the soil and densities of Russian thistle (warm season annual forb, Chenopodiaceae) are reduced in the presence of mycorrhizal fungi (Allen and Allen, 1988). However, grass densities can also be decreased by mycorrhizal inoculates (all *Agropyron* species) by reducing Russian thistle which facilitates grass establishment (Allen and Allen, 1988). In 2011, we examined the effect of mycorrhizal fungi on halogeton, grass, and shrub establishment at the Scooby post-fire seeding location. Intensive soils analyses will be used to document the presence of mycorrhizae and soil chemical and physical attributes under the reseeding and moisture treatments.

<u>Description of Study Sites</u>
The biomass study was conducted on the site of the Scooby Fire in Wildcat Hills, southwest of Snowville, UT in the Great Salt Lake Area (MLRA 028A, NRCS 2010). The fire burned a native, semi-desert sagebrush community (Wyoming big sagebrush, Indian ricegrass

[*Achnatherum hymenoides*], and bluebunch wheatgrass [*Pseudoroegneria spicata*]) in August 2008, and was seeded with native shrubs, grasses, and forbs in November 2008. The Scooby Fire Site is located at an elevation of 1440 m (4725 ft) on fan terraces and alluvial plains with 1 to 15% slopes. Mean annual precipitation varies from 203-305mm (8-12 in), mean annual air temperature fluctuates from 7.2 to 10°C (45 to 50°F), and the frost-free period ranges from 116 to 151 days (NRCS SSS 2010). Xeric Haplocalcids (Hiko Peak, cobbly loam) and Xeric Torriorthents (Sheeprock, gravelly coarse sand) dominate the site, and both are characterized as deep (≥ 60 cm), well drained soils (NRCS SSS 2010). The site is grazed by livestock in fall, winter, and spring, and provides critical winter range for wildlife.

Treatment Application and Experimental Design at the Scooby Fire Site

Rehabilitation seeding experiments conducted at the Scooby Fire Site were primarily designed to investigate strategies and equipment for reestablishing mixtures of grasses, forbs and shrubs on burned Wyoming big sagebrush sites. Treatments address methods for applying two seed mixes, larger grass and forb seeds which require soil coverage (drill mix) and small-seeded grasses, forbs and shrubs which require surface seeding (broadcast mix). Treatments tested include combinations of drill type, dates, and methods for applying small-seeded species mixes, and Wyoming big sagebrush seeding rates.

Establishing mixtures of native species entails dealing with seeds of many sizes and shapes that require different planting depths and seeding mechanisms because of their morphology (shape, fluffiness, etc). Small-seeded species are generally less competitive than larger seeded species, and cannot be seeded through a standard drill drop because they are placed too deep into the soil, which hinders germination. Rangeland drills have been less effective for small-seeded species, even when seeded in alternate rows, as the disk action tends to bury the seeds. Therefore, small-seeded species are often broadcast on the soil surface even though the practice can be risky as the soil surface dries rapidly and good seed-to-soil contact may not be achieved. The minimum-till drill drops seed on the surface and then presses it into the soil with a brillion imprinter unit to facilitate seed-to-soil contact.

The drill seed mixture consisted of Indian ricegrass, bluebunch wheatgrass, bottlebrush squirreltail (*Elymus elymoides*), sulphur-flower buckwheat (*Eriogonum umbellatum*), and Munro globemallow (*Sphaeralcea munroana*). The broadcast mixture included Wyoming big sagebrush, rubber rabbitbrush (*Ericameria nauseosa*), western yarrow (A*chillea millefolium*), blue penstemon (*Penstemon cyaneus*) and Sandberg bluegrass (*Poa secunda*). There were three broadcast rate mixes: standard, 5x, and 10x, differing only in the Wyoming big sagebrush seeding rate (see Shaw et al., this volume for details).

All plots (excepting controls) were drill seeded in November 2008 in alternating rows through the seed drops of a rangeland drill (R) or the seed boots of a minimum-till drill (MT). The broadcast mix was 1) surface seeded between the drill rows through the drills at the same time the drill mix was seeded (seed was either covered with a chain (R) or a brillion imprinter (MT)), 2) hand broadcast immediately after drill seeding, or 3) hand broadcast over snow in winter to simulate aerial seeding.

Five fenced blocks of the thirteen seeding treatments (65 plots total), were established and are surrounded by a perimeter fence to deter grazing by livestock. Our study used 4 blocks (blocks 1, 2, 4, and 5). Each treatment plot measured 70 m x 30 m (approximately 0.52 acres) with a 10 meter buffer surrounding the perimeter of the blocks. Buffer zones were seeded with a mix of *A. hymenoides* and *P. spicata* to reduce weed encroachment. The assignment of the 13 seeding treatments was randomized within each block. The thirteen seeding treatments installed at the Scooby site are:

- Control (C), unseeded
- Rangeland, R(0), or Minimum-till, MT(0), drilled without seed (2 treatments)
- Rangeland, R(std), or Minimum-till, MT(std), drill seeded and machine broadcast with the standard Wyoming big sagebrush seeding rate mixture (2 treatments)
- Rangeland, (R5x), or Minimum-till, (M5x), drill seeded and machine broadcast with the 5x Wyoming big sagebrush seeding rate mixture (2 treatments)
- Rangeland, R(10x), or Minimum-till, MT(10x), drill seeded and machine broadcast with the 10x Wyoming big sagebrush seeding rate mixture (2 treatments)
- Rangeland, R+BC(5x), or Minimum-till, MT+BC(5x), drill seeded and then hand broadcast with the 5x Wyoming big sagebrush seeding rate mixture (2 treatments)
- Rangeland, R+wBC(5x), or Minimum-till, MT+wBC(5x), drill seeded and then hand broadcast with the 5x Wyoming big sagebrush seeding rate mixture in winter over snow (2 treatments)

Four additional unfenced replicate blocks of three seeding treatments (12 plots total) were established to examine persistence of seeded native vegetation under grazing. Each plot measures 90 m by 70 m (approximately 1.56 acres). The assignment of the three seeding treatment plots was randomized within each block. Only three seeding treatments were installed on the unfenced plots: 1) rangeland drill seeded and machine broadcast at the 5x rate, 2) minimum-till drill seeded and machine broadcast at the 5x rate, and 3) an unseeded control. Unfenced biomass is not reported here.

<u>Sampling Methodology for Biomass Collection, Summer 2010</u>
Five transects were established five meters away from the 70 m edge of each plot at the 15, 25, 35, 45, and 55 m marks using a 100 m tape, beginning at the southeast corner of each plot and running northwest. Biomass samples were located on the 25 m and 45 m transects with the tape arranged so that transects ran perpendicular to the drill seeded rows. Two 0.25 m^2 quadrats were placed at randomly selected points 2 meters away from, and on the southeast side of each of the two transects (for a total of four quadrats, Figure 1). Quadrats were placed 2 meters away from transects to avoid interference with areas reserved for future sampling along the transects. The quadrats were oriented at each random point with the long side parallel to the transect and perpendicular to the drill rows.

Within each quadrat, seeded forbs (western yarrow, sulphur-flowered buckwheat, blue penstemon, and Munroe's globemallow, were clipped and bagged separately by species. All native grasses, both volunteer (primarily *Poa secunda*) and seeded (Indian ricegrass, bottlebrush squirreltail, Sandberg's bluegrass, and bluebunch wheatgrass, were clipped and bagged as a group. Three exotics, cheatgrass, halogeton, and Russian thistle were clipped and bagged separately by species. We clipped residual forbs (native and exotic, primarily mustards

(*Descurania* spp.), lambsquarter (*Chenopodium album*), salsify (*Tragopogon dubius*), desert prince's plume (*Stanleya pinnata*) and a variety of small annual forbs as a group. Forbs of the seeded forb species found in control plots were considered residual forbs. Shrubs were recorded when found in clipped plots, but were not collected as their presence was highly variable. Only current year growth that was rooted in and encompassed by the quadrat was collected (e.g. if a plant base was bisected by the quadrat only the portion of the plant encompassed by the quadrat was sampled). Biomass was clipped at 2.5 cm above ground, bagged and labeled with the plant species or plant group as defined above, block, plot, transect, and random point number. When halogeton was not encountered within a randomly placed quadrat, an additional targeted halogeton quadrat was clipped. Targeted quadrats were placed within 4.5 m of the random point, parallel to the transect; the quadrat was flipped three times parallel to the transect in both directions or until halogeton was encountered. The number of flips required to encounter halogeton was recorded to allow us to calculate total area searched. If no halogeton was located within 4.5 m from the randomly selected point and adjacent to transects, the search was discontinued. The total number of plots clipped equaled 52, resulting in 208 random quadrats and 37 additional halogeton targeted quadrats. Bagged plant biomass was oven dried at 60^{0}C for 48 hours (Bonham, 1989) and plant biomass was recorded to the nearest 0.02 g.

Additional sampling for soil mycorrhizal presence in 2011

In addition to biomass harvests, we collected soil samples for mycorrhizal analysis under seeded grass rows (combination of bluebunch wheatgrass, Indian ricegrass and squirreltail), and under two exotic annuals (halogeton and cheatgrass) microsites at the Scooby Fire Site in June and July 2011 to evaluate relationship of minimum till drill (MT) to tillage (R) and native mycorrhizal fungi in seedings (Kabir, 2005). Sampling was conducted under a subset of the 13 seeding treatments (the three controls C, M0 and R0 and the rangeland and minimum till 5x treatments, R5x and M5x). Samples were hand trowelled immediately adjacent to the root system of the targeted plants to a depth of 10 cm (Allen and Allen, 1988). We collected four samples taken from seeded grass rows, halogeton, and cheatgrass in each of the five treatments in four blocks. We collected cheatgrass and grass row samples in early June and then returned in July to repeat grass row sampling and add the halogeton samples. Samples will allow comparison of mycorrhizal presence beneath grasses over the seasonal transition from cool to warm season by comparing June to July samples. We will also compare soil biota under the two exotics, a cool season annual grass, cheatgrass, versus a warm season annual forb, halogeton. We anticipate that mycorrhizal presence will differ beneath the two exotics versus areas where seeded native grasses dominate. Salt exuded from halogeton tissues accumulates on the soil surface, facilitating its growth and inhibiting the growth of other species including microorganisms (Pavek, 1992). Therefore, halogeton should not readily form associations with native mycorrhizal communities and if refugia sites beneath seeded grass rows exist, we hope to document them. This portion of the project is ongoing and results are not reported here.

<u>Data Summary and Analysis</u>

Samples collected (seeded forbs, volunteer native forbs, all native grass [seeded and volunteer together], and exotics (halogeton, Russian thistle and cheatgrass) from the four random 0.25 m^2 quadrats in each plot were summed so that their totals resulted in an estimate of production as g/m^2 per plot. The four blocks were used to control for variation associated with moving within the study area and serve as replicates for analysis of variance (ANOVA). Biomass weights in

g/m^2 per plot were also relativized by dividing each species or plant group by the total amount of biomass collected in the plot (resulting in % of total biomass within each plot). Biomass data (as % per plot) were also subjected to ANOVA but are not reported here.

Results and Discussion

Total plant biomass was comparable among the treatments in 2010 ($P = 0.0927$); total biomass ranged from 247.5 g/m^2 in the R10x treatment to 121.9 g/m^2 in the control. Exotic production was greatest in the controls and was at least 5 times as great as the exotic biomass in seeded treatments (Figure 2). Native grass production (seeded and residual native grasses together) was greater in seeded treatments than in controls except in the R5x, R+BC5x and M5x, which were intermediate and did not differ from other treatments (Figure 2). Exotic production was primarily Russian thistle (Saka), halogeton (Hagl) and cheatgrass (Brte, Figure 3). Halogeton weights did not differ among treatments ($P= 0.0865$). Russian thistle and cheatgrass weights were much lower in seeded treatments than the three controls.

Biomass of seeded forbs was absent from controls and did not differ among seeded treatments ($P = 0.1670$, Figure 4). Residual forb (native and exotic) biomass was as much as 16 times greater in unseeded controls than in seeded treatments overall. Residual forb weights in the non-drilled controls was intermediate and did not differ from other treatments.

Because total biomass production did not differ among treatments, it is likely that increased native production reduced the relative amount of residual forbs and exotics. Grass seedings effectively reduced productivity of both cheatgrass and Russian thistle at the Scooby site. Residual forbs (primarily annual mustards) were twice as productive in the unseeded controls as in any of the seeded treatments. In the absence of seeding, soil disturbance with empty drills (R0, M0) appears to enhance recruitment of residual forbs and Russian thistle relative to undisturbed controls.

Differences in seedling establishment in seeded plots under the two drills are subtle and not compelling at this time. Although both drills, in the absence of seed, enhanced Russian thistle production relative to the undrilled control, seeding reversed this effect. Seeded species also increase desired species and thus competition with exotic and residual annuals. Russian thistle often enters seeded sites and its presence declines over time in successful seedings.

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Taylor, Megan M., A. L. Hild, N. L. Shaw and E. K. Denney. 2010. Establishment of exotic and seeded species in post-fire seeded sites in northern Utah. Society for Range Management, Wyoming Section. 2010 November 6-10, Laramie, WY.

Management Applications:

Our data demonstrates that native grasses and forb seedings can effectively reduce the production of annual forb and exotic species following wildfire. Because annuals (especially exotic annuals), can produce large numbers of seeds when they are not challenged by competitive neighbors, it is critical to use post-fire reseeding to limit their success. Managers may be enticed to seed non-native species to dominate sites subjected to wildfire because they are sometimes thought to be more effective competitors than native species. These results indicate natives can provide a strong competitive environment to limit exotic annual production.

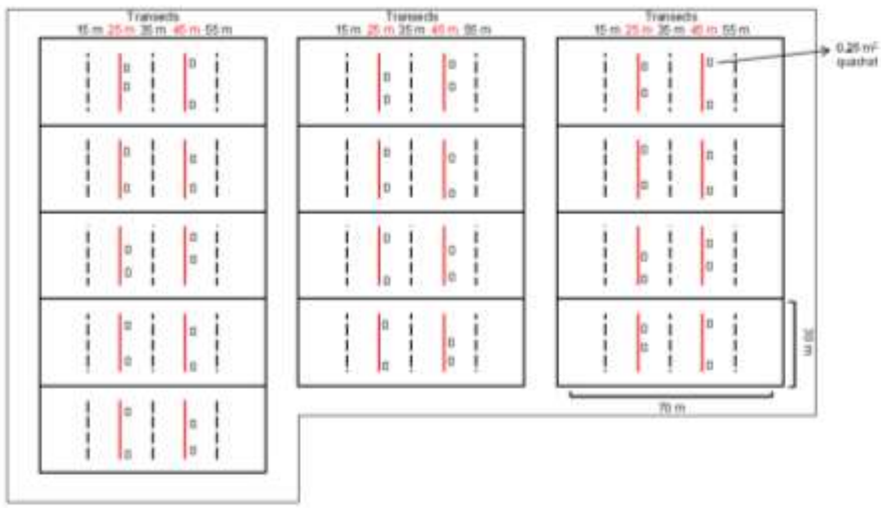

Figure 1. Representative layout of biomass sampling quadrats in seeded plots at Scooby fire. Four 0.25 m^2 quadrats were clipped in each treatment to document biomass production. Each quadrat was placed 2-m from transects to avoid traffic areas.

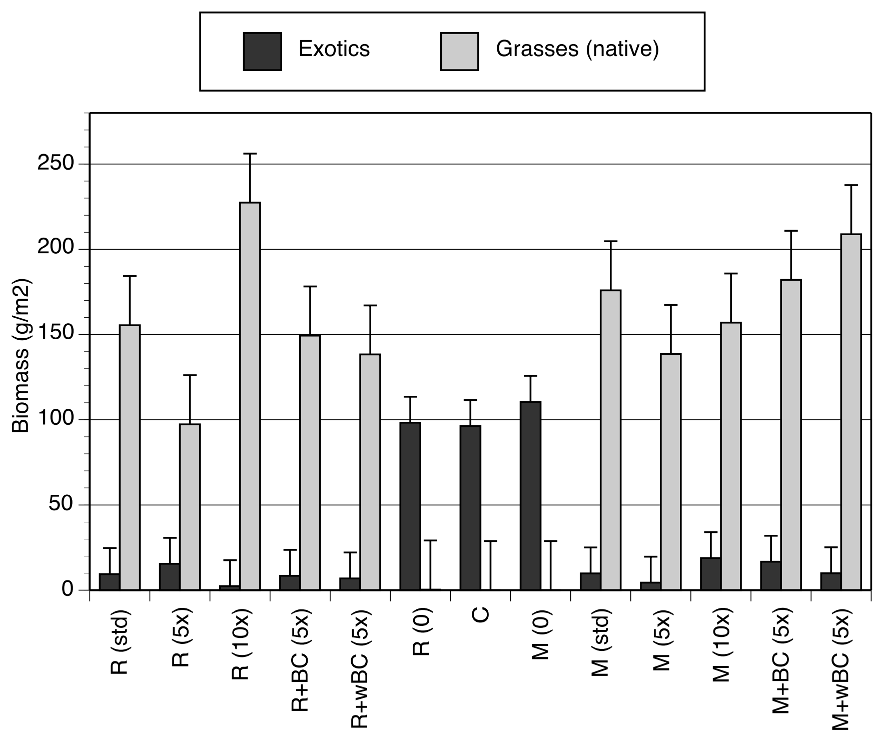

Figure 2. Native grass and exotic species (cheatgrass, Russian thistle and halogeton) biomass at Scooby fire in 2010 under 13 seeding treatments. Bars are standard errors of means within each plant group. Exotics and native grasses differ among treatments ($P < 0.0001$ in both cases).

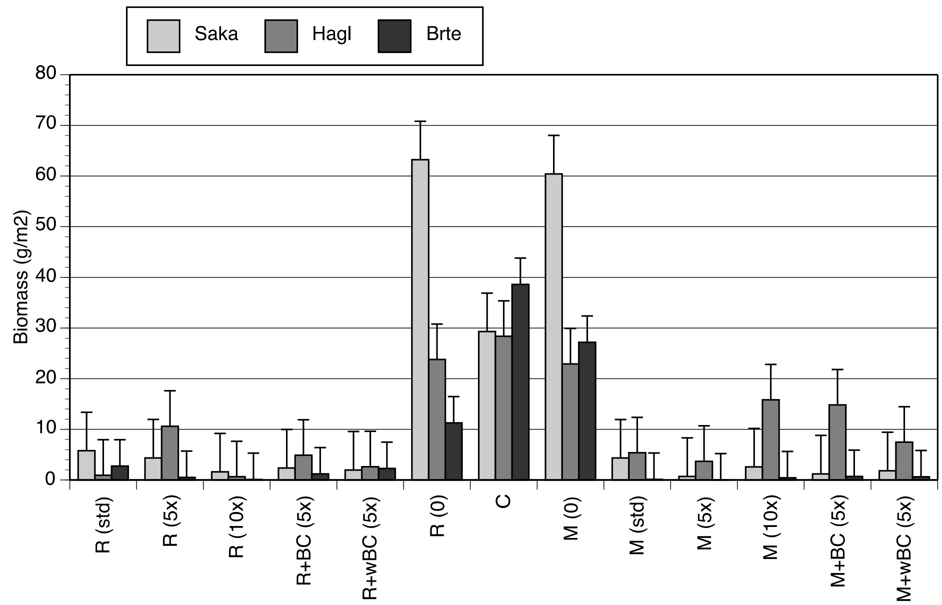

Figure 3. Exotic species biomass at Scooby fire in 2010 under 13 seeding treatments. Bars are standard errors of means within each species. Biomass differs among treatments within Russian thistle (Saka, $P < 0.0001$) and cheatgrass (Brte, $P < 0.0001$). Halogeton (Hagl, did not differ among treatments, $P = 0.0865$).

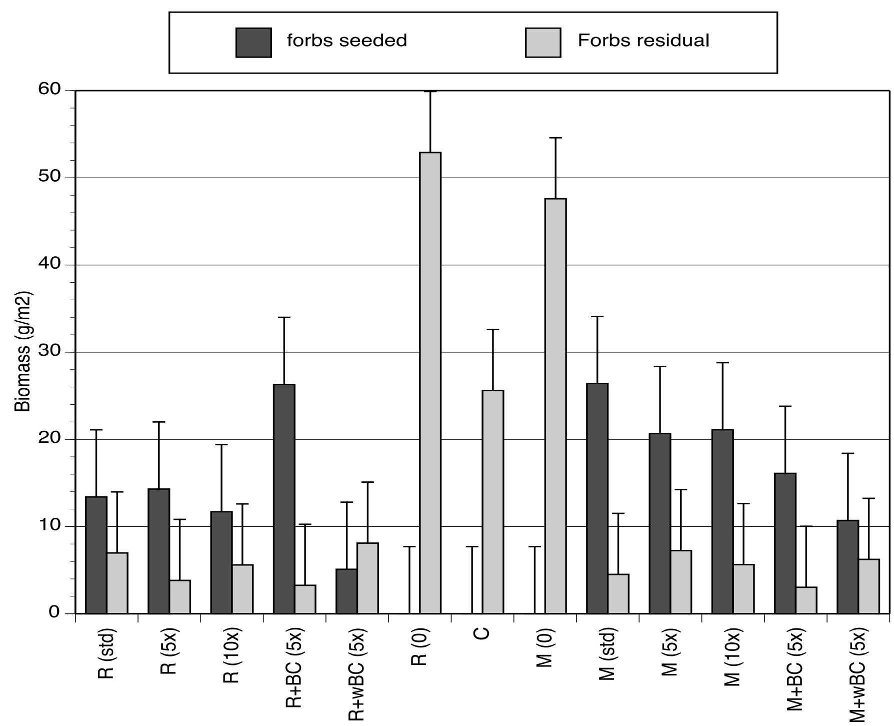

Figure 4. Seeded and residual forbs in 2010 at Scooby fire site under 13 seeding treatments. Bars are standard errors of means within each forb group. Residual forbs differ among treatments $P < 0.0001$.

Project Title: Native Plant Selection and Restoration Strategies

Project Location: USDA Forest Service, Rocky Mountain Research Station, Boise, Idaho

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Project Description:

1. Plant Materials

Seed Collection

Seventy-eight collections were made in 2011, this included seed of 22 species. Collections were completed with the assistance of one College of Western Idaho and two Job Corps interns.

Distribution of Seed to Growers

Seeds of four species were distributed to three private sector seed growers for commercial sales via the Utah Crop Improvement Association. Seed of two species were provided to Lucky Peak Nursery, Boise, ID for seed stock increase (Table 1).

Seed Distribution

Forty-six collections were distributed to the USDA Agricultural Research Service, Western Regional Plant Introduction Station via the Seeds of Success Program for addition to the GRIN system (Appendix II).

Stock seed *Achillea millefolium* var. *occidentalis* (Eagle Selected germplasm) was provided to the Utah Crop Improvement Association for distribution to interested growers (Table 1). Sixteen collections and two seed mixes were distributed to cooperators and other users (Appendix III).

Table 1. RMRS Boise seed increase and stock seed distributed to private growers via the Utah Crop Improvement Association (UCIA) in 2011.

Species	Distribution	Seed Orign (county, state or ecoregion)	Source Type	kg	No. growers
Achillea millefolium var. *occidentalis* Western yarrow	Private grower	Snake River Plain	Single	0.61	1
Achillea millefolium var. *occidentalis* Western yarrow	UCIA	Snake River Plain	Single	1.50	In stock
Eriogonum umbellatum Sulphur-flower buckwheat	Seed increase	Snake River Plain	Pooled	0.28	1
Eriogonum umbellatum Sulphur-flower buckwheat	Private grower	Northern Basin & Range	Pooled	0.58	1
Penstemon acuminatus Sharpleaf penstemon	Private grower	Snake River Plain	Pooled	2.15	1
Penstemon acuminatus Sharpleaf penstemon	Private grower	Snake River Plain	Single	0.25	1
Penstemon cyaneus Blue penstemon	Private grower	Lincoln Co., ID	Single	4.50	1
Penstemon speciosus Royal penstemon	Seed increase	Snake River Plain	Pooled	0.31	1
		TOTAL SEED DISTRIBUTED (kg)		10.18	

2. Post-fire Native Seeding Strategies: Results from a Wyoming Big Sagebrush Site in Northern Nevada

Additional collaborators: Mike Pellant, USDI BLM, Boise, ID; Jim Truax, Truax Co., Inc., New Hope, MN; Dan Ogle, USDA NRCS Idaho State Office, Boise, ID; Loren St. John, USDA NRCS Aberdeen Plant Materials Center, Aberdeen, ID; Tom Warren and Tyson Gripp, USDI BLM, Elko, NV; Lee Turner, Nevada Department of Wildlife, Reno, NV. Additional funding for this project was provided by the Joint Fire Science Program and National Fire Plan.

Introduction

Post-fire restoration with native species on former Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) rangelands is conducted to provide functional and sustainable plant communities. Seeding strategies and equipment are needed to effectively plant mixtures of species with diverse seed shapes and sizes, growth rates and competitive abilities. We examined the effectiveness of two drills (standard rangeland drill and minimum-till drill) and two seeding rates on community establishment and development.

Materials and Methods

The study site is located on the East Humboldt Fire, Elko Co., Nevada that burned in August 2006. Pre-burn vegetation was a Wyoming big sagebrush community. Soils are coarse loams and silts and elevation is 155 m. Seven treatments (Table 1) were applied to 30-m x 70-m plots with five replications in early November 2006.

Table 1. Seeding treatments

Code	Description
C	Control, no drill and no seed
M0	Minimum-till drill, no seed
R0	Rangeland drill , no seed
ML	Minimum-till drill, low rate[1]
RL	Rangeland drill, low rate
MH	Minimum-till drill, high rate[2]
RH	Rangeland drill, high rate

[1]Low rate is 75% of BLM recommended seeding rate.
[2]High rate is 125% of BLM recommended seeding rate.

The drill seed mix (large seeds) (Table 2) was seeded in alternate rows. The seed passed from the large seed box (Fig. 1) through the drill assembly of each drill. The broadcast mix (small seeds) (Table 2) was allowed to fall to the soil surface of the intervening rows from the broadcast seed box (Fig. 1) and covered by chains (rangeland drill) or imprinter units (minimum-till drill) (Fig. 2). The site was fenced to exclude livestock for long-term evaluation.

Figure 1. Triple seed box used on both the minimum-till drill (left) and rangeland drill (right).

Figure 2. Chains on rangeland drill (left) and imprinter units on minimum-till drill (right)

Table 2. Species seeded and rates (pure live seeds [PLS] m^{-2}).

Species	**Seeding Rate ($PLS\ m^{-2}$)**	
	Low	**High**
Broadcast seeding mix[1]		
Sandberg bluegrass, Mt. Home germplasm (*Poa secunda*)	114	195
Western yarrow, Eagle germplasm (*Achillea millefolium* var. o*ccidentalis*)	106	171
Rubber rabbitbrush (*Ericameria nauseosa*)	10	17
Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*)[2]	10	15
Total Broadcast	*240*	*398*
Drill seeding mix[1]		
Bluebunch wheatgrass, Anatone germplasm (*Pseudoroegneria spicata*)	68	95
'Rimrock' Indian ricegrass (*Achnatherum hymenoides*)	39	55
Bottlebrush squirreltail, Toe Jam Creek germplasm (*Elymus elymoides*)	6	8
'Appar' Blue flax (*Linum perenne*) (non-native)	24	33
Munro's globemallow (*Sphaeralcea munroana*)	30	41
Fourwing saltbush (*Atriplex canescens*)	4	5
Total Drill	*171*	*237*
Total Drill + Broadcast	411	635

[1] Rice hulls were added as a diluent to improve seed flow.
[2] Additional Wyoming big sagebrush seed was also aerially seeded over all plots.

The site was monitored in June 2007, June 2008 and August 2011. Monitoring procedures were modified from Herrick et al. (2005). Five 20-m transects were installed perpendicular to the drill rows in each 30-m x 70-m plot. Cover data was collected using line-point intercept with points read at 1-m intervals along each transect (100 points per plot). Density data was recorded for seeded species and cheatgrass (*Bromus tectorum*) in four 0.5-m^2 quadrats per transect (10 m^2 per plot). Native residuals of seeded species were included in counts. Basal gaps were measured between the base of perennials along each 20-m transect and summed by size class for each plot. Size classes were: 20-50 cm, 51-100 cm, 101-200 cm and >200 cm.

Figure 3. East Humboldt burn, seeding and monitoring, 2006-2011.

<u>Results</u>
Spring and total water year precipitation were below average in 2007 and 2008 during the periods of germination, emergence and establishment. Greater amounts of precipitation were received in 2009 through 2011 (Fig. 4).

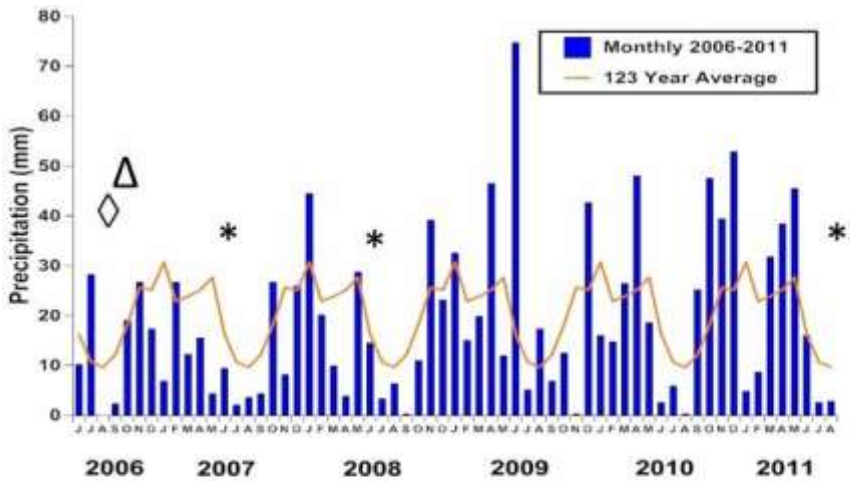

Figure 4. Monthly precipitation, June 2006 to August 2011 and 123 year average annual precipitation at Elko, NV (WW 2011, WWRC 2011)
◊ = Fire, August 2006. Δ = Seeding, October 2006
* = Vegetation monitoring: June 2007 and 2008, August 2011

Density of Seeded Species and Cheatgrass
Drilled seeded species. Drill seeded species and recovering or emerging plants of the same species were not possible to separate, thus total counts for each species were recorded for each plot. Total density was 68 times greater on seeded than on nonseeded plots in 2007 (Fig. 5). In 2008 and 2011 density of drill seeded species was 7.5 times greater on three of the seeded treatments (MH, ML and RH) than on nonseeded plots, with RL intermediate in both years.

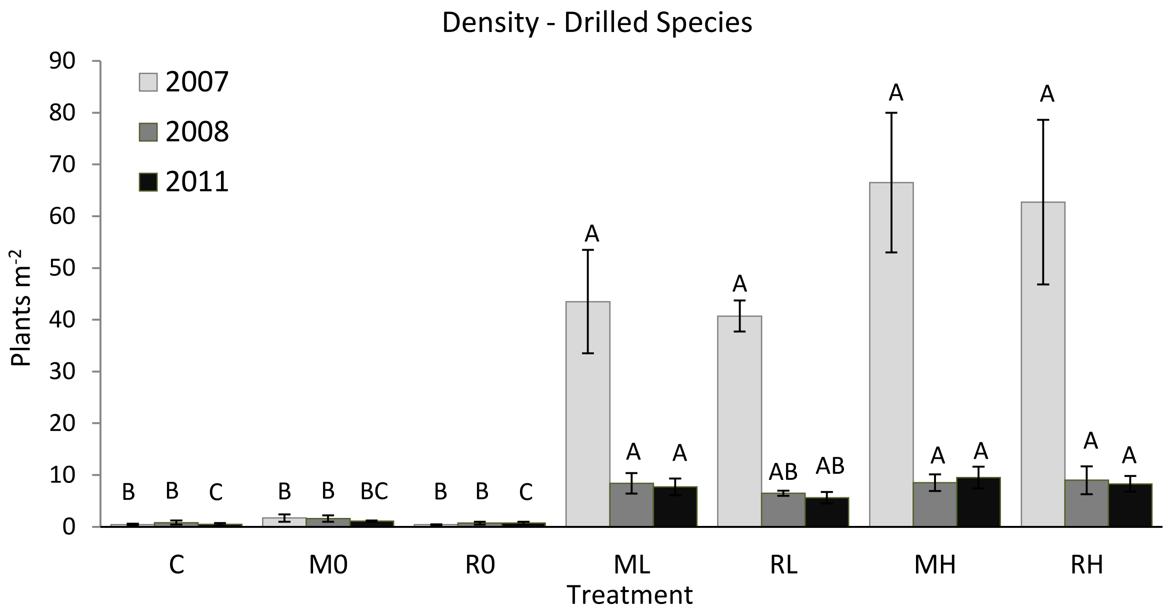

Figure 5. Density of drilled species (plants $m^{-2} \pm 1$ s.e.) by year. Within years means with the same letter do not differ. ($P \geq 0.05$)

Broadcast species. Drill seeded species and recovering or emerging plants of the same species were not possible to separate, thus total counts for each species were recorded for each plot. Density was greater in the MH compared to the R0 and C treatments in 2007, but there were no differences among treatments in 2008 or 2011 (Fig. 6).

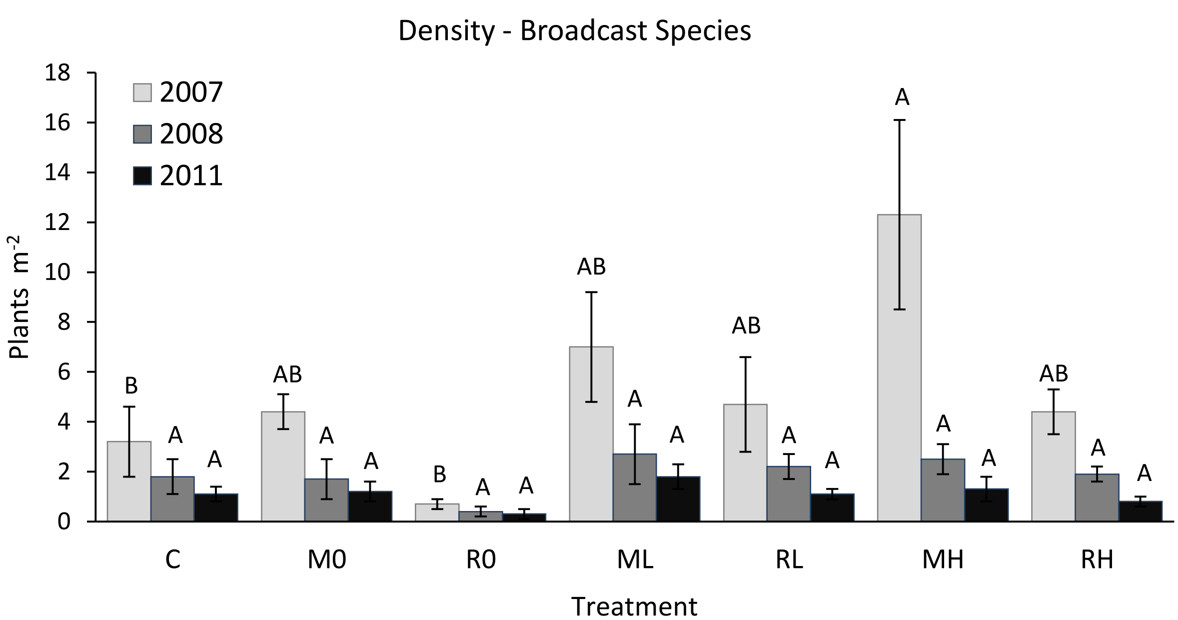

Figure 6. Density of broadcast species (plants $m^{-2} \pm 1$ s.e.) by year. Within years means with the same letter do not differ. ($P \geq 0.05$)

Cheatgrass. Density in 2007 and 2008 was less than 10 plants m^{-2} and did not vary among treatments or years (data not shown).

Aerial Cover – 2011

Drilled seeded species. Aerial cover was similar on all seeded treatments and 7.9 times greater than on nonseeded treatments. Bluebunch wheatgrass, squirreltail, and blue flax accounted for most of the increased cover on seeded plots (Fig. 7)

Broadcast seeded species. Aerial cover of individual species and total aerial cover of broadcast species were similar among treatments (Fig. 7). Rubber rabbitbrush was the single exception (ML > C, R0, M0, with other treatments intermediate).

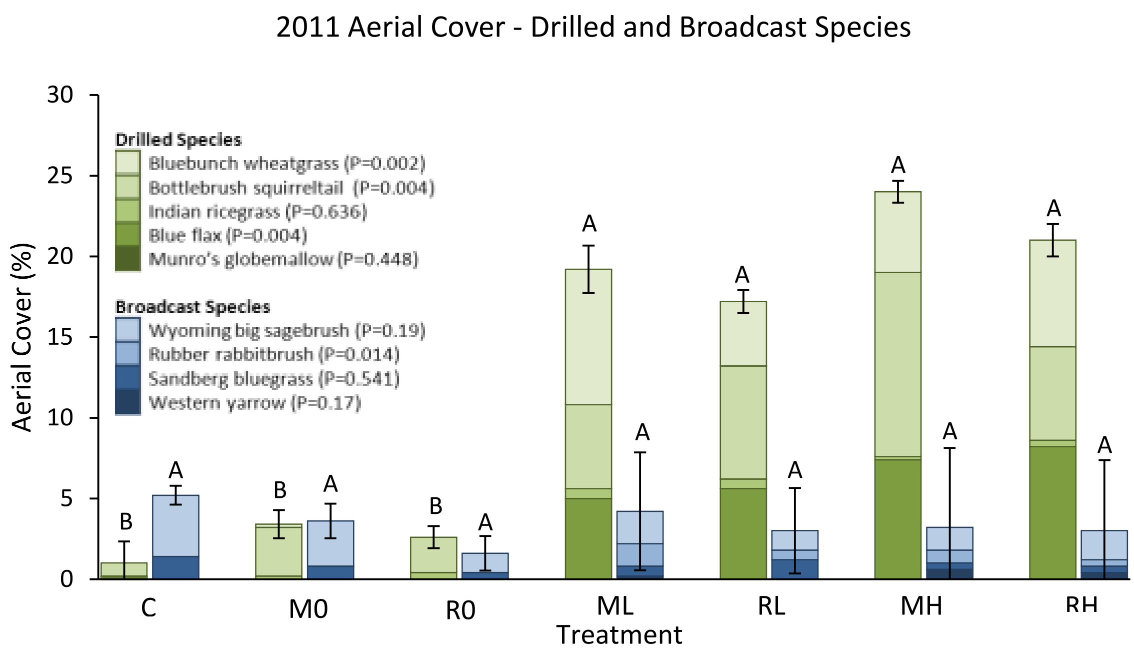

Figure 7. Aerial cover of seeded species (% ± 1 s.e.) by treatment in 2011. Means with the same letter do not differ (P ≥ 0.05).

Total Aerial Cover

Native species. Total native cover was greater in the RH and MH than in the R0 and M0 treatments, the remainder (C, RL and ML) were intermediate. Differences resulted from cover provided by perennial grasses and forbs; shrub cover did not vary among treatments (Fig. 8).

Exotic species. Cover provided by Greater in R0 than in MH with remainder intermediate. Exotics were dominated by cheatgrass; annual forbs accounted for less than one-third of the treatment totals (Fig. 8).

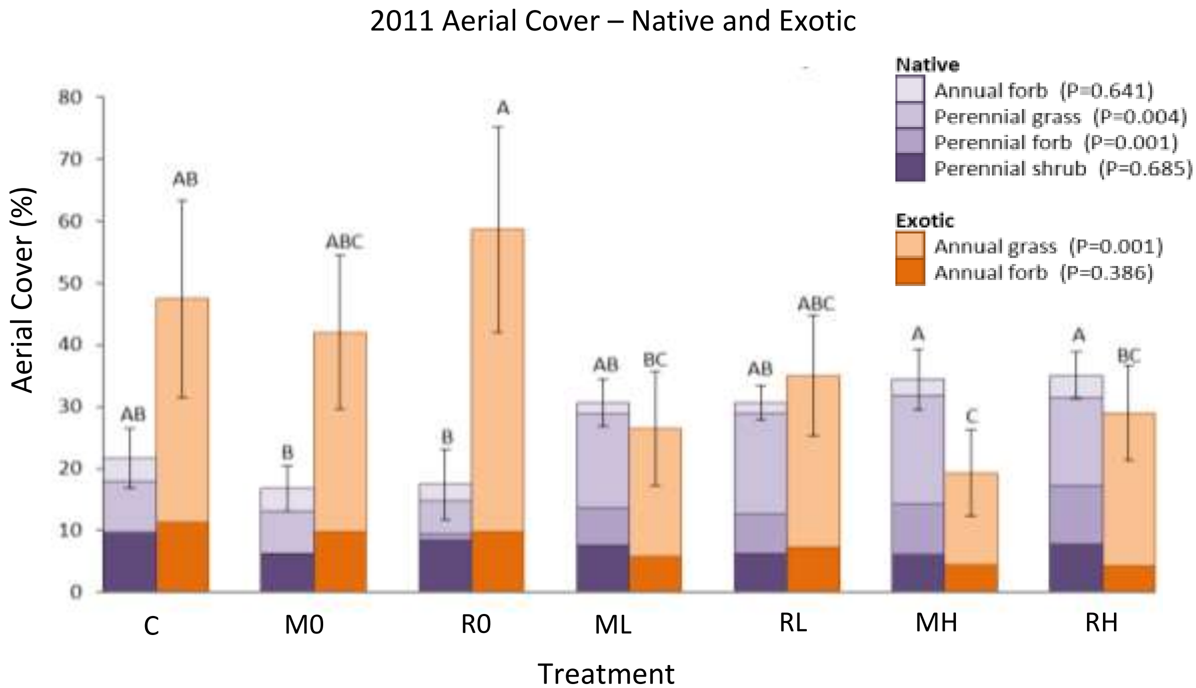

Figure 8. Aerial cover of native and exotic species (% ± 1 s.e.) by treatment in 2011. Means with the same letter do not differ (P ≥ 0.05)

Basal Gaps – 2011

Total basal gap length averaged 91.5 m with no differences among treatments. There was a tendency towards an increase in total length of smaller gap size classes in the seeded compared to the nonseeded treatments (Fig. 9).

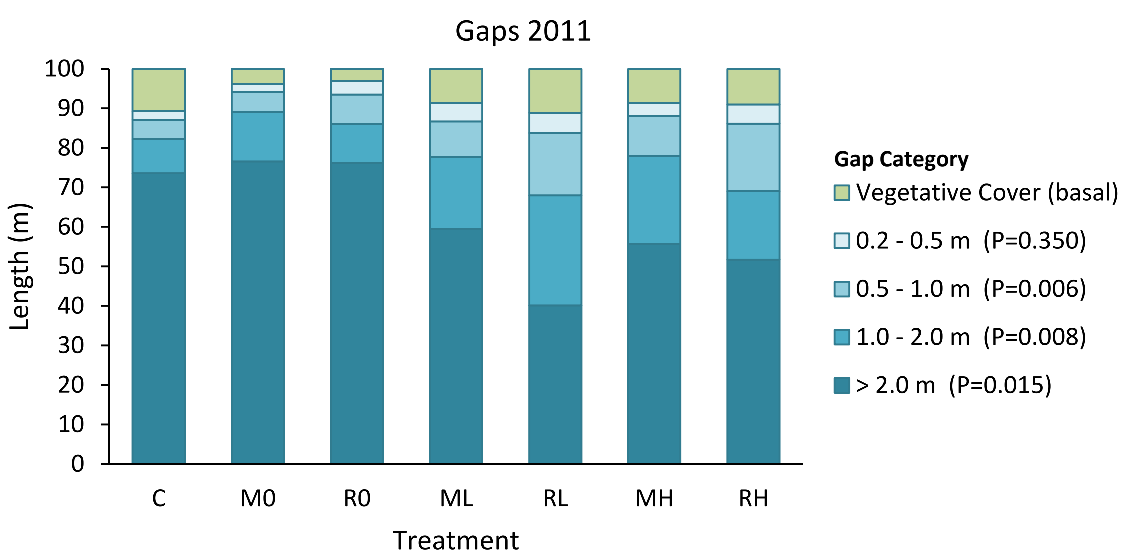

Figure 9. Total gap length (m) by gap size class and treatment in 2011

Discussion and Conclusion

The minimum-till drill and high seeding rate treatment provided greater emergence of broadcast species. All drill and seeding rate combinations provided similar emergence of drilled species. After five growing seasons, density and aerial cover of drilled, but not broadcast species, was greater in all seeded treatments compared to nonseeded treatments. There was also a tendency toward reduced basal gap lengths in seeded treatments. Presence of longer basal gaps is associated with greater water erosion potential. When seeding a diverse native seed mix, the minimum-till drill may provide better emergence of small-seeded species. Subsequent survival and community development is dependent upon environmental conditions.

References:

Herrick J.E.; Van Zee J.W.; Havstad K.M.; Burkett L.M.; Whitford, W.G. 2005. Monitoring manual for grassland, shrubland and savanna ecosystems. Vol. 1: Quick start. USDA ARS Jornada Experimental Range, Las Cruces, NM. 36 p.

Weather Warehouse (WW). 2011. http://weather-warehouse.com/

Western Regional Climate Center (WWRC). 2011. http://www.wrcc.dri.edu/

3. Equipment and Strategies for Post-fire Establishment of Native Species in Sagebrush Shrublands - Scooby and Saylor Creek Seedings

(Funded by the Joint Fire Science Program, the Great Basin Native Plant Selection and Increase Project, and the National Fire Plan)

Methods

Recently burned Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) communities designated Scooby, west of Snowville, Utah, and Saylor Creek, near the Mountain Home Air Force Base Training Range in southern Idaho were selected as seeding locations (Table 1). The sites met the criteria of supporting shrubs prior to the wildfires and burn severities that provided clean seedbeds. Fall seedings were installed at Scooby in 2008 and Saylor Creek in 2010. Treatments addressed methods for applying two seed mixes, one consisting of larger grass and forb seeds, which required soil coverage (drill mix), and a second mix containing small-seeded grass, forb and shrub seeds, which require surface seeding and firming into the soil surface (broadcast mix). Thirteen treatments included combinations of drill type, seeding dates and techniques, and Wyoming big sagebrush seeding rates (Table 2).

Table 1. Seeding locations, wildfire and seeding dates, and site descriptions.

	SCOOBY	SAYLOR CREEK
Location	41^{o}51"16" N, 113^{o}2'46" W	42^{o}39'43" N, 115^{o}28'18" W
County, State	Box Elder, UT	Elmore, ID
Fire	Scooby	Black Butte
Date	22 Sep 2008	29 Jun 2010
Size (ha)	154	6,587
Cause	Lightning	Lightning
Seeding dates	11/18-19/2008	10/27-28/2010
Fall	11/18-19/2008	27-28 Oct 2010
Winter broadcast	1/29/2008	Feb 15 2011
Elevation (m)	1422-1475	1,204
Annual precipitation (mm)	203-356	203-330
Frost-free season (d)	100-160	90-135
Soils	Hiko Peak-Sheeprock-Rock outcrop association, 3-25% slopes	Purdam-Sebree-Owsel complex, 0-8% slopes
Ecological site(s)	Semidesert Gravelly Loam (Wyoming big sagebrush) North	Loamy 8-12 ARTRW8/PSSPS-ACTH7; Slickspot sodic 8-14 ARTRW8/ACTH7
Vegetation	*Artemisia tridentata wyomingensis*, *Achnatherum hymenoides*	*Artemisia tridentata wyomingensis*, *Pseudoroegneria spicata*, *Achnatherum thurberianum*

Table 2. Seeding treatments applied post-fire at Scooby and Saylor Creek.

<table>
<tr><th>Treatment</th><th>Drill</th><th>Drill mix[1]</th><th>Broadcast mix[2]</th><th>Wyoming big sagebrush seeding rate[2]</th></tr>
<tr><td>C</td><td colspan="4">Control (no drill, no seed)</td></tr>
<tr><td>R0</td><td rowspan="7">Rangeland drill</td><td colspan="3">No seed</td></tr>
<tr><td>R1X</td><td rowspan="6">Drilled in alternate rows in fall</td><td rowspan="3">Broadcast through drill in alternate rows - fall</td><td>1X</td></tr>
<tr><td>R5X</td><td>5X</td></tr>
<tr><td>R10X</td><td>10X</td></tr>
<tr><td>Rf+BC5X</td><td>Hand broadcast in fall</td><td>5X</td></tr>
<tr><td>Rw+BC5X</td><td>Hand broadcast in winter</td><td>5X</td></tr>
<tr><td>M0</td><td rowspan="7">Minimum-till drill</td><td colspan="3">No seed</td></tr>
<tr><td>M1X</td><td rowspan="6">Drilled in alternate rows in fall</td><td rowspan="3">Broadcast through drill in alternate rows in fall</td><td>1X</td></tr>
<tr><td>M5X</td><td>5X</td></tr>
<tr><td>M10X</td><td>10X</td></tr>
<tr><td>Mf+BC5X</td><td>Hand broadcast in fall</td><td>5X</td></tr>
<tr><td>Mw+BC5X</td><td>Hand broadcast in winter</td><td>5X</td></tr>
</table>

Drills utilized were the standard rangeland drill (P&F Services) and an experimental minimum-till drill (Truax Co., Inc.). Both drills were calibrated by USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center (Aberdeen PMC) personnel and configured to drill and broadcast seed in alternating rows. Each drill seeded 10 rows spaced 30.5 cm apart per drill pass.

The rangeland drill planted larger seeds in furrows created by disks. The drill was modified to broadcast small seeds by raising the disk assemblies and removing the seed tubes from alternate drops. These seed tubes were replaced with 7.6 cm diameter aluminum pipes to improve seed flow and allow the broadcast seed mix to drop onto the soil surface. Chains drug behind the drill covered the seed in all rows.

The minimum-till drill utilized fully hydraulic disk assemblies to plant larger seeds in a narrow furrow. Broadcast seeds passed through disk-less seed tubes and fell onto undisturbed soil, where patterned imprinter wheels pressed them into the soil surface. The precise furrow openers and imprinter wheels created a minimal amount of soil disturbance compared to the standard rangeland drill.

Seed mix composition (Table 3) was adjusted to match site conditions to the extent possible. Seeding rates were based on standard USDI Bureau of Land Management (BLM) recommendations for post-fire seedings. A single drill mix was used for all seeded treatments at each site. The broadcast seed mix varied only by the Wyoming big sagebrush seeding rate. Rates were denoted by 1X, 5X and 10X (see Table 3). Seed was mixed by Aberdeen PMC personnel. Rice hulls were added to both the drill and broadcast mixes following methods described by St. John et al. (2005) to maintain seeds of different weights in the mix, prevent bridging of light and fluffy seed, and to simplify drill calibration when planting complex seed mixes.

Table 3. Scooby and Saylor Creek seed mixes.

				PLS/m^2		
			PLS (%)	**1X**	**5X**	**10X**
SCOOBY	Broadcast mix					
	A. tridentata ssp. *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

Treatments were three late fall treatments with no seed: an undrilled control (no drill and no seed) (C), rangeland drill with no seed (R0), and minimum-till drill with no seed (M0) (Table 1). The latter two treatments simulated failed seedings and permitted evaluation of drill impacts on vegetation and soil characteristics. Three additional treatments for each drill examined success of seeding drill and broadcast mixes through the drill. These were installed by planting the two mixes through alternate seed drops in late fall. These treatments varied only by the amount of Wyoming big sagebrush seed (1X, 5X, or 10X) in the small seed/broadcast mix (see Table 3 for actual rates at each location). The final two treatments for each drill simulated aerial seeding. These involved planting the drill mix through alternate seed drops in late fall. The broadcast mix with Wyoming big sagebrush at the 5X seeding rate was then applied by hand over the entire plot immediately after drill seeding (R+fBC5X, M+fBC5X) or in winter (R+wBC5X, M+wBC5X) (Table 1).

At each location the 13 treatments were applied to 30-m x 70-m plots arranged in a randomized complete block design with five blocks for a total of 65 plots. At Saylor Creek an additional minimum-till drill treatment (M+D) was added to each block to determine whether water catchment for drill seeded rows could be improved by removing the depth bands. Perimeter fences were installed around the 65 plots to exclude livestock but not wildlife.

Plots were also established outside the fenced area to provide for long-term evaluation of livestock use on the persistence and population dynamics of grazed and nongrazed native seedings. Four randomized complete blocks of three treatments each (C, R5X, and M5X; 70-m x 90-m plots) were installed at Scooby and five at Saylor Creek.

Vegetation is monitored for two growing seasons at each site. Second year monitoring for the Saylor Creek location will be completed in 2012. Five 20-m transects were established perpendicular to the long axis of each plot for data collection. Monitoring protocols were modified from Herrick et al. (2005). Measurements include:

1) Density: Number of plants of each seeded species is counted and presence of all non-seeded species recorded for each of four 0.5-m x 1-m quadrats located along each transect (10 m^2 per plot). Cheatgrass (*Bromus tectorum*) plants are counted in one 20-cm x 25-cm subplot within each quadrat (1 m^2 per plot).
2) Cover and richness: Aerial, intermediate, and basal layers by species or ground cover category are determined using the line-point-intercept method. Points are read at 1-m intervals along each transect (100 points per plot).
3) Basal gaps: Length of basal gaps greater than 20 cm long occurring between the bases of perennial plants intersecting the transect lines are measured (100 m examined per plot). Gap data is summarized as the total gap length represented by each of four gap size classes: 20-50 cm, 51-100 cm, 101-200 cm, and >200 cm in each plot.

<u>Results</u>

Precipitation (Figure 1)

Above average precipitation fell at Scooby and Saylor Creek in the spring following seeding. Neither site has experienced extended dry periods during the study. Scooby developed a snow cover each winter, but Saylor Creek was open and exposed to wind erosion through most of the 2010-2011 winter. Consequently, the winter hand broadcast seeding treatment was applied over snow at Scooby, but over bare ground at Saylor Creek.

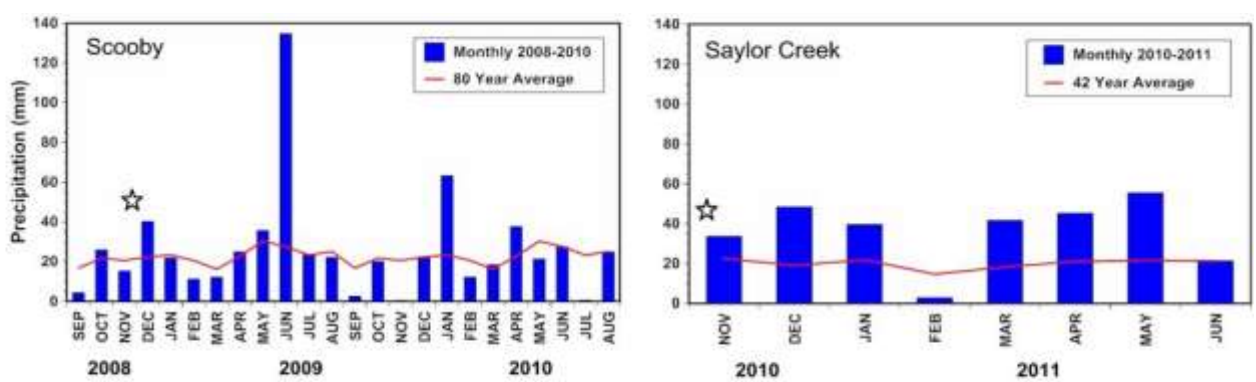

Figure 1. Monthly and long-term precipitation for Scooby and Saylor Creek (WRCC 2011). ☆ = planting date.

Response to Seeding Treatments
Cheatgrass density
Scooby: Cheatgrass density was similar across treatments and increased from 26.1 + 7.5 plants m^{-2} in 2008 to 178.5 + 32.8 plants m^{-2} in 2009. Aerial cover of cheatgrass was less than 10% on all seeded treatments in both years (Figure 2). Aerial cover of cheatgrass was greatest on the undrilled control in 2009 and on the undrilled control and unseeded minimum-till drill treatment in 2010.

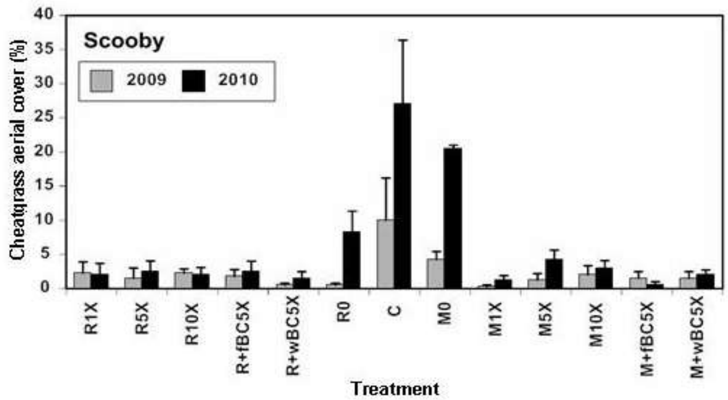

Figure 2. Treatment means (± s.e.) for aerial cover of cheatgrass at the Scooby post-fire seeding by treatment in 2009 and 2010. See table 1 for treatment descriptions.

Saylor Creek: Vegetation was poorly developed at the time of sampling in 2011 due to the cool spring. Cheatgrass density (2.8 ± 0.2 plants m^{-2}) and aerial cover (3.2 ± 0.3%) did not vary among treatments.

Emergence and establishment of seeded species (Figure 3)
Scooby: The total density of drilled grasses was similar across seeded treatments and years with the exception that density was greater on three of the rangeland drill treatments (R1X, R+fBC5X, R+wBC5X) in 2009 but not in 2010. The density of drilled forb species was similar across treatments and years, while the density of broadcast forbs was similar among treatments, but increased from 2009 to 2010. Density of broadcast grass was similar between years and greater on the M5X treatment than on all rangeland drill treatments except the R5X with other treatments intermediate. Seeding at the high rate (10X) through the minimum-till drill increased the density of broadcast shrubs, primarily big sagebrush. Shrub density was similar in both years.

Saylor Creek: Total density of all seeded species (18.1 ± 3.8 plants m^{-2}) and all drilled species was generally similar across treatments. Seeding the broadcast grass through the drill increased its density in the M5X and M10, but broadcasting it in winter resulted in lower densities relative to other treatments. As at Scooby, broadcast shrub (big sagebrush and rubber rabbitbrush) density was greater for the M10X treatment than for the remaining treatments with the exception of the M5X and M+D which were intermediate.

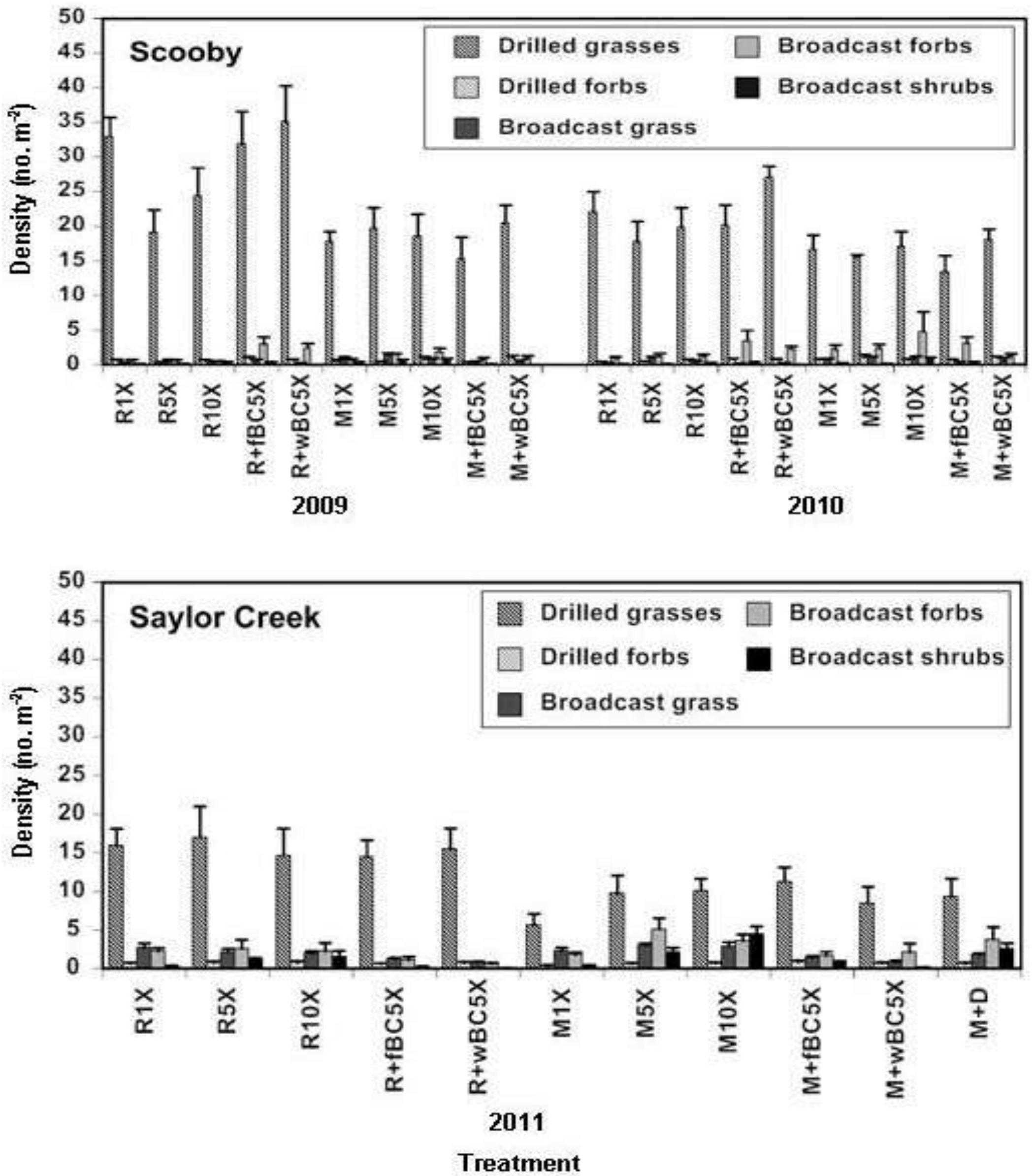

Figure 3. Treatment means (± s.e.) for post-fire seedling density of seeded species at Scooby in 2009 and 2010 (above) and Saylor Creek in 2011 (below) by seeding treatment and year. See table 1 for treatment descriptions.

Development of aerial cover

Scooby: Aerial cover of seeded species was similar among seeded treatments (Figure 4) and increased 4.6 times from 2009 to 2010. Aerial cover of residual natives, primarily annual native mustards, declined from 2009 to 2010 and was greater on the M0 treatment than on the R1X, R5X or M1X treatments with the remaining treatments intermediate and similar. Aerial cover of exotic species on the three unseeded controls increased by 6.9 times from 2009 to 2010, but was similar and low (< 10%) on all seeded treatments in both years. Total aerial cover doubled from 2009 to 2010 with no variation among treatments.

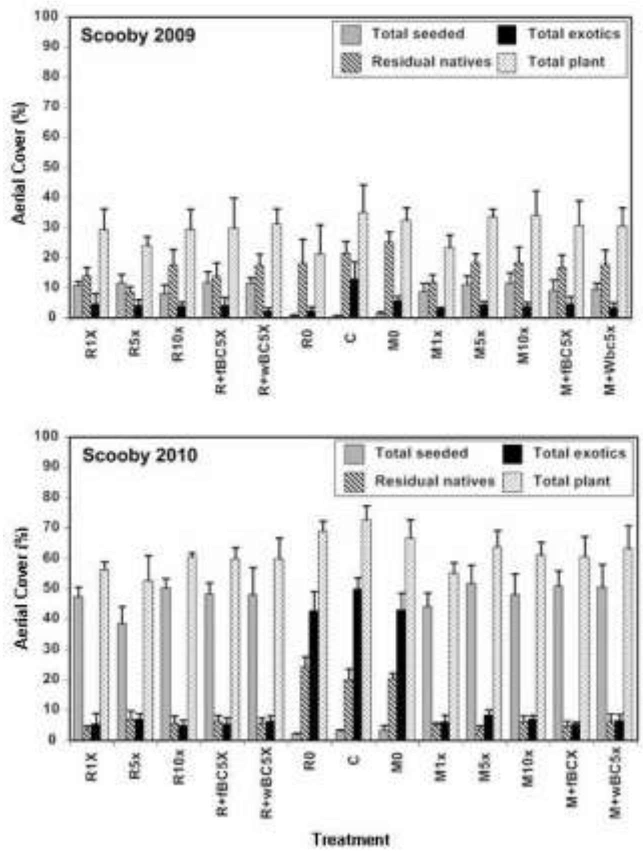

Figure 4. Treatment means (± s.e.) for aerial cover of seeded species, exotics, residual natives (annuals and perennials), and total aerial cover at the Scooby post-fire seeding by treatment in 2009 and 2010. See table 1 for treatment descriptions.

Plant growth was minimal at the time of sampling at Saylor Creek in 2011. Aerial cover provided by seeded species (4.2±0.4%), residual native species (2.2±0.3%), exotic species (3.4±0.4%) and total aerial cover (9.6±0.7%) was similar among treatments.

Distribution of basal gaps

Scooby: The > 200 cm basal gap category dominated all treatments in 2009 as seedlings were small and residual perennials were just beginning to recover. With development of the seeded perennials, this category declined on the seeded, but not on the nonseeded treatments in 2010 (Figure 5). The three smaller basal gap size classes were similar among seeded treatments and generally increased in 2010; they were nearly absent in the unseeded controls in both years.

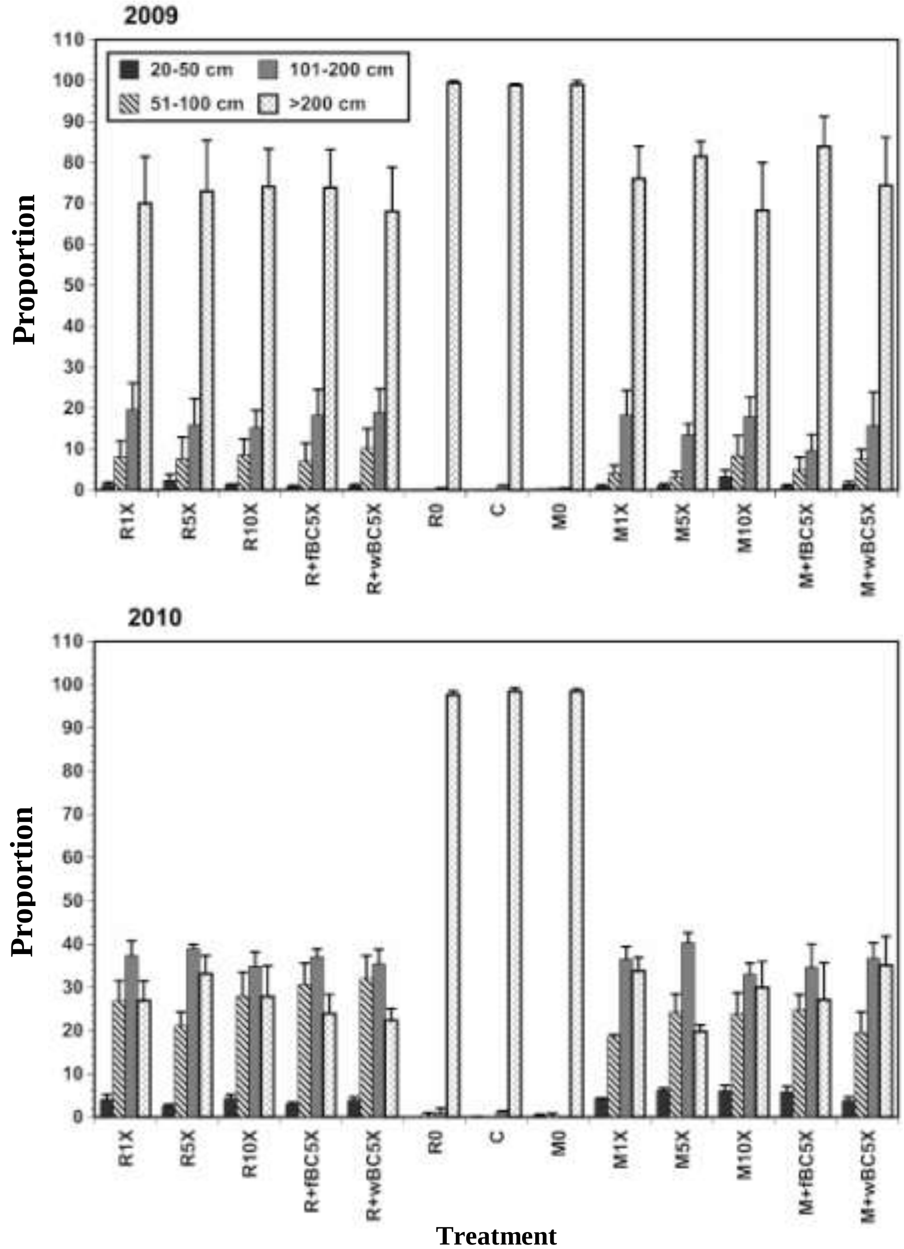

Figure 5. Treatment means (± s.e.) total length (m) of each gap size class by treatment and year at the Scooby post-fire seeding. See table 1 for treatment descriptions.

Saylor Creek: Gap size classes did not vary among treatments in 2011. The > 2 m basal gap size class constituted more than 85% of the total basal gap length.

Richness of native residual species

The number of residual native species (annuals and perennials) exhibited little variation among treatments at either location. At Scooby residual natives increased from 7.0±0.3 species in 2009 to 11.3±0.4 species in 2010. The number of residual native species (8.0±0.2) did not vary among treatments at Saylor Creek in 2011, the first year following seeding.

Management Implications:
Post-seeding precipitation is critical; lack of timely or adequate precipitation can negate or seriously impair the best efforts to install a native seeding. Seedling emergence and survival of seeded species are likely to be reduced when precipitation is low, leaving a void for invasion by exotic annuals. Although precipitation and other environmental risk factors cannot be managed, preparation or selection of seedbeds with minimal weed seeds; selection of seeding equipment and strategies that provide appropriate seedbed conditions for germination, emergence and establishment; careful calibration and operation of drills; selection of plant materials appropriate to site conditions; and careful post-seeding management can improve the probability of seeding success.

Differences in seedling establishment between the standard rangeland drill and the minimum-till drill were not clear-cut. Results at Scooby suggest emergence of drill-seeded grasses was improved when seeded with the rangeland drill, but this difference was lost by the second year. Broadcast seeding through the minimum-till drill and pressing the seed into the soil with the imprinter unit tended to increase emergence of the small-seeded species. Wyoming big sagebrush was responsive to seeding at the medium and high rates (234 and 495 PLS m^{-2}) at Scooby, particularly when seeded through the minimum-till drill. Hand broadcasting small-seeded species in fall or winter simulated aerial seeding and provided highly erratic results. These treatments can be successful, but success can be reduced by poor seed-to-soil contact, and in the case of the winter broadcast treatment, an inadequate period of exposure to cool moist conditions required to release the physiological dormancy common to many forb species.

Basal gaps provide an indication of community vulnerability to water erosion. They are easily measured and related well to perennial community development, whether seeded or native.

Our conclusions after two years of monitoring are preliminary. Our results are most applicable to similar sites and post-seeding weather patterns. Monitoring over a longer term is necessary to evaluate the development of community dynamics in response to environmental conditions and management programs.

Publications:
Cox, R.D.; Kosberg, L.; Shaw, N.; Hardegree, S.P. 2011. Effect of fungicides on Wyoming big sagebrush seed germination. Native Plant Journal 12:263-267.

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Lambert, S. M.; Monsen, S. B.; Shaw, N. 2011. Notice of release of Mountain Home Sandberg bluegrass selected germplasm (natural track). USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO: USDI Bureau of Land Management, Idaho State Office, Boise, ID; Utah State University, Agricultural Experiment Station, Logan, UT; University of Idaho Agricultural Experiment Station, Moscow, ID; U.S. Air Force, Mountain Home Air Force Base. 7 p.

Hardegree, S.P.; Jones, T.A.; Roundy, B.A.; Shaw, N. L.; Monaco, T.A. 2011. Ch. 4: Assessment of range planting as a conservation practice, p. 171-213. In: Briske, D.D., ed. Conservation benefits of rangeland practices: assessment, recommendations, and knowledge gaps. Lawrence, KS: Allen Press.

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Tilley, D.; St. John, L.; Ogle, D.; Shaw, N.; Cane, J. 2011. Plant guide for fernleaf biscuitroot (*Lomatium dissectum* [Nutt.] Mathias & Constance). USDA Natural Resources Conservation Service, Idaho Plant Materials Center. Aberdeen, ID. 7 p.

Tilley, D.; St. John, L.; Ogle, D.; Shaw, N. 2011. Plant guide for Gray's biscuitroot (*Lomatium grayi* [J. M. Coult. & Rose.] J.M. Coult. & Rose). USDA-Natural Resoruces Conservation Service, Idaho Plant Materials Center, Aberdeen, ID. 4 p.

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Hardegree, S.; Cho, J.; Roundy, B.; Moffet, C.; Jones, T.; James, J.; Shaw, N.; Cox, R. 2011. Hydrothermal indices for classification of seedbed microclimate. Society for Range Management 64th Annual Meeting, 2011 February 6-10, Billings, MT. Abstract.

McAdoo, K.; Swanson, J.; Shaw, N. 2011. Diversifying crested wheatgrass seedings in northern Nevada, Society for Range Management 64th Annual Meeting, 2011 February 6-10, Billings, MT. Abstract.

Parkinson, H.; Zabinski, C.; Shaw, N. 2011. Impacts of native and exotic grasses on forb seedling growth and establishment. Society for Range Management 64th Annual Meeting, 2011 February 6-10, Billings, MT. Abstract.

Pellant, M.; Shaw, N. 2011. Great Basin Native Plant Selection and Increase Project: a science/management success. Society for Range Management 64th Annual Meeting, 2011 February 6-10, Billings, MT. Abstract.

Shaw, N.; Pellant, M. 2011. The Great Basin Native Plant Selection and Increase Project - linking research, management and the native seed industry. Society for Range Management 64th Annual Meeting, 2011 February 6-10, Billings, MT. Abstract.

Taylor, M.M.; Hild, A.L.; Shaw, N.L.; Denney, E.K. 2011. Establishment of invasive species in post-fire seeding treatments. Society for Range Management 64th Annual Meeting, 2011 February 6-10, Billings, MT. Abstract. (Also presented at Society for Range Management Wyoming Section 2010 meeting, Laramie, WY and Great Basin Native Plant Selection and Increase Project Annual Meeting, Salt Lake City, UT. (poster)

Richardson, B.A.; Shaw, N.L. 2011. First-year evaluations of big sagebrush common garden trials. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22-23, Salt Lake City, UT.

Shaw, N.; Fisk, M.; Denney, E.; Truax, J. 2011. Post-fire seeding strategies and native plant materials for the northern Great Basin. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22-23, Salt Lake City, UT.

St. Clair, Brad; Johnson, R.; Shaw, N. 2011. Genecology and seed transfer guidelines for bluebunch wheatgrass. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2011 February 22-23, Salt Lake City, UT.

Jensen, S.; Shaw, N. 2011. The development and use of forb species in restoration. Vegetation resilience, the role of perennial herbaceous understory and intact sagebrush. Great Basin Science Delivery Project, 2011 May 17-18, Winnemucca, NV.

Richardson, B.A.; Udall, J.A.; Bajgain, P.; Shaw, N.L. 2011. Correlations between adaptive and molecular genetic variation. Western Forest Genetics Association Annual Meeting, 2011 July 25-28, Troutdale, OR.

Feibert, E. B. G.; Shock, C.; Parris, C.; Saunders, L.; Shaw, N. 2011. Challenges for Intermountain West native wildflower seed production: stand establishment. American Society of Horticultural Science Annual Conference, 2011 September 25-28. Waikoloa, HI

Meeting and Field Tour organization and presentations:

Shaw, N. 2011. Post-fire seeding strategies (Scooby seeding study). Society for Range Management, Utah Section Summer Tour, Park Valley, UT.

Shaw, N. 2011. Rocky Mountain Research Station experimental plantings. Orchard restoration site field day: two decades of studies. Great Basin Science Delivery Program, Boise, ID

Shaw, N. 2011. Introduction. Native plant seed production field day, Oregon State University Malheur Experiment Station, Ontario, OR.

Shaw, N. 2011. Post-fire seeding strategies (Saylor Creek, E. Humboldt, and Gopher seeding studies). Southern Idaho and northern Nevada tour.

Shaw, N.; Fisk, M.; Denney, E., organizers. Great Basin Native Plant Selection and Increase Project Annual meeting, 2011 February 22-23, Salt Lake City, UT.

Johnson, R.C.; Shaw, N.L., organizers. 2011. Special Session: Seed zones, climate change and utilization of native plants for ecological restoration, Society for Ecological Restoration 7th World Conference on Ecological Restoration: Re-establishing the Link between Nature and Culture. 2011 August 21-25, Merida, Mexico.

Appendix I. 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)

[1]Developmental details (official release notice or equivalent information) on file with appropriate certification agency
[2]Optional for SI, recommended for S, T
[3]If developer wishes to maintain intellectual property rights
[4]Unique designation for this specific lot
[5]Or other geographic designation; pooled plant materials may include more than one county or state; details to certification agency
[6]Where germplasm was developed (as released)

Appendix II. Germplasm conservation samples contributed to the Seeds of Success Program/ARS Western Regional Plant Introduction Station in 2011 by USDA FS Rocky Mountain Research Station, Boise, ID.

Symbol	Scientific Name	Common Name	Ecoregion	Ecoregion Name	County	State
ACMI 01	*Achillea millefolium*	Common yarrow	12j	Unwooded Alkaline Foothills	Ada	ID
BAHO 04	*Balsamorhiza hookeri*	Hooker's balsamroot	12h	Mountain Home Uplands	Ada	ID
BAHO 08	*Balsamorhiza hookeri*	Hooker's balsamroot	12h	Mountain Home Uplands	Ada	ID
CLLU 06	*Cleome lutea*	Yellow spiderflower	12a	Treasure Valley	Malheur	OR
ERLA 04	*Eriophyllum lanatum*	Common woolly sunflower	80f	Owyhee Uplands and Canyons	Malheur	OR
LODI 06	*Lomatium dissectum*	Fernleaf biscuitroot	12h	Mountain Home Uplands	Ada	ID
LODI 17	*Lomatium dissectum*	Fernleaf biscuitroot	12f	Semiarid Foothills	Camas	ID
LODI 18	*Lomatium dissectum*	Fernleaf biscuitroot	16f	Foothill Shrublands-Grasslands	Ada	ID
LODI 38	*Lomatium dissectum*	Fernleaf biscuitroot	16f	Foothill Shrublands-Grasslands	Ada	ID
LODI 41	*Lomatium dissectum*	Fernleaf biscuitroot	80a	Dissected High Lava Plateau	Malheur	OR
LODI 46	*Lomatium dissectum*	Fernleaf biscuitroot	16f	Foothill Shrublands-Grasslands	Ada	ID
LODI 74	*Lomatium dissectum*	Fernleaf biscuitroot	80j	Semiarid Uplands	Owyhee	ID
LODI 88	*Lomatium dissectum*	Fernleaf biscuitroot	12h	Mountain Home Uplands	Elmore	ID
LODI 104	*Lomatium dissectum*	Fernleaf biscuitroot	12h	Mountain Home Uplands	Elmore	ID
LODI 106	*Lomatium dissectum*	Fernleaf biscuitroot	12f	Semiarid Foothills	Elmore	ID
LODI 108	*Lomatium dissectum*	Fernleaf biscuitroot	12j	Unwooded Alkaline Foothills	Payette	ID
LODI 109	*Lomatium dissectum*	Fernleaf biscuitroot	16f	Foothill Shrublands-Grasslands	Boise	ID
LODI 110	*Lomatium dissectum*	Fernleaf biscuitroot	11i	Continental Zone Foothills	Malheur	OR
LODI 111	*Lomatium dissectum*	Fernleaf biscuitroot	12j	Unwooded Alkaline Foothills	Malheur	OR
LODI 112	*Lomatium dissectum*	Fernleaf biscuitroot	80f	Owyhee Uplands and Canyons	Malheur	OR
LOGR 10	*Lomatium grayi*	Gray's biscuitroot	12h	Mountain Home Uplands	Ada	ID
LONU 02	*Lomatium nudicaule*	Barestem biscuitroot	12h	Mountain Home Uplands	Gooding	ID
LONU 03	*Lomatium nudicaule*	Barestem biscuitroot	16f	Foothill Shrublands-Grasslands	Elmore	ID
LONU 10	*Lomatium nudicaule*	Barestem biscuitroot	12f	Semiarid Foothills	Gem	ID
LONU 11	*Lomatium nudicaule*	Barestem biscuitroot	12f	Semiarid Foothills	Elmore	ID
LOTR 01	*Lomatium triternatum*	Nineleaf biscuitroot	12a	Treasure Valley	Ada	ID

Appendix II. Continued.

Symbol	Scientific Name	Common Name	Ecoregion	Ecoregion Name	County	State
LOTR 40	*Lomatium triternatum*	Nineleaf biscuitroot	16f	Foothill Shrublands-Grasslands	Ada	ID
LOTR 76	*Lomatium triternatum*	Nineleaf biscuitroot	80a	Dissected High Lava Plateau	Malheur	OR
PEAC 08	*Penstemon acuminatus*	Sharpleaf penstemon	12h	Mountain Home Uplands	Elmore	ID
PEAC 11	*Penstemon acuminatus*	Sharpleaf penstemon	12j	Unwooded Alkaline Foothills	Malheur	OR
PEAC 20	*Penstemon acuminatus*	Sharpleaf penstemon	80a	Dissected High Lava Plateau	Malheur	OR
PEAC 36	*Penstemon acuminatus*	Sharpleaf penstemon	12a	Treasure Valley	Malheur	OR
PEAC 45	*Penstemon acuminatus*	Sharpleaf penstemon	12j	Unwooded Alkaline Foothills	Owyhee	ID
PEAC 56	*Penstemon acuminatus*	Sharpleaf penstemon	12j	Unwooded Alkaline Foothills	Owyhee	ID
PEAC 57	*Penstemon acuminatus*	Sharpleaf penstemon	12j	Unwooded Alkaline Foothills	Owyhee	ID
PEDE 02	*Penstemon deustus*	Hotrock penstemon	16f	Foothill Shrublands-Grasslands	Boise	ID
PEDE 09	*Penstemon deustus*	Hotrock penstemon	16k	Southern Forested Mountains	Boise	ID
PHHA 01	*Phacelia hastata*	Silverleaf phacelia	80f	Owyhee Uplands and Canyons	Malheur	OR
PHHA 02	*Phacelia hastata*	Silverleaf phacelia	80f	Owyhee Uplands and Canyons	Malheur	OR
PHHA 03	*Phacelia hastata*	Silverleaf phacelia	80f	Owyhee Uplands and Canyons	Harney	OR
PHHA 04	*Phacelia hastata*	Silverleaf phacelia	80f	Owyhee Uplands and Canyons	Harney	OR
PHHA 05	*Phacelia hastata*	Silverleaf phacelia	16k	Southern Forested Mountains	Boise	ID
PHLI 02	*Phacelia linearis*	Threadleaf phacelia	80g	High Lava Plains	Harney	OR
SPCR 01	*Sporobolus cryptandrus*	Sand dropseed	80f	Owyhee Uplands and Canyons	Malheur	OR

Appendix III. Seed lots distributed to cooperators in 2011 by USDA FS Rocky Mountain Research Station, Boise, ID.

Species	**Common Name**	**Seed Origin (county, state)**	**Affiliation**	**kg**
Achnatherum thurberianum	Thurber's needlegrass	Ada, Idaho	University of Idaho	0.003
Achnatherum thurberianum	Thurber's needlegrass	Ada, Idaho	Oregon State University	0.25
Chaenactis douglasii	Douglas' dustymaiden	Elmore, ID	USDI BLM Birds of Prey	0.004
Cleome lutea	Yellow spiderflower	Malheur, OR	OSU Malheur Experiment Station	0.2
Elymus elymoides	Emigrant bottlebrush squirreltail	Harney, OR	University of Idaho	0.003
Elymus elymoides	Emigrant bottlebrush squirreltail	Harney, OR	Oregon State University	0.22
Eriogonum umbellatum	Sulphur-flower buckwheat	Elmore, ID	USDI BLM Birds of Prey	0.006
JFSP seed mixes	N/A	N/A	College of Western Idaho	0.5
JFSP seed mixes	N/A	N/A	College of Western Idaho	0.5
Machaeranthera canescens	Hoary tansyaster	Elmore, ID	USDI BLM Birds of Prey	0.007
Penstemon cyaneus	Blue penstemon	Lincoln, ID	College of Western Idaho	0.1
Penstemon speciosus	Royal penstemon	Malheur, OR	USDI BLM Birds of Prey	0.003
Phacelia hastata	Silverleaf phacelia	Malheur, OR	USDA ARS Pollinating Insects Research Center	0.001
Sphaeralcea munroana	Munro's globemallow	Uintah, UT	University of Idaho	0.002
Sphaeralcea munroana	Munro's globemallow	Uintah, UT	Oregon State University	0.18
Sphaeralcea munroana	Munro's globemallow	Payette, ID	USDI BLM Birds of Prey	0.02
			TOTAL SEED DISTRIBUTED (kg)	**1.99**