Great Basin Native Plant Selection and Increase Project FY06 Progress Report

USDI Bureau of Land Management Great Basin Restoration Initiative
USDA Forest Service, Rocky Mountain Research Station,
Shrub Sciences Laboratory, Provo, UT and Boise, ID
Utah Division of Wildlife Resources, Great Basin Research Center, Ephraim, UT
USDA Agricultural Research Service, Forage and Range Research Laboratory, Logan, UT
USDA Agricultural Research Service, Bee Biology and Systematics Laboratory, Logan, UT
Utah Crop Improvement Association, Logan, UT
Association of Official Seed Certifying Agencies, Moline, IL
USDA Natural Resources Conservation Service - Idaho, Utah, Nevada,
and the Aberdeen Plant Materials Center, Aberdeen, ID
Brigham Young University, Provo, UT
USDA Forest Service, National Seed Laboratory, Dry Branch, GA
Colorado State University Cooperative Extension, Tri-River Area, Grand Junction, CO
USDA Agricultural Research Service, Western Regional Plant Introduction Station,
Pullman, WA
Oregon State University, Malheur Experiment Station, Ontario, OR
USDA Agricultural Research Service,
Eastern Oregon Agricultural Research Center, Burns, OR

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March 2007

COOPERATORS

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Introduction

The use of native plants for rehabilitation after wildfires and restoration of disturbed wildlands is being encouraged by various BLM programs, initiatives, and policies. Examples include the 2001-2006 Interior Appropriations Bills, the Great Basin Restoration Initiative, Departmental guidance (DOI Emergency Stabilization and Rehabilitation Manual), Executive Order 13112 (Invasive Species – 2/99) and the BLM's Standards for Rangeland Health. The 2007 USDI Healthy Lands Initiative calls for landscape-scale restoration to reduce the spread of invasive species and re-establish native communities.

This project integrates several proposals to increase native plant production and use within the Great Basin, utilizing an applied science approach in a collaborative project. Original partners in this proposal included BLM (Utah, Idaho, and Nevada); USDA Forest Service, Rocky Mountain Research Station, Grassland, Shrubland and Desert Ecosystems Program, Boise, ID and Provo, UT; Utah Division of Wildlife Resources, Great Basin Research Center, Ephraim, UT; Utah Crop Improvement Association, Logan, UT; USDA Agricultural Research Service, Forage and Range Research Laboratory, Logan, UT; and USDA Agricultural Research Service, Bee Biology and Systematics Laboratories, Logan, UT. Other cooperators have been added over time to address specific research issues.

Project Priorities

The project covers development of native plant materials and practices for their use on degraded rangelands. Initial and ongoing priorities include: 1) development of native plant materials for restoration and the cultural practices required for their increase; 2) management or re-establishment of wildland seed sources; 3) technology to improve the diversity of introduced species monocultures; and 4) technology transfer. Focus of the Project is now shifting to include development of application strategies and technologies to improve native plant establishment. New projects in 2006 included studies to evaluate rangeland drills and determine appropriate native seed application rates. The BLM representatives recommend that following identification of a funding level for this proposal, the BLM representatives, with input from the cooperators, will develop priorities, given the available funding.

This document provides a review of work completed in 2006. Appendix I summarizes ongoing plant materials research and the principal investigators for each study.

Funding Strategy

This effort requires sustained funding over a long period to be successful. To meet this need, Interagency Agreements are used to transfer the majority of the approved funds to the USDA FS Rocky Mountain Research Station, Grassland, Shrubland and Desert Ecosystem Program.

Mike Pellant, Great Basin Restoration Initiative Coordinator, is the Contracting Officer's Representative for the Agreement. The BLM representatives recommend that following identification of annual funding levels, the BLM representatives, with input from the cooperators, will develop priorities. The Rocky Mountain Research, Grassland, Shrubland and Desert Ecosystems Program prepares or amends agreements with the other cooperators on this project and distributes funding to these other entities per the Interagency Agreement and annual task orders. The Rocky Mountain Research Station assesses a reasonable 12% indirect charge used internally to administer this assistance agreement with BLM for in-house funding. No indirect charge is assessed on pass-through funds to cooperators. An estimated 20 WM's per year will be required from FY02-08 for BLM coordination in the states of Utah, Oregon and Nevada, however, BLM will pursue these needs outside of this agreement.

Acknowledgments

We thank our collaborators for their expertise and in kind contributions that have made it possible to address the many issues involved in native plant materials development and use. We offer a special thanks to Durant McArthur for his continuing support and to Ann DeBolt for her assistance in writing and compiling this report and for her contributions to the Project.

Nancy Shaw, Team Leader
Great Basin Native Plant
Selection and Increase Project

Mike Pellant, Coordinator
Great Basin Restoration Initiative

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APPENDIX

Project Title: Plant Material Development, Seed Technology and Seed Production of Great Basin Forbs

Project Location: USDA-FS-RMRS, Shrub Sciences Laboratory, Boise, ID

Principal Investigators and Contact Information:

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Project Description:

Although forbs are components of most native communities, their use in revegetation has been limited. This work is being conducted to provide plant materials, seed supplies, and seed transfer guidelines for common forb species of the Great Basin. Efforts in Boise focus on seven species in three families: *Eriogonum umbellatum* (Polygonaceae); *Lomatium dissectum, L. grayi,* and *L. triternatum* (Apiaceae); *and Penstemon acuminatus, P. deustus*, and *P. speciosus* (Scrophulariaceae). Collaborative work in support of genecological research on several important native grass species (*Pseudoroegneria spicata*, *Achnatherum hymenoides*, and *Poa secunda*) led by project cooperators was initiated in 2006. We are beginning to develop application strategies and technologies to improve establishment of diverse native seedings that include species being developed through this project. Cooperative studies are examining the interactions of native restoration species with exotic wheatgrasses and invasives. We are also conducting a new project to evaluate rangeland drills, determine appropriate native seed application rates, and examine approaches for improving the establishment of Wyoming big sagebrush.

Project Status:

A. Native Plant Materials

1. Native Forbs (N. Shaw and A. DeBolt)
Penstemon spp.: In 2006, we made 11 bulk collections of *P. acuminatus*, 20 of *P. deustus*, and 5 of *P. speciosus*. Individual plant collections were made for 34 *Penstemon* populations (15-20 plants/population). Phenology, morphology, and seed production data were collected from dryland gardens established in 2004 at Orchard (*P. deustus*) and Niagra Springs (*P. acuminatus*). A new irrigated common garden of *P. speciosus* tubelings produced by the Lucky Peak Nursery were planted at the Nursery (13 sources) in May 2006 and survival data were collected in late summer.

Lomatium spp.: In 2006, we made 32 bulk collections of *L. dissectum*, 11 collections of *L. grayi*, and 17 collections of *L. triternatum*. Individual plant collections were made for 14 populations. Phenology, morphology, and flower and seed production data were collected for *L. grayi* and *L. triternatum* at the BSU common gardens established by direct seeding in fall 2004. *Lomatium dissectum* common gardens were established by direct seeding at Lucky Peak Nursery (46 sources; early October) and at Wells (44 sources; late September) in 2006.

***Eriogonum umbellatum*:** In 2006, we made 19 bulk collections of *E. umbellatum* and individual plant collections from 12 populations. Common gardens of tubelings produced by the FS Lucky Peak Nursery were planted at two irrigated locations, Lucky Peak Nursery (20 sources) and Boise State University (17 sources), and survival data were collected in late summer. An additional common garden of *E. umbellatum* will be planted at the Orchard dryland site in spring 2007.

2. Genecology of bluebunch wheatgrass (Brad St.Clair, R.C. Johnson, Nancy Shaw, Vicky Erickson): Research to examine genetic variation of bluebunch wheatgrass ([*Pseudoroegneria spicata* (Pursh) Á. Löve]) in relation to environmental gradients was initiated in 2005. Common gardens of 127 populations and five cultivars were established at Boise, ID; Pullman, WA; and Central Ferry, WA in fall 2006. Growth and phenological trait data will be collected in 2007 and 2008 for use in developing guidelines for seed transfer in the northern Great Basin and Pacific Northwest. (See also: Johnson and Hellier, this document).

3. **Seed collections** (A. DeBolt): We made 142 bulk collections of 19 species and 69 individual plant collections (15-20 plants/population) of 14 species in 2006. These included:

a. Boise research species: 115 collections, emphasizing *Lomatium dissectum* and *Eriogonum umbellatum* for common garden studies. Samples of the L. dissectum collections were provided to USDA ARS Pullman for molecular genetics studies and to USDA PNW for a genecology study.
b. Ephraim and Provo research species: 4 collections.
c. AOSCA project: Several collections.

d. USDA ARS Pullman, WA (R.C. Johnson): Twenty-five sources of Indian ricegrass (*Achnatherum hymenoides*) for common garden studies, most of these were collected through a contract with Berta Youtie, Eastern Oregon Stewardship Services.
e. National Seed Laboratory: 52 accessions of 12 species for seed germination studies and development of seed cleaning protocols (Table 1).
f. University of Idaho (S. Love): 3 collections of sulfur buckwheat for horticultural introduction evaluations.
g. USDA ARS EOARC, Burns (J. James): One collection of *L. dissectum* for physiological research.

Table 1. Accessions provided to the National Seed Laboratory.

Scientifc Name	Common Name	No. Accessions
Aristida purpurea	Purple threeawn	1
Agoseris glauca	Pale agoseris	2
Astragalus eremiticus	Hermit milkvetch	2
Balsamorhiza sagittata	Arrowleaf balsamroot	1
Crepis acuminata	Tapertip hawksbeard	1
Eriogonum heracleoides	Wyeth buckwheat	1
Eriogonum umbellatum	Sulfur buckwheat	5
Lomatium dissectum	Fernleaf biscuitroot	16
Lomatium grayi	Gray's biscuitroot	4
Lomatium triternatum	Nineleaf biscuitroot	4
Penstemon acuminatus	Sand penstemon	4
Penstemon deustus	Hotrock penstemon	11

4. Forb increase at Lucky Peak Nursery (A. DeBolt): Pale agoseris (*Agoseris glauca;* Nevada), rock buckwheat (*Eriogonum sphaerocephalum;* Oregon), Douglas false-yarrow (*Chaenactis douglasii*; Idaho), and showy townsendia (*Townsendia florifer*; Idaho) were sown in test plots at LPN in fall 2006 to evaluate their establishment and potential for seed production.

5. Native Germplasms (N. Shaw, A. DeBolt): Several germplasms from the earlier Greenstripping Program are to be released soon in cooperation with Steve Monsen:
a. Mountain Home Sandberg bluegrass: In cooperation with Mountain Home Air Force Base personnel and volunteers, 11 pounds of seed were collected at the 100,000 acre Saylor Creek Bombing Range on May 25-26. G0 seed (6.5 pounds) was distributed to a grower for increase and the remainder was sent to UCIA for the Buy-back program. The release notice is being drafted.
b. Eagle western yarrow: The release notice is being drafted.
c. Orchard Thurber's needlegrass: About 3.5 pounds of seed was collected southeast of Boise on June 6, 2006. G0 seed (2.5 pounds) was distributed to a grower for increase and the remainder was sent to UCIA for the Buy-back program. The release notice is being drafted.

6. Enclosure maintenance (A. DeBolt):

Boise State University: Control of rush skeletonweed has substantially reduced weed problems at this site.

Lucky Peak Shrub Garden: Rush skeletonweed (*Chondrilla juncea*) treatment is being continued in this 16-ha enclosure. Herbicide was spot-applied as needed on previously treated sites and an additional 1 ha was given initial treatment in 2006.

Orovada: A 2-ha area was sprayed with Round-up in spring to prepare new areas for future common garden plantings. The existing exclosure fence was repaired to ensure livestock exclusion.

Orchard: The enclosure fence was repaired by a BLM fire crew. Wildlife depredation (badgers, ground squirrels, jack rabbits) of plantings continues to be a problem.

Wells: Expansion of the enclosure was delayed until funds are available.

B. Restoration Ecology and Technology

1. Reestablishing diverse native Wyoming big sagebrush communities: a comparison of seeding equipment and techniques (R. Cox, N. Shaw, M. Pellant, and NRCS and Elko District BLM cooperators)

To evaluate the capabilities of the Kemmerer rangeland drill and the Truax RoughRider drill to seed seeds of diverse sizes and shapes at appropriate depths to reestablish grasses, forbs, and shrubs on former Wyoming big sagebrush sites, study plots were established at two locations near Elko, Nevada in October 2006. Locations were selected on areas that had burned in 2006. One location was selected on the East Humboldt fire about 10 miles SW of Elko. The second location was selected on the Gopher fire, about 10 miles N of Deeth, NV, which is about 30 miles NE of Elko.

Table 1. Species seeded and rates, in PLS/m^2.

Species	Seeding Rate, PLS/m^2 High	Seeding Rate, PLS/m^2 Low
Broadcast mix		
Wyoming big sagebrush	15.3	9.5
Rubber rabbitbrush	17.3	10.2
Eagle yarrow	171.1	105.9
Sandberg bluegrass	194.6	114.2
Rice hulls		
Total Broadcast	*398.3*	*239.8*
Drill seeding mix		
Fourwing saltbush	5.1	3.6
Blue flax	33.4	23.7
Munro globemallow	41.2	29.8
Bluebunch wheatgrass	94.8	67.7
Bottlebrush squirreltail	8.2	5.9
Indian ricegrass	54.8	39.1
Rice hulls		
Total Drill	*237.5*	*169.9*
Total Drill + Broadcast	**635.8**	**409.6**

At each location, 35 plots were established in 5 blocks (7 plots per block). Two seeding rates of native species plus a control of no seed were drilled into the plots on Nov. 7-10, 2006. An untreated “double control” (no seed and no drill) was also kept to provide adequate comparison. Species and rates seeded are listed in Table 1. BLM Elko Field Office personnel were instrumental in all stages of this project, including planning, site selection, treatment application, and logistics. Tom Warren, Stan Kemmerer, Mark Coca, Brock Uhlig, Mike Mowray, and Kyle Blackburn were especially helpful. Seeding was done by personnel from the NRCS Plant Materials Center in Aberdeen, ID, including Brent Cornforth, Charlie Bair, and Boyd Simonson. The broadcast mix was seeded by allowing seed to fall on the soil surface in front of either the furrow-chain (Kemmerer drill) or the Brillion packer wheels (Truax drill). The drill mix was seeded through the drill assembly. On December 19, 2006, autonomous weather stations were placed at each location to record rain, temperature, and soil moisture. Data collection will be in late spring/early summer, and include cover and frequency of all native and exotic species.

2. Equipment and strategies to enhance the post-wildfire establishment and persistence of Great Basin native plants (R. Cox, N. Shaw, M. Pellant, R. Karrfalt, D. Pyke and NRCS, BLM and FS Lucky Peak Nursery cooperators)
This study further investigates the capability of the Truax Rough Rider drill and the Kemmerer rangeland drill to reestablish Wyoming big sagebrush plant communities. The study will test seeding rates and methods for establishing Wyoming big sagebrush along with a mixture of other grasses, forbs, and shrubs and evaluate the physical placement of seeds in the soil by the two drills. Data collection will follow methods that are currently being recommended by the USGS for BLM use as standard techniques for ES&R monitoring, and data will be uploaded into a central ES&R monitoring database being developed by the USGS and will be permanently stored and available to land managers and researchers. In addition, the proposed study also facilitates analysis of long-term grazing effects on sagebrush seedings by establishing adjacent plots designed to allow grazing exclusion.

We will also track the viability of sagebrush seeds through long-term storage. Seedlots harvested at locations across the Great Basin have been cleaned to two purity levels and will be stored at three different storage temperatures and two moisture contents in two types of bags. Viability and moisture content will be tested periodically over a 5-year storage period. Results will aid in determining appropriate storage conditions and duration for holding big sagebrush seed beyond the season of harvest.

3. Requirements for dormancy break and germination in *Lomatium dissectum* seeds.
(M. Scholten, M. Serpe, Boise State University, and N. Shaw)
Seeds of *Lomatium dissectum* exhibit morphophysiological dormancy, common in the Apiaceae. We analyzed the effect of dry after-ripening, warm stratification, and cold stratification on embryo growth (Fig. 1a). Of these treatments, only cold stratification promoted embryo growth. During 12-weeks of cold stratification, the embryo length increased 6x with most growth occurring during the first 6 weeks.

Cold stratification promoted germination (Figure1b), but germination was less than 20% when embryos reached full length after 8 or 10 weeks. Release from dormancy in most seeds required an additional 5 to 6 weeks of cold stratification.

Embryo growth occurred at the three stratification temperatures tested (1, 6, and 11°C), but was greatest when stratification occurred at 6°C. After 14 weeks of stratification, there were significant differences in germination between seeds stratified at 1 and 6°C and those stratified at 11°C with little germination occurring at the highest temperature. Germination occurred when the seeds were under cold stratification at either 1 or 6°C and without transfer to warmer temperatures. Thus, in *L. dissectum* the temperatures that break seed dormancy are also adequate for germination.

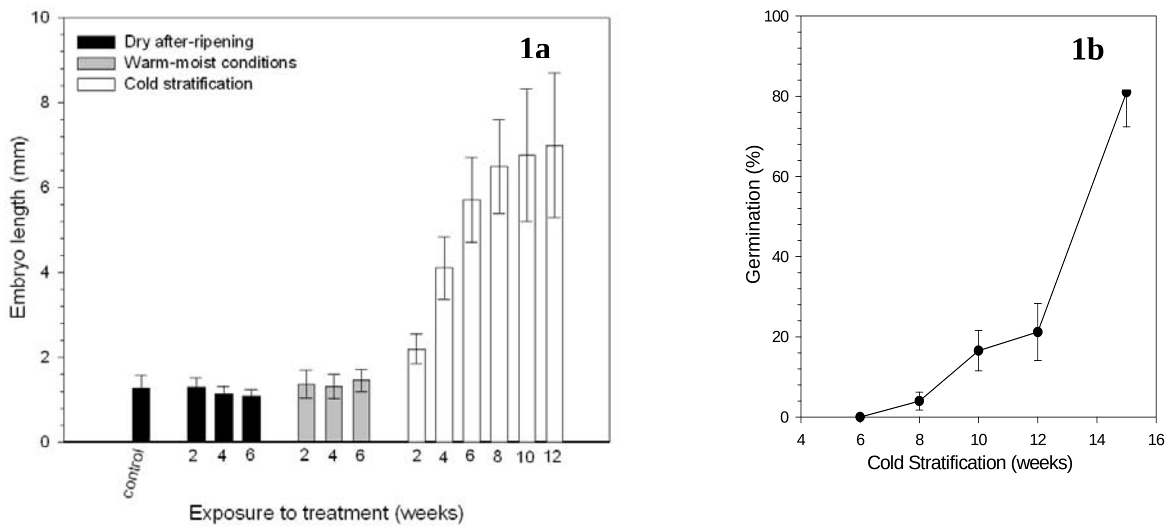


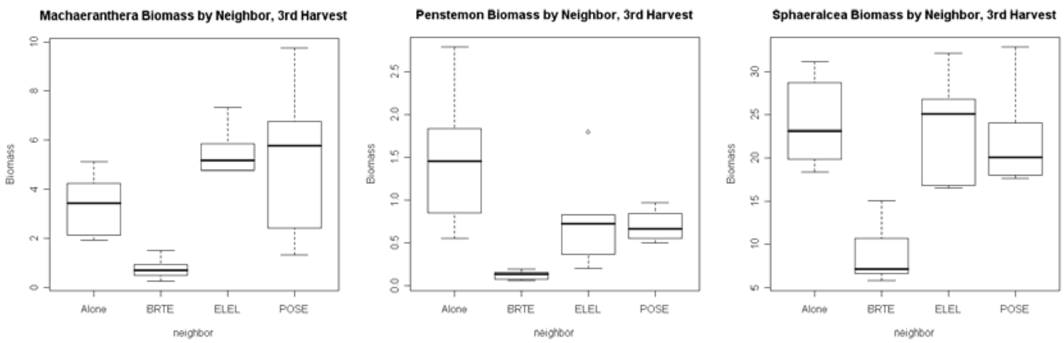
Figure 1. (a) Effect of dry after-ripening, warm-moist conditions, and cold stratification on embryo growth of *L. dissectum.* (b) Effect of cold-moist stratification on germination of *L. dissectum* seeds.

To analyze the effect of natural weather conditions on embryo growth and germination, we set an experiment in the field in mid November of 2005. Seeds in nylon mesh bags were placed in soil at a depth of 2 to 3 cm. Soil moisture sensors were placed near the seeds. Embryo growth and germination were promoted by soil temperatures between 0 and 10°C and soil moisture content above 5%. The temperatures and stratification conditions that promoted embryo growth and germination under field conditions were similar to those that were effective in the laboratory. Conditions associated with the release from dormancy in this species appear to be an adaptation to the climatic regime of the Great Basin to trigger germination in early spring.

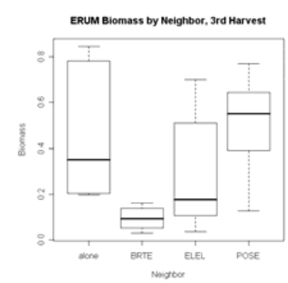
4. Does cheatgrass density limit the recruitment and growth of native forbs on Southern Idaho's Snake River Plain? (H. Parkinson, C. Zabinski, Dept. of Land Resources and Environmental Sciences, Montana State University, and N. Shaw)

Land managers require information on the biotic and abiotic factors that limit germination, survival and population establishment of native forbs. Understanding of phenology, growth and shoot and root morphology is needed to better understand how these species use resources in time and space. A greenhouse experiment was conducted to determine the relative growth rates of five forb species by harvesting them after 6, 9, and 12 weeks of growth, and to determine if forb response to a grass neighbor varied based on the identity of the grass neighbor. The five forbs were *Eriogonum umbellatum*, *Lomatium* sp., *Machaeranthera canescens, Penstemon speciosus,* and a *Sphaeralcea munroana/grossulariifolia* mixture (the *Lomatium* was misidentified as *L. grayi* and is possibly *L. ambiguum;* the *Sphaeralcea* was originally collected as *S. munroana* but turned out to be a mixture of both species). The native bunchgrasses included *Poa secunda* and *Elymus elymoides*, and the exotic annual, *Bromus tectorum*. *Machaeranthera canescens*, *P. speciosus*, and *Sphaeralcea* spp. biomass was significantly reduced when grown with *B. tectorum,* but biomass of these species was not reduced when grown with either of the native grasses.

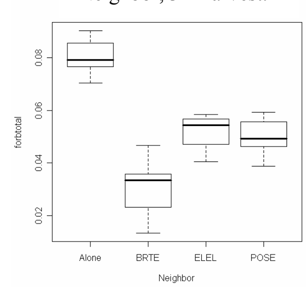
While environmental conditions in the field are different than conditions in the greenhouse (particularly in regards to phenology and soil moisture), these results suggest that seeding these three forbs with either of the two commonly seeded native grasses may not cause adverse forb-grass interactions during the critical stage of seedling establishment. It also suggests that despite the larger biomass and faster growth rate of *E. elymoides*, this grass is not significantly different as a competitor than the much smaller native *P. secunda.*



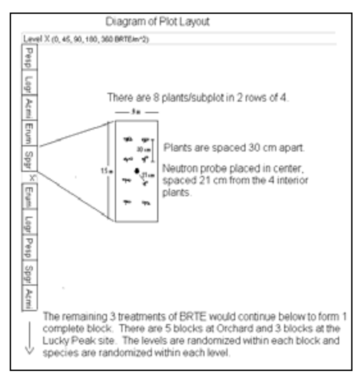
E. umbellatum biomass was similar when grown with *P. secunda* as when grown alone. Competition with *E. elymoides* or *B. tectorum* resulted in reduced *E. umbellatum* biomass. The biomass of the *Lomatium* species was significantly greater when grown alone than when grown with any of the grasses. As a taprooted species, it was postulated that its contrasting root morphology would limit negative forb-grass interactions.



Lomatium Biomass by Neighbor, 3rd Harvest.



To assess the effects of cheatgrass competition on forbs, five forb species were seeded in single species plots with increasing cheatgrass densities at two locations in southern Idaho: Lucky Peak Nursery (915 m) and the Orchard Research Site (930 m), both within 20 miles of Boise, ID. The forbs are *Achillea millefolium, Eriogonum umbellatum, Lomatium grayi, Penstemon speciosus* and *Sphaeralcea grossulariifolia*. *Bromus tectorum* was seeded to create densities of 45, 90, 180 and 360 plants/m^2. The plots are .9 x 1.5 m with forbs seeded in two rows of four for a total of 8 plants in each plot (see figure at right).



This experiment is designed to identify the biomass of cheatgrass at which native forb seedling survival and growth is reduced and to determine if this varies by forb species. To determine how soil water content changes with increasing densities of cheatgrass, and if this effect varies based on the forb species, a neutron probe will be used to measure soil water content in the control plots (forbs only) and in the plots seeded at 180 and 360 cheatgrass plants/m^2. Soil water content will be determined at depths from .2 - 1.2 m at 20 cm intervals beginning in early spring 2007 with measurements taken at 7-14 day intervals throughout the growing season.

5. Competitive dynamics among Siberian wheatgrass and native forbs and grasses (J. Muscha, M. Haferkamp, L. Vermeire, USDA ARS Fort Keogh LARRL, Miles City, MT, and N. Shaw)
Members of the crested wheatgrass complex (*Agropyron* spp.) have been planted in extensive monocultures in the interior western United States for many decades. These non-native monocultures are susceptible to or currently invaded by exotic annual grasses and forbs. Approaches are being examined to incorporate native species into these sites to enhance stand diversity and structure, however the residual wheatgrasses may interfere with establishment of natives. We examined competitive interactions of native grass/forb mixtures with Siberian wheatgrass (*Agropyron sibiricum*). Native species were two forbs - *Achillea millefolium* (ACMI) and *Penstemon speciosus* (PESP), and two grasses - *Elymus elymoides* (ELEL) and *Poa secunda* (POSE). Treatments were: 1) AGSI (1 plant); 2) AGSI (2); 3) AGSI (1), ELEL, ACMI, PESP; 4) AGSI (2), ELEL, ACMI, PESP; 5) ELEL, ACMI, PESP, 6) AGSI (1), POSE (2), ACMI, PESP; 7) AGCR (2), POSE (2), ACMI, PESP and 8) POSE (2), ACMI, PESP. Ten replicates of the treatments were grown in a greenhouse for 5 months. Greatest aboveground biomass was produced by AGSI (2 plants) (39.1 g), AGSI (1), ELEL, ACMI, PESP (37.4 g), and AGSI (1) (34.9 g). AGSI biomass was smaller when grown with any of the native plant combinations (24.7 g) than when grown alone (37.0 g). Biomass was twice as great for ELEL and nearly three times as great for POSE when grown without AGSI. Forb biomass was generally reduced by two AGSI (5.4 g vs 1.4 for ACMI, 0.9 g vs 0.6 g for PESP). Although competitive effects appear reciprocal, the impact on natives underscores the need to provide good wheatgrass control prior to seeding natives into these monocultures. The study will be repeated in 2007.

Management Applications

1. Documentation and description of the area of origin for Eagle yarrow, Mt. Home Sandberg bluegrass and Orchard Thurber’s needlegrass will guide managers in the appropriate use of these materials in southern Idaho and surrounding areas.
2. Examination of variation in native forbs (*Penstemon* and *Lomatium* species and *Eriogonum umbellatum*) and bluebunch wheatgrass in relation to environmental gradients will aid in delineation of seed transfer zones for the lower Snake River Plain and northern Great Basin.
3. Evaluation of competitive interactions among Siberian wheatgrass and native forbs and grasses will aid in selecting species and planting techniques for diversifying wheatgrass monocultures.
4. Studies on the phenology, relative growth rate and root morphology of native forbs species will improve our understanding of how these species utilize resources in time and space. This will aid in designing seed mixes and seedings to enhance partitioning of limited resources and reduce negative forb-forb interactions.
5. Establishment of diverse seed mixes requires new seeding equipment or modification of existing equipment. Ongoing research evaluates available drills and seeding rates for native species.
6. Reestablishment of Wyoming big sagebrush has been problematic. We are examining seeding techniques for improving seed-soil contact. Research is also examining

appropriate storage of sagebrush seed to permit carrying seed from time of harvest to seeding in the same or subsequent year.

7. Post-fire spread of rush skeletonweed (*Chondrilla juncea*) is primarily by root sprouting of existing plants; long distance spread is by seed.

Products

Publications:

Chambers, J.C; McArthur, E.D.; Monsen, S.B.; Meyer, S.E.; Shaw, N.L.; Tausch, R.J.; Blank, R.R.; Bunting, S.; Miller, R.R.; Pellant, M.L.; Roundy, B.A.; Walker, S.C.; Whittaker, A. 2005. Sagebrush steppe and pinyon-juniper ecosystems: effects of changing fire regimes, increased fuel loads, and invasive species. Fort Collins, CO: USDA FS Rocky Mountain Research Station. 66 p. Online: http://www.treesearch.fs.fed.us/pubs/23523

Hild, A. L.; Muscha, J. M.; Shaw, N. L. [in press]. Emergence and growth of four winterfat accessions in the presence of the exotic annual cheatgrass. In: Sosebee, R.E., comp. 2005. Shrubland dynamics: fire and water: proceedings; 2004 August 10-12; Lubbock, TX. Proc. Fort Collins, CO: USDA FS Rocky Mountain Research Station.

Kinter, C.L.; Shaw, N.L.; Hild, A.L.; Mealor, B.A. [in press]. Post-fire seed ecology of rush skeletonweed (*Chondrilla juncea* L.) - assessment of invasion potential. Rangeland Ecology and Management.

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DeBolt, A. 2006. Landscaping with native plants. University of Idaho Green Thumb Micro-College, Boise, ID (two presentations).

DeBolt, A. 2006. When ornamentals go bad. Idaho Rare Plant Conference Invasive Species Special Topics Session, Boise, ID.

DeBolt, A.; Shaw, N.L. 2006. Progress in the development of native forbs for Great Basin restoration. Joint meeting of the Northwest Scientific Association and Idaho Wildlife Society, Boise, ID.

Johnson, R.; Shaw, N. 2006. Provisional seed transfer zones for the Great Basin and Columbia River Plateau. National USFS and BLM Botanist and Geneticist Meeting, Las Vegas, NV. Also presented as a seminar at USDA R-9 Office, Milwaukee, WI.

Shaw, N. 2006. Native plants for public rangelands - USA. Revegetation Technology and Equipment Council. Society for Range Management 59th Annual Meeting, Vancouver, British Columbia.

Shaw, N. 2006. Great Basin Native Plant Selection and Increase Project.

a. Mojave Desert Native Plant Symposium and Workshop, Las Vegas, NV.
b. Intermountain Native Plant Summit IV, Boise, ID.
c. National USFS and BLM Botanist and Geneticist Meeting, Las Vegas, NV.
d. Nevada Emergency Stabilization and Rehabilitation Meeting, Las Vegas, NV.

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Shaw, N.L.; Gurr, J.; Scholten, D.L.; Scholten, M.D. 2006. Population structure and recruitment of winterfat as influenced by the presence of cheatgrass. 14th Wildland Shrub Symposium, Cedar City, UT.

Technology Transfer

Poster presentations ***(We thank Kerry Overton, Acting Program Leader, Boise Aquatic Sciences Laboratory, for presenting our posters at the Invasives Species meeting in Albuquerque, NM and the FS R4 Integrated Resources Workshop in Ogden, UT):***

Anon. 2006. Development of native forbs for the Great Basin. Society for Range Management 59th Annual Meeting, Vancouver, British Columbia. (presented by Shaw at the Rangeland Technology and Equipment Council meeting and the SRM tradeshow).

DeBolt, A.; Shaw, N.L. 2006. Progress in the development of native forbs for Great Basin restoration (poster/fact sheet).

- a. Invasive Species research in RMRS: Strengths, Needs, and Future Plans. Albuquerque, NM.
- b. USDA FS Region 4 Integrated Resources Workshop, Ogden, UT.
- c. Intermountain Native Plant Summit IV, Boise, ID.

Pellant, M.; Shaw, N. 2006. Great Basin Native Plant Selection and Increase Project. Workshop on Collaborative Watershed Management and Research in the Great Basin, Reno, NV

Scholten, M.; Shaw, N.L.; Serpe, M. 2006. Embryo growth and germination in *L. dissectum* seeds (poster/fact sheet).

- a. Joint meeting of the Northwest Scientific Association and Idaho Wildlife Society, Boise, ID
- b. Invasive Species research in RMRS: Strengths, Needs, and Future Plans, Albuquerque, NM.
- c. USDA FS Region 4 Integrated Resources Workshop, Ogden, UT.
- d. Intermountain Native Plant Summit IV, Boise, ID.

Scholten, M.; Zimmerman, S.; Shaw, N., Serpe, M. 2006. Requirements for embryo growth and dormancy break in *Lomatium dissectum*. Botanical Society of America, Chico, CA.

Shaw, N.L.; DeBolt, A.; Jensen, S.; Meyer, T.; Vernon, J.; Pellant, M.; Lambert, S.; Boruff, C. and cooperating state foundation seed agencies. 2006. Cooperative native seed increase program. Society for Range Management 59th Annual Meeting, Vancouver, British Columbia (Rangeland Technology and Equipment Council Meeting and the SRM tradeshow).

Shaw, N.L.; Pellant, M. 2006. The Great Basin Native Plant Selection and Increase Project: plant materials for the Great Basin and surrounding areas (poster/fact sheet).

- a. Invasive Species research in RMRS: Strengths, Needs, and Future Plans, Albuquerque, NM.
- b. USDA FS Region 4 Integrated Resources Workshop, Ogden, UT.
- c. Intermountain Native Plant Summit IV, Boise, ID.
- d. National USFS and BLM Botanist and Geneticist Meeting, Las Vegas, NV.
- e. Mojave Desert Native Plant Symposium and Workshop, Las Vegas, NV.

Meetings, Committees and Field Tours – Planning and Participation:

DeBolt: Participant on seed increase contract review team for Umatilla National Forest, Pendleton, OR.

DeBolt: 0.5 day field tour in Boise area for UI field ecology class.

DeBolt: Oregon State University, Malheur Experiment Station Field Day tour, Ontario, OR.

Shaw: Planning committee for 2006 RTEC Annual Meeting: Seeding Equipment and Native Plant Materials in Canada and the US: New Approaches and Products, Vancouver, B.C.

Shaw, DeBolt: GBNPSIP 2006 annual meeting, Salt Lake City. Planned meeting and gave reports.

Shaw: Planning for GBNPSIP Symposium, SRM 2007, Reno, NV.

Shaw: Organizer for sage-grouse habitat session for SERNW/SWS PNW annual meeting, September 2007, Yakima, WA and co-chair of poster sessions.

Shaw: Planning committee, Native Wildflower Seed Production Research Symposium, July 2007, Orlando, Florida.

Shaw, DeBolt: Field evaluation of original Mountain Home Sandberg bluegrass collection area, the Saylor Creek Training Range, with Chief of Conservation, Mountain Home Air Force Base, and Steve Monsen.

Project Title: Forb and Shrub Genetics Research

Project Location: USDA-FS Shrub Sciences Laboratory, Provo, UT

Principal Investigators and Contact Information:

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Reporting for work funded, in part, by both the USDI Bureau of Land Management Native Plant Selection and Increase Project and USDA Forest Service National Fire Plan (Cooperators USDA Forest Service Rocky Mountain, Pacific Northwest, and Pacific Southwest Research Stations; Utah Division of Wildlife Resources, and Brigham Young University).

Project description:
This work is designed to determine the levels of genetic variation of plant species used or with potential for use in rehabilitation and restoration of fire impacted and other disturbed sagebrush steppe and pinyon-juniper ecosystems. Additional genetics work is also underway in delimiting seed transfer zones for restoration plant materials. The genetic variation research is designed to explore both within and between population variation by using isozyme and molecular genetic markers. It also explores the possible genetic consequences of past revegetation plantings by comparing the genetic architecture of source populations, seeded populations, and indigenous populations adjacent to the seeded populations. Work to date suggests that genetic patterns need to be assessed on a species by species basis and take into account pollination systems and population size. We briefly summarize the initial results from isozymes, DNA-based molecular genetics (AFLPs, ISSRs, RAPDs, cpDNA), revegetation plantings, gene flow, and seed transfer zones.

Isozymes and DNA based molecular genetics: Over 30 species (6 shrubs, 3 grasses, and 26 forbs) and more than 180 populations have been examined in a series of studies. These include *Artemisia tridentata, Astragalus utahensis, Atriplex canescens, Balsamorhiza sagittata, Bromus carinatus, Castilleja miniata, Chrysothamnus nauseosus (Ericameria nauseosa), Crepis acuminata, Epilobium angustifolium (Chamerion angustifolium*), *Erigeron pumilus, Eriogonum umbellatum, Linum lewisii, Linum perenne, Lomatium dissectum, Lomatium grayi, Lupinus argenteus/sericeus, Penstemon deustus, Penstemon palmeri, Penstemon speciosus, Phlox longifolia, Sphaeralcea ambigua, Sphaeralcea grossulariifolia, Stipa comata, Vicia americana, and Viguiera multiflora (Heliomeris multiflora)*].

Revegetation plantings gene flow: Several species are being examined in this portion of the study. Results for *Linum, Sphaeralcea, Penstemon, Artemisia, Chrysothamnus,* and *Atriplex* are available. The results are species specific. Many but not all of the studied seedings show that the seeded populations lie within the natural range of the indigenous genetic architecture. *Linum perenne* in the form of 'Appar' blue flax has been seeded widely in revegetation plantings. It has not hybridized with native *L. lewisii* nor is it likely to based on artificial hybridization experiments.

The work of the above studies is progressing toward a summary status. The first significant output will be a Rocky Mountain Station General Technical Report summarizing all of the collection and research information. From that summary more detailed publications will be developed and submitted to peer reviewed outlets. The methods were reported in previous annual reports.

Management applications: This information, when completed and fully evaluated, will be useful for managers when they need to make decisions about the appropriateness restoration seeding, e.g., will the seeding be appropriate in maintaining the natural variation and genetic integrity of the site under consideration.

Publications:

Miglia, K. J., E. D. McArthur, W. S. Moore, H. Wang, J. H. Graham, and D. C. Freeman. 2005. Nine-year reciprocal transplant experiment in the gardens of the basin and mountain big sagebrush (*Artemisia tridentata*: Asteraceae) hybrid zone of Salt Creek Canyon: the importance of multiple-year tracking of fitness. Biological Journal of the Linnean Society 86: 213-225.

Thompson, T. W., B. A. Roundy, E. D. McArthur, B. D. Jessop, B. Waldron, and J. N. Davis. 2006. Fire rehabilitation using native and introduced species: a landscape trial. Rangeland Ecology and Management 59: 237-248.

Abstract:

Garcia, S., T. Gamatje, S. C. Sanderson, E. D. McArthur, and J. Vallès. 2005. Genome size variation in the endemic sagebrush and their allies (*Artemisia,* Anthemideae, Asteraceae) of North America. Abstract P0644, XVII International Botanical Congress, Vienna, Austria.

Project Title: Status of Work with *Astragalus, Agoseris, Lupinus, Phlox* and *Hesperostipa*

Project Location: USDA-FS Shrub Sciences Laboratory, Provo, UT

Principal Investigator and Contact Information:

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Project Description:
A core objective of the GBNPSIP is identifying and selecting plant material germplasm to meet the seed needs of rehabilitation and revegetation efforts in the Great Basin. At the outset of the GBNPSIP in 2001, staff at Provo selected species from several genera for germplasm evaluation. Wildland seed collections of *Agoseris aurantiaca, A. glauca, A. grandiflora, A. heterophylla, Astragalus utahensis, Lupinus arbustus, L. argenteus, L. caudatus, L. polyphyllus, L. sericeus, Phlox longifolia,* and *Hesperostipa comata* have accumulated since that time. Initial germplasm work focused on germination requirements, greenhouse propagation methods and seed related issues. In recent years, as our germplasm pool has increased, common gardens have been established to evaluate morphological and phenological attributes as well as site adaptation. Pilot studies evaluating increase plot establishment techniques have been a continual part of the program and cultural practice studies have been implemented to assess potential yields under cultivation. In all these efforts, we have had many failures and many successes. As these species have been observed in field settings it is apparent the crux of eventual success with many has less to do with selecting the best biotype and more to do with developing cultural techniques for economical production. Plants with the combined traits of irregular seed ripening and seed shatter are extremely costly to produce. To eventually see these species in the market will require specialized growing and harvesting practices. Thus, complementing our germplasm selection program is a growing effort in cultural practices.

Project Status:
2006 Seed Collections and New Site Locations: Typically, small quantities of seed are harvestable from a given site any particular year. Research needs often exceed the seed we have available for a given biotype, thus, where necessary, annual seed collections are made at known sites. Whenever new populations are found, we desire to represent these biotypes in the selection process. Continual efforts are made to record newly discovered populations. In 2006, 78 new sites were recorded and seed collections were made at 88 sites.

Equipment: To evaluate production methods, a subsurface drip tape layer and weed barrier layer were purchased. A 3-shank subsoiler was purchased to prepare the ground for the subsurface drip tape layer and fracture hardpans caused by years of cultivation. A small rock tumbler was purchased to evaluate its utility in scarifying seed. Metal working equipment was purchased to permit construction of two sprayers. Piped sprinkler systems were designed and bid for field sites at Fountain Green and Ephraim, UT.

Plant Material Evaluation and Increase: Beginning in 2004, as plant material collections began to approximate the Great Basin distribution of individual species, common gardens were planted to evaluate biotypes. Prior to these plantings, and annually since, small scale seeding trials have been conducted to evaluate various planting methods and establish increase plots. The following summarizes those efforts.

1. Fountain Green:
Cultural Practice Studies: Cultural practice studies evaluating 3 mulch treatments and 3 plant spacings were installed using plugs of *Agoseris* and *Lupinus*. All plants went dormant shortly after transplanting. We anticipate low survival on this plot.

Increase Plots - Project priority species:
Phlox longifolia – seeded in weed barrier 10/06. Efforts to increase this species through transplanting plugs have failed.
Agoseris grandiflora - Plugs were installed with a tree transplanter.

Increase Plots - Opportunistic collections: Comparative production plots were installed with *Heliomeris multiflora*. The comparison evaluates seeding rate, establishment, weeding effort and seed yield. A replicated plot was established with a precision drill, seeding 20, 40, 60 or 80 pls seeds/linear foot with a pre-emergent herbicide banded between the seeded rows and powdered charcoal banded with the seed. Charcoal deactivates the chemical upon contact. The second plot was hand planted on weed barrier with a 2-foot spacing within and between rows. Both plots will be overhead irrigated through establishment, then subsurface irrigated with drip tape.

2. Nephi, UT:
Common Garden Establishment:
Astragalus utahensis – 27 biotypes transplanted 4/06
Lupinus arbustus – 13 biotypes transplanted 4/06
Lupinus argenteus – 9 biotypes transplanted 4/06
Lupinus caudatus – 5 biotypes transplanted 4/06
Lupinus polyphyllus – 2 biotypes transplanted 4/06
Lupinus sericeus - 3 biotypes transplanted 4/06

Increase Plots: *Agoseris glauca* and *Agoseris grandiflora* - Plugs of each were transplanted into weed barrier fabric.

Other studies: *Astragalus utahensis* fungal study field trials planted in cooperation with Dr. Brad Geary of BYU.

3. Wells, NV:
Common Garden Establishment:
Hesperostipa comata – 60 biotypes direct seeded 11/ 06
Lupinus arbustus – 14 biotypes transplanted 4/06

Lupinus argenteus – 10 biotypes transplanted 4/06
Lupinus caudatus – 5 biotypes transplanted 4/06
Lupinus polyphyllus – 2 biotypes transplanted 4/06
Lupinus sericeus - 3 biotypes transplanted 4/06

4. Orovada, NV:
<u>Common Garden Establishment</u>:
Astragalus utahensis – 16 biotypes planted with a tree transplanter 4/06
Hesperostipa comata – 60 biotypes direct seeded 11/06

5. Snow College Farm:
<u>Common Garden Establishment</u>: *Hesperostipa comata* – 60 biotypes direct seeded 11/06.

<u>Increase Plots</u>: Four species of lupine (*Lupinus argenteus* - Nephi Canyon, UT; *L. arbustus* – Deep Creek, UT; *L. polyphyllus* - Tintic, UT; *L. caudatus* – Winnemucca Mountain, NV) were planted in increase plots. Seedbeds were prepared by sub-soiling, then installing 1 line of drip tape (T1508LR-15mil 8 OC low flow) 12 inches deep in the center of the bed. One inch of NutriMulch was spread over the bedding surface and incorporated to a depth of 4 inches. Beds were then packed and flattened with a Brillion seeder and covered with 5' x 250' woven weed barrier fabric. Three-inch holes spaced at 2-foot intervals within and between rows were burned into the fabric with an electric branding iron powered with a truck mounted power inverter. Where appropriate, seed was scarified by boiling water treatment and planted at 4-5 seeds/hole.

Agoseris aurantiaca and *A. glauca* - Plugs were transplanted into fallow plots.

6. Ely, NV: We anticipate a new 10-acre test site will be established near the Hwy 6/318 Junction west of Ely, NV in 2007. The Ely BLM office is assisting with clearances and preparations.

Products:
Equipment: Weed control costs are a significant factor in the profitability of any native forb seed production operation. We designed and built two sprayers to evaluate their utility and effectiveness in weed control operations. The first is an ATV mounted hooded sprayer, the second a pre-emergent band sprayer.

The ATV sprayer is designed around two streamlined 20" spray hoods attached to a telescoping frame. The telescoping frame allows the hoods to be appropriately positioned on both sides of a row crop. The contoured spray hoods slide under the canopy of taller plants and deliver herbicide to the ground to maintain a weed free area between planted rows. The hooded design is intended to prevent herbicide drift to the adjacent crop. This permits the use of herbicides that may be detrimental to the planted crop. The sprayer mounts on the front rack of an ATV and is supplied by a rear mounted ATV spray tank.

The pre-emergent band sprayer is an attachment to a Hege 1000 series drill. The sprayer delivers adjustable width bands of pre-emergent herbicide between seeded rows. Liquefied charcoal is sprayed over the seeded row to deactivate herbicide that may drift. Additionally, powdered charcoal is delivered by a separate bulk seed box and banded with the seed to further mitigate against herbicide movement toward the seeded row.

Stock Seed: A Nevada source of *Agoseris heterophylla* was increased in our greenhouse to provide additional seed for future work. Approximately 15 grams of seed were produced on 30 ft^2 of bench. This seed is currently being increased again with an anticipated production of 2 lbs.
Pilot trials for greenhouse increase of *Agoseris grandiflora* were conducted.

Publications:
Jensen, Scott L. 2007. Propagation protocol for production of container *Agoseris grandiflora.* In: Native Plant Network. URL: http://www.nativeplantnetwork.org. Moscow, ID: University of Idaho, College of Natural Resources, Forest Research Nursery.

Jensen, Scott L. 2007. Propagation protocol for production of container *Agoseris aurantiaca.* In: Native Plant Network. URL: http://www.nativeplantnetwork.org. Moscow, ID: University of Idaho, College of Natural Resources, Forest Research Nursery.

Jensen, Scott L. 2007. Propagation protocol for production of container *Agoseris glauca.* In: Native Plant Network. URL: http://www.nativeplantnetwork.org. Moscow, ID: University of Idaho, College of Natural Resources, Forest Research Nursery.

Jensen, Scott L. 2007. Propagation protocol for production of *Agoseris heterophylla.* In: Native Plant Network. URL: http://www.nativeplantnetwork.org. Moscow, ID: University of Idaho, College of Natural Resources, Forest Research Nursery.

Jensen, Scott L. 2007. Propagation protocol for production of container *Astragalus utahensis.* In: Native Plant Network. URL: http://www.nativeplantnetwork.org. Moscow, ID: University of Idaho, College of Natural Resources, Forest Research Nursery.

Jensen, Scott L. 2007. Propagation protocol for production of container *Lupinus arbustus*. In: Native Plant Network. URL: http://www.nativeplantnetwork.org. Moscow, ID: University of Idaho, College of Natural Resources, Forest Research Nursery.

Jensen, Scott L. 2007. Propagation protocol for production of container *Lupinus argenteus.* In: Native Plant Network. URL: http://www.nativeplantnetwork.org. Moscow, ID: University of Idaho, College of Natural Resources, Forest Research Nursery.

Jensen, Scott L. 2007. Propagation protocol for production of container *Lupinus caudatus.* In: Native Plant Network. URL: http://www.nativeplantnetwork.org. Moscow, ID: University of Idaho, College of Natural Resources, Forest Research Nursery.

Jensen, Scott L. 2007. Propagation protocol for production of container *Lupinus polyphyllus.* In: Native Plant Network. URL: http://www.nativeplantnetwork.org. Moscow, ID: University of Idaho, College of Natural Resources, Forest Research Nursery.

Jensen, Scott L. 2007. Propagation protocol for production of container *Lupinus sericeus.* In: Native Plant Network. URL: http://www.nativeplantnetwork.org. Moscow (ID): University of Idaho, College of Natural Resources, Forest Research Nursery.

Jensen, Scott L., Stephen B. Monsen, and Pat Fosse. Spatial and Temporal Seed Dispersal of Squarrose Knapweed (*Centaurea virgat*a Lam. spp. *squarrosa* (Willd.) Gugler) in West Central Utah, a Case Study. 14th Wildland Shrub Symposium – Shrublands Under Fire, June 6-8, 2006 Cedar City, Utah.

Technology Transfer:

Presentations:

Jensen, Scott. 2006. Status of plant materials development work for ten Great Basin species. GBNPSIP annual coordination meeting, Salt Lake City, UT.

Jensen, Scott. 2006. The GBNPSIP: looking back and forward. Native Vegetation Restoration Workshop, Ephraim, UT.

Posters:

Whittaker, Alison; Jensen, Scott L. 2006. Effects of fire and restoration seeding on establishment of squarrose knapweed (*Centaurea virgata* var. *squarrosa*). 14th Wildland Shrub Symposium: Shrublands Under Fire: Disturbance and Recovery in a Changing World, Cedar City, UT.

Tours:

Jensen, Scott. 2006. Discussion of field plots. Native Vegetation Restoration Workshop, Ft. Green, UT.

Attended a tour of Pacific Northwest Seed Growers. June 2006.

Project Title: Native Plant Material Development and Seed and Seeding Technology for Native Great Basin Forbs and Grasses

Project Location: Great Basin Research Center, Ephraim, Utah.

Principal Investigators and Contact Information:

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Project Description:
This project was organized for the collection, testing, selection and development of forb and grass species and/or ecotypes for habitat improvement in the Great Basin. A suite of species was chosen as desirable for restoration of degraded ecosystems throughout the area (Table 1). The species were chosen either for their usefulness as important food for wildlife or as diminished or missing constituents in the various ecosystems.

Table 1. Species under study.

Plant Family	Plant Code	Genus Species	Common Name
Apiaceae	CYMOP	*Cymopterus* sp.	Spring-parsley
Apiaceae	LOGRGR	*Lomatium graveolens* var. *graveolens* (syn: *L. nuttallii*)	Stinking lomatium
Apiaceae	PEBO2	*Perideridia bolanderi*	Yampah
Asteraceae	BAHO	*Balsamorhiza hookeri*	Hooker balsamroot
Asteraceae	BASA	*Balsamorhiza sagittata*	Arrowleaf balsamroot
Asteraceae	CRAC	*Crepis acuminata*	Tapertip hawksbeard
Asteraceae	CRIN	*Crepis intermedia*	Gray hawksbeard
Capparaceae	CLLU	*Cleome lutea*	Yellow beeplant

Plant Family	Plant Code	Genus Species	Common Name
Fabaceae	HEBO	*Hedysarum boreale*	Northern sweetvetch
Fabaceae	HEOC	*Hedysarum occidentale*	Western sweetvetch
Malvaceae	SPCO2	*Sphaeralcea coccinea*	Scarlet globemallow
Malvaceae	SPGR	*Sphaeralcea grossulariifolia*	Gooseberryleaf globemallow
Malvaceae	SPPA	*Sphaeralcea parvifolia*	Nelson globemallow
Poaceae	ELCI	*Elymus cinereus (Leymus c.)*	Great Basin wildrye
Poaceae	POFE	*Poa fendleriana*	Muttongrass
Poaceae	POSE	*Poa secunda*	Sandberg bluegrass
Poaceae	STCO3	*Stipa comata (Hesperostipa c)*	Needle-and-thread grass
Polygonaceae	EROV	*Eriogonum ovalifolium*	Cushion buckwheat

Project Status:

Seed Collection and Testing:

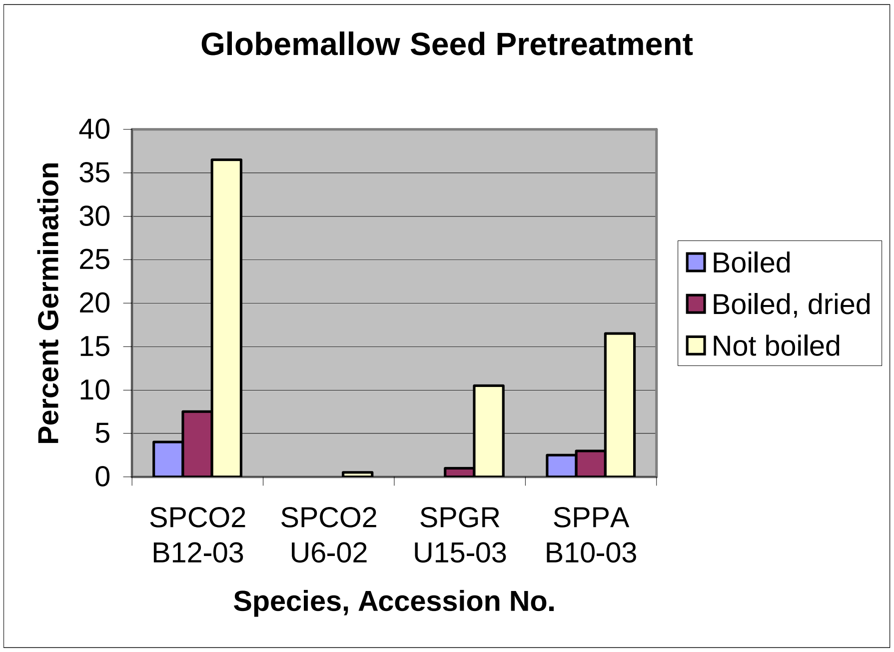
In 2006 the GBRC staff made 31 wildland seed collections of 13 species of forbs and grasses in Utah and Nevada (Table 1), totaling approximately 1,630 grams of cleaned seed. Wildland seed production in our seed collection area was very poor in summer 2006. This may have been a result of late freezing in much of our collection range. Remaining flowers then appeared to be heavily preyed upon by herbivores, both insect and large browsers.

Seed cleaning, inventory, and database work was continued. The database now registers 904 collections of 44 species of forbs and grasses.

Germination tests continued in 2006. In-house germination experiments were completed on the following: CRAC/CRIN--33 accessions; EROV--19 accessions; BASA--38 accessions; Apiaceae including PEBO2--12 accessions; *Sphaeralcea* (SPGR, SPPA, SPCO2)--43 accessions.

More germination work on *Sphaeralcea* was done in 2006, specifically, applying the hot-water treatment suggested by Stan Kitchen, but with careful timing and temperature control. Again, boiling the seed gave lower germination percentages than merely planting the seed untreated (Fig. 1). Other treatments described in the literature (for instance: soaking seed for 12 to 24 hours in water initially at boiling temperature, but removed from the heat source before the seed is added (Graham 2003)) will be tried next. Additionally, a study trial was initiated on the use of sulfuric acid to break down the dormancy of scarlet globemallow seed (Roth and others 1987).

Figure 1. Globemallow seed germination following hot water treatments.



Timing of planting:

Experience with direct-seeding demonstrated that for some of the species we are studying (BASA, CRAC, PEBO2, and EROV), it is difficult to accumulate enough stratification to break seed dormancy when seeds are planted in early March. This agrees with our experiments with stratification on these species which show that they require 1-4 months of stratification to break seed dormancy. This means that in wildland plantings using these species, seeding may have to occur in fall. *Sphaeralcea* spp. and *Hedysarum* spp., however, do not require stratification and although they both might profit from some sort of heat treatment, scarification, or inoculation with beneficial organisms, it is possible to get some germination without these treatments.

To better understand seed fate and the causes of stand failure in direct-seeded plantings, we initiated a seed retrieval experiment with six of our principal forb species: BASA, CRAC, EROV, PEBO2, HEBO, SPGR. We planted the study at Fountain Green in September 2006, with two subsequent retrievals. Retrievals will resume in the early spring. A second planting will be placed in March of 2007 and retrieved throughout the summer and fall.

Results from the first two retrievals showed that the species have different responses to planting in fall. Results from the second retrieval are presented here (Fig. 2). EROV, SPGR and HEBO suffered the highest seed mortality at over 30%. BASA and CRAC seed suffered less than 15% mortality, and PEBO2 had almost no seed mortality. Some seed of two species, SPGR and HEBO, was hard and exhibited no apparent changes 2 months after planting. This seed was still hard, intact and had not imbibed water. HEBO had the greatest germination at

23%. CRAC, BASA and EROV had between 7-10% germination, SPGR had only 1% germination, and the PEBO2 had no germination.

The most interesting seed condition was the imbibed portion: these were seeds that were fully imbibed but which had not yet germinated. Presumably these seeds were undergoing stratification required to release the embryos from dormancy. The species with the highest percentage of fully imbibed seeds was PEBO2, which had 98% in this condition. This correlated well with previous germination studies demonstrating that PEBO2 required approximately 4 months of cold stratification to germinate. Both CRAC and BASA had about 80% imbibed seed, SPGR and EROV had 45-55%, and HEBO had the smallest percentage imbibed at 16%.

From these data, we predict that fall planting may not be advised for SPGR and HEBO because of high overwinter seed mortality. EROV is problematic, since fall planting results in fairly high seed mortality, but spring planting may not allow sufficient stratification to break seed dormancy. For this species, therefore, fall planting will probably be required, and land managers will have to accept some loss of viability over the winter. The other three species, PEBO2, BASA and CRAC probably require fall planting for the best outcome, specifically to overcome embryo or seed coat dormancy.

The repeat of this experiment will be planted in spring 2007, as well as the remainder of the retrievals of this fall planted series, will further elucidate seed fate among these species. We also intend to install soil moisture and temperature monitors in this study to correlate the soil environment with the seed responses.

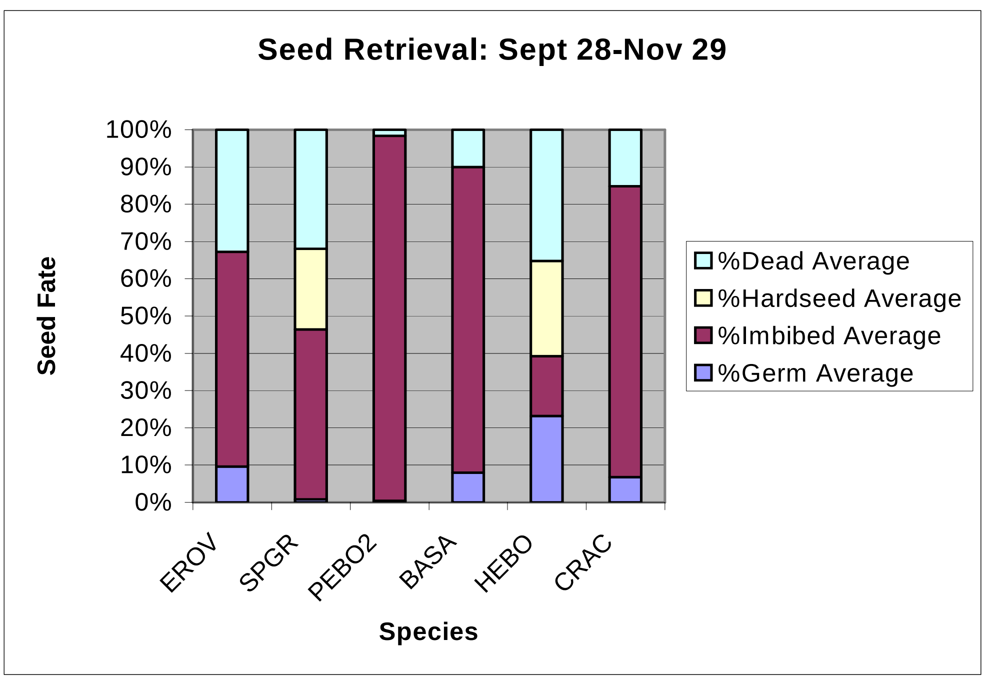


Fig. 2. Fall seed retrieval (2 months of data).

Spacing and Weed Barrier Study:

In May 2006 we installed a study at Fountain Green to evaluate two weed barrier mulches compared to bare ground, and also planted two of our study species' plugs (CRAC and BASA) at various spacings in the weed barrier trials. The entire trial is under drip irrigation, with each species on a separate system. The treatments are in a Latin Square design with six replicates. This is a continuation of the work started by Brigham Young University at the Spanish Fork Farm, because that study did not include all of the species. The trial is still in the establishment phase, and we are experiencing problems with keeping the weed barriers in place. If necessary, we will re-install the weed barriers and replant the plugs.

Field Trial Common Gardens:

Direct-seed Planting:

In order to expose the seed to sufficient stratification for germination, we direct seeded a large trial of most of the research forb accessions (all but *Hedysarum*) in November of 2005 using the Hege 1000 precision planter at the Fountain Green experimental farm. Each common garden had approximately 10 forb species, with a total of more than 110 accessions with each accession in five repeated blocks per garden.

The 2005 spring-planted Wells trial was unsuccessful with the exception of a few *Hedysarum* plants. The 2005 spring-planted Fountain Green trial also failed: there was not enough cold, wet weather after the planting to successfully stratify the seed, so, of six species groups planted, only *Hedysarum* germinated well in the first year and I was able to get some trait data from the trial. The remainder of the trial was tilled up in July 2006.

In the spring of 2006 some of the accessions in the 2005 fall planted trial in Fountain Green germinated, particularly in the BASA, CRAC/CRIN, and a few of the *Perideridia* lines. Overall the stands in the trials were poor and the weeds were out-competing, so the trials were tilled out in July 2006.

Plug production for trials and seed increase:

Greenhouse propagation for common gardens continued and several trials were planted: Plug seedlings were produced in the greenhouse for field trials of *Sphaeralcea* (12 accessions to Fountain Green), *Eriogonum* (25 accessions to be planted in spring 2007 at Fountain Green), *Balsamorhiza* (38 accessions to Wells and Orovada, Nevada), *Crepis* (57 accessions to Wells and Orovada, Nevada). A new greenhouse planting of all of our *Sphaeralcea* accessions is in production for late spring planting in a new, enlarged trial at Fountain Green.

Scarlet globemallow seed of one accession that performed well in previous trials has been planted in the greenhouse to produce plugs to be planted at Snow Field Station to increase seed quantity.

In a cooperative activity with the Forest Service Shrub Sciences Laboratory, 40 flats (~4,000 plants) of *Linum lewisii* 'Maple Grove' were grown in Ephraim for a seed increase field planting in the Fountain Green exclosure. Insufficient isolation distance from other cooperator's *Linum* plants preclude use of seed from this field for foundation seed at the present, but we expect that conflict to be resolved in 2007 or 2008. Alternatively, recent work by one of the cooperators (McArthur) suggesting that the two species of *Linum* do not introgress with each other, may allow us to use this seed in spite of the proximity. DWR will irrigate, weed, and harvest seed from the planting for other uses until such time as Forest Service determines that the seed is needed for foundation purposes.

Two large trial plots of bluebunch wheatgrass using plug transplants produced by the ARS successfully established at the Wells, NV exclosure and at the Nephi Farm in March of 2005. Harvests in 2006 from these plantings (dry matter, seed production and fill, seed weights, and germination) are currently being evaluated in our laboratory.

Products:

Results Based on Common Gardens:

Based on the existing forb common gardens, we have been able to gather enough trait data on *Sphaeralcea, Eriogonum, Hedysarum* and *Perideridia* to begin to narrow the fields on those species with regard to choosing up to four accessions per species to focus on with the goal of releasing them. Part of the selection process will involve using geographic, Ecoregion and Ecological Site Description information for those accessions. Not all of the ecological data has been gathered, but we are working with collaborators to obtain it and combine our maps.

We have 2 years of field data on the *Hedysarum* trial in Fountain Green. The trial is spotty, but with five replicates we have been able to observe plant habit, flowering and fruiting. Based on this, we have focused on three accessions that have potential. A new *Hedysarum* trial will be planted by direct seeding this spring. More data on plant and seed production (in particular, seed shatter vs. seed retention) will be collected from the mature, 3-year old trial.

The Ephraim common garden has yielded data on *Sphaeralcea* and *Eriogonum*. The Fountain Green common garden of *Sphaeralcea* is the largest trial we have of that species and has been very helpful in gaining information on plant habit, size, flowering and fruiting. In both of these trials, the most important information has thus far been to clarify the identity of all accessions Particularly with *Sphaeralcea*, determining species has been very confusing.

Likewise for *Eriogonum* we have been able to determine species and observe, among the EROV accessions, which ones performed the best in terms of winter survival, growth and establishment, and flowering. The next trait to be evaluated will be seed production. EROV produces imperfect and perfect flowers on individual plants, starting with imperfect (either male or female functional) and later in the flowering cycle, perfect flowers. We wish to monitor this physiological function more closely to assure seed will be produced in sufficient quantity.

The *Perideridia* and *Lomatium* trial in Ephraim is small, but we have been able to observe which accessions demonstrated the most robust growth and reached maturity most rapidly.

Some of the accessions flowered in the second field season, and one of these robust accessions has been distributed to a grower for increase.

The *Crepis* (CRAC/CRIN) trial in Ephraim, although spotty, began flowering in 2006. In both greenhouse production and field trials, CRIN (a species probably derived from a hybrid origin between CRAC and CROC [C*repis occidentalis*] consistently showed more robust growth than CRAC, supporting the idea that this species has some fixed heterosis. The CRIN plants survived better than the CRAC plants, and many more accessions of CRIN flowered in the field than CRAC accessions. Although the temptation is to proceed with CRIN to the exclusion of CRAC, analysis of the native distribution of the species' throughout Utah shows that CRAC is more common, and therefore is probably preferable to CRIN for our purposes. The trial will be continued, and more data will be obtained in the coming season.

The BASA and CRAC/CRIN trials in Nevada will be evaluated throughout the spring and summer of 2007. We hope to obtain enough information from the Ephraim trial and the Nevada trials of CRAC and CRIN to choose one or two accessions to put into seed increase plots that will seeded in fall of 2007.

BASA, of all of our lead species, shows the least progress in our program due to difficulty with establishment and slow maturity. Hopefully some headway with this species will be made in the Nevada common gardens.

Seed Increase and Cooperator Studies:
We distributed seed and/or seedlings/plugs to cooperators and other entities to be used for seed increase and research purposes:

Janett Warner of Wildland Nursery in Joseph, UT: 360 CRAC seedlings/plugs for seed increase.

Ann M. DeBolt, for a grower (Mustoe) in Oregon: seed of CRAC U36-04 for seed increase.

Robert Fitts, Pleasant Grove: CRAC and BASA seedlings/plugs, 60 of each. PEBO2 seed one accession, 0.8g for seed increase.

Kevin Heaton, USU Extension, Panguitch: 1200 seedlings/plugs of CRAC and CRIN for seed increase.

Robert Johnson, BYU: seed of BASA, CRIN, CRAC and PEBO2 for insect herbivory studies.

Jeremy James, USAD-ARS Burns, OR: seed of LILE, SEMU2 and PEBO2 for a study on weed versus native competition.

Tuan Beddes, USU, Logan, UT: seed of one *Sphaeralcea* accession for horticultural work.

David Van Tassel (associate of Stan Kitchen, FS Shrub Lab): LILE seed for research.

Clint Shock, OSU Malheur Exp. Station: SPGR seed, and 480 seedling plugs of CRAC for irrigation studies.

Brad Geary, Brigham Young University (via Scott Jensen): CRAC, CRIN, BASA, and SPGR seed for fungal transfer studies.

Corey Ransom, USU Department of Plants, Soils, and Biometeorology: CRAC seed for herbicide studies.

Rhonda Pace, Brigham City, UT: We are currently growing SPGR and CRAC plugs for this gardener/farmer for seed increase for research.

Publications, Presentations, Posters:

Meyer, T. 2006. Presented progress on the forb work at the Annual Native Plant Summit meeting in Boise, ID.

Meyer, T.; Vernon, J. 2006. Hosted a tour of the GBRC facility and discussed current research activities for the Utah Division of Wildlife Central Region, Ephraim, UT.

Meyer, T. 2006. Selections and Increase of Native Plants for Rehabilitation of Disturbed Wildlands. Shrublands Under Fire: Disturbance and Recovery in a Changing World, Wildland Shrub Symposium, Cedar City, UT

Meyer, T.; Vernon, J. 2006. Presentations and tour of GBRC facility for Utah State University, Agricultural Extension Agents, Ephraim, UT.

Meyer, T.; Vernon, J.; Whittaker, A. 2006. Presentations and tour of GBRC facility for Utah Partners in Conservation and Development/Great Basin Restoration Initiative meeting, Ephraim, UT.

Meyer, T. Vernon, J.; Whittaker, A. 2006. Growing Native Seeds as a High-Value Agronomic Crop. Utah Agricultural Extension Alternative Agriculture Workshop, Cedar City, UT.

Vernon, J.; Meyer, T.; Whittaker, A. 2006. Tour for Governor Huntsman's Economic Team and Department of Natural Resources Director's Office, Ephraim, UT.

Vernon, J.; Meyer, T.; Whittaker, A., and other GBRC staff. 2006. Hosted the Plant Community Restoration Workshop, Ephraim, UT.

Vernon, J.; Memmott, K. 2006. Species Selection, Remedial Plans, Utilizing High Quality Adapted and Ecologically Adapted Species. Plant Community Restoration Workshop, Ephraim, UT.

Vernon, J. 2006. Provided research updates at the Tri-state Interagency Plant Materials Committee annual meeting, Elko, NV.

Vernon, J. 2006. Site Preparation and Seeding. Plant Community Restoration Workshop, Ephraim, UT.

Meyer, T.; Jensen, S. 2006. Update on Native Forb Development Program at GBRC. Plant Community Restoration Workshop, Ephraim, UT.

Vernon, J.; Whittaker, A. 2006. Tour of GBRC facility and discussion of seed needs and uses. Plant Community Restoration Workshop, Ephraim, UT.

Meyer, T. 2006. Great Basin Research Center (Utah Division of Wildlife Resources)

Native Forb Development. Distributed on a CD to Plant Community Restoration Workshop attendees, Ephraim, UT.

Meyer, T. 2006. Growing Native Seed as High-Value Agronomic Crop: Alternative Agriculture Meeting of the Panoramaland Resource Conservation and Development Council, USDA Service Center, Richfield, UT.

Meyer, T. 2007. Simplified Dichotomous Key for Common Utah Globemallows. Utah Native Plant Society Newsletter, January 2007.

Meyer, T.; Vernon, J. 2007. Attended Society for Range Management 60th Annual Meeting and Trade Show in Reno, NV.

Meyer, T.; Vernon, J. 2007. Native Forb Development for Wildland Restoration: Research Update from the Great Basin Research Center. Society for Range Management 60th Annual Meeting and Trade Show, Reno, NV.

Technology Transfer:

a) April, June, and September 2006 and January 2007: Presented specific information to agency representatives about species we are developing and their potential use and applicability in habitat restoration projects.

b) September 2006: T. Meyer and J. Vernon presented information and demonstrated restoration equipment in Fairview, Utah, for attendees at the Plant Community Restoration Workshop.

c) November 2006: T. Meyer met with Bureau of Land Management representatives to discuss collaboration on native seed development, and to deliver native seed collections (58 kilos) that we had cleaned for them.

d) January 2007: T. Meyer updated and revised .pdf handouts describing the need for native seeds in the Great Basin and the potential for private growers to produce the seed.

e) January 2007: J. Vernon provided information and advice to Jan Anderson of the Utah Farm Bureau concerning native seed availability for the Great Basin and seed transfer zones for fourwing saltbush in the Mojave desert.

f) February 2007: Sent out .pdf files of information for potential native seed growers to Jan Anderson of the Utah Farm Bureau.

g) February 2007: T. Meyer sent out .pdf files of information for potential native seed growers to Erik Feiler in Boulder, Utah.

Management Applications:

a) Seed planting time protocols based on germination studies and seed retrieval studies will aid restoration biologists planning seedings to maximize the outcome of seed application.

b) Seed planting time protocols will aid native seed growers in maximizing stand establishment.

c) Weed barrier mulch and spacing studies will be important tools for native seed growers to reduce costs for weed control, and to maximize seed production through proper plant spacing.

References:

Graham, Jean. 2003. Propagation protocol for production of container *Sphaeralcea ambigua* Gray plants (1 gallon PVC Pipe container); Joshua Tree National Monument Native Plant Nursery, Twentynine Palms, California. In: Native Plant Network. URL: http://www.nativeplantnetwork.org. Moscow (ID): University of Idaho, College of Natural Resources, Forest Research Nursery.

Roth, T. E., Holechek, J. L., Hussain, M. Y. 1987. Germination response of three globemallow species to chemical treatment. Journal of Range Management 40 (2): 173-175.

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

Project Location: USDA-ARS Western Regional Plant Introduction Station (WRPIS), Pullman, WA

Principal Investigators and Contact Information:

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Project Description:
The conservation and utilization of native plant resources in the western United States is becoming increasingly important ecologically and economically, yet genetic information to identify locally adapted seed sources for restoration and reclamation is generally lacking. An understanding of the geographic and ecological distance that plant material should be transferred from original source populations is critically needed. *Allium acuminatum* Hook. (Taper-tip onion) is an important Great Basin forb associated with healthy rangeland and good habitat for sage-grouse. Studies using molecular markers and phenotypic traits are being conducted to determine genetic variation and seed transfer zones of *A. acuminatum* across the Great Basin. Genetic resource management strategies based on biological conservation principals will be developed leading to identification of candidate *in-situ* reserves (sites on federal lands where key populations are located). Populations maintained *in-situ* would provide conservation of genetic variation representing eco-geographic areas in the Great Basin. In addition, *ex-situ* conservation will be carried out at the USDA-ARS gene bank at Washington State University, Pullman, WA. Gene bank conservation will provide 1) readily available, source-identified genetic resources for research and increase and 2) security back-up of *in-situ* sites. Overall, this project will provide information to federal agency policy makers, Plant Material Centers, and commercial collectors/producers to improve genetic quality and production efficiency of this species.

Objectives:

1. Collect and maintain native *Allium acuminatum* (Taper-tip onion) for use in restoration and reclamation on western public lands.
2. Link ecological-geographic variation with genetic variation of *Allium acuminatum* to identify key populations for conservation and to delineate seed transfer zones.
3. Identify candidate *in-situ* sites for the conservation of *Allium acuminatum* genetic variation representing eco-geographic areas in the Great Basin.

Project Status: In 2005, 55 populations of *A. acuminatum* were collected from eastern Oregon, southern Idaho and northeastern Nevada. In spring 2006, plants were established in common gardens located at Pullman and Central Ferry, Washington sites. Plants were evaluated for numerous phenotypic factors. Data analysis showed that plant attributes differed according to location and thus varied across the Great Basin. In addition, DNA was extracted from bulks of 20 plants for each collection site and a total of 167 SRAP (Sequence related amplified polymorphism) molecular markers were derived from 9 primer pairs. Using the STRUCTURE program, the molecular data distinguished five main groups. Although there was some overlap, differences among locations and geographic areas were found. Thus both the phenotypic and molecular data confirmed the existence of genetic variation for *A. acuminatum* across the Great Basin. This suggests that population differences should be considered when using this species for revegetation. In 2007, continued phenotypic evaluations will be completed in the common gardens and genecology studies similar to those outlined by Johnson et al. (2004) will be continued to determine seed transfer zones for *A. acuminatum*.

<u>Collections</u>: In 2005, *A. acuminatum* bulbs were collected from 55 populations throughout eastern Oregon, southern Idaho and northeastern Nevada (Fig. 1). Potential population locations were gathered from herbaria records and US Forest Service and Bureau of Land Management personnel. This information was organized into a spreadsheet for field use and entered into a GIS-based map to aid in collection planning. We had two collecting teams of two persons each, one focused on Oregon and Idaho, the other team collected in Nevada. Each team followed the same collection protocol. First the population size and area were estimated. Then 40 to 50 bulbs per population were collected from across the given population. Only populations with 250 or more individuals were collected so *in situ* population integrity was not compromised. Collections were made from June 17 to July 2, 2005 and spanned 1430 m (4692 ft) of elevation and covered approximately 620 km (385 mi.) east-west and 445 km (277 mi.) north-south, between N 39° to 44° latitude and W 114° to 119° longitude. *Allium acuminatum* was collected in 20 of the Level IV Omernick Ecoregions across the Great Basin.

<u>Common Gardens</u>: Bulbs were planted in the greenhouse and vernalized at 4°C. After plant emergence, leaf tissue was collected for DNA marker analysis. Plants were transplanted to the field in the spring of 2006. Common gardens were established at Pullman, WA (780 m elevation; 46° 43’ 28.05” N and 117 08’ 07.94”W) and Central Ferry, WA (206 m elevation; 46° 41’ 52.78” N and 117° 39’ 52.55” W). Four plants from each of the 55 collection sites were randomized in five complete blocks at both locations. Thus there were 1,100 plants established at each site. In 2006, plants were evaluated for the factors in Table 1. For eight of

the 11 factors there were significant location effects (Table 1). Differences in bolting, flowering, and seed maturity dates occurred along with differences in leaf number, and flower and umbel characteristics. This shows that *A. acuminatum* from different locations had developed at different rates and had different morphological attributes, and that it may be possible to model adaptation zones based on environmental data. There were also significant garden site by collection location interactions for bolting and seed maturity dates, and for flower color.

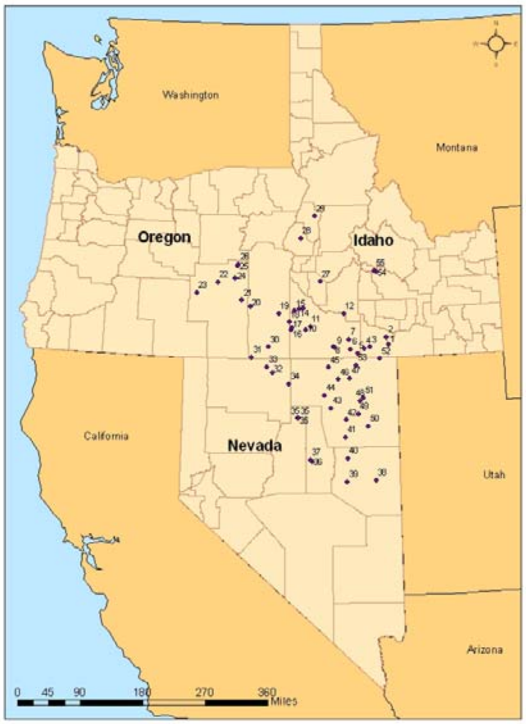

Figure 1. Collection locations for *Allium acuminatum* in 2005 representing 20 level IV Omernick ecoregions.

This shows that for these traits, differences in where the plants were grown modified their development and flower color. The implication is that seed from one location planted in another will grow and develop differently then local material and as such may be ecologically unsuitable.

The number of plots evaluated at the two sites (n in Table 1) varied widely as many plants senesced soon after transplanting to the field. In 2006, many plants showed active growth in the 4°C vernalization chamber and these often became dormant soon after transplanting. This is not expected in 2007 as bulbs are under natural field conditions.

Molecular Markers: Using nine primer pairs and Sequence Related Amplified Polymorphisms (SRAP) (Li and Quiros, 2001), 167 unambiguous polymorphic markers were scored for each of the 55 *A. acuminatum* collections. The STRUCTURE program as described by Evanno et al. (2005) was used with the marker data to find five main *A. acuminatum* groups for Great Basin germplasm. Although there was overlap, the groups tended to cluster in different geographic areas across the collection area. Thus, both the field evaluation and molecular markers showed differences among *A. acuminatum* populations from different collection locations. This means that continuing work to define seed zones is needed to ensure that properly adapted material is used for restoration.

Table 1. *Allium acuminatum* ANOVA summary from common gardens at Pullman and Central Ferry, WA sites and 55 collection locations (2006).

Factor	n	mean	CV	Prob. Site	Prob. Loc	Prob. Site X Loc
Leaves/plant	467	2.17	19.5	ns‡	<0.001	ns
Plants w/leaves	469	2.74	30.4	<0.001	<0.001	ns
Bolting date†	248	113	4.0	<0.001	<0.001	0.003
Scape length (mm)	230	99.8	28.8	ns	<0.001	ns
Scape dia. (mm)	231	1.71	28.4	ns	ns	ns
Flowering date†	229	146	2.23	<0.001	<0.001	ns
Flower color (1-8)	230	6.95	11.4	ns	<0.001	0.008
Flowers/umbel	227	15.6	38.6	0.012	0.020	ns
Umbel dia.(mm)	227	37.1	25.6	0.023	ns	ns
Seeds/plant	170	15.7	70.9	0.001	ns	ns
Seed Maturity date†	183	174.8	6.72	<0.001	0.024	<0.001

†Day of year; ‡ns, not significant; flower color from 1, white to 8, purple

Future plans: In 2007, data collection will continue for leaf, scape, flower and umbel characteristics at the common gardens in Pullman and Central Ferry. Additional leaf characteristics will include leaf color, habit, length, and width. Phenotypic variation within and among populations will be determined and compared with molecular variation using multivariate statistics. This will show if and to what extent molecular and phenotypic evaluation data correlate. The phenotypic data will be analyzed to understand patterns of variation across the Great Basin in relation to climatic and ecological factors. This information will be used to establish adaptation zones and to guide conservation and revegetation decisions for *A. acuminatum* in the Great Basin.

As this work is completed, informed decisions on seed transfer zones and population selection for potential *in situ* conservation/seed collection sites for *A. acuminatum* will be made. Then, as funding permits, work on seed production and stand establishment across the landscape will be pursued. For *Allium* there are two options for establishing field stands; sowing of true seed or dormant bulbs. Both methods are used in production of *A. cepa,* onion and *A. sativum,* garlic. The small size of *A. acuminatum* bulbs lends themselves to planting with conventional mechanical seeders. These two methods of stand establishment for *A. acuminatum* will be tested. Seeding rates and densities, weed control, methods for lifting bulbs from soil, and mechanical harvest will be examined. This will give the needed information on stand establishment and agronomic factors for seed production.

Products: Plant germplasm appropriate for restoration of Great Basin environments is being developed and conserved.

Publications:

Adair, R., R.C. Johnson, B.C. Hellier, W. J. Kaiser. 2006. Collecting Taper-Tip Onion (*Allium acuminatum* Hook.) in the Great Basin using traditional and GIS methods. Native Plant Journal 7: 141-148.

Technology Transfer:

<u>Presentations 2006</u>

March 28. Diversity of *Allium acuminatum* in the Great Basin. Robert Adair, R.C. Johnson, Barbara Hellier, and Walter Kaiser. Poster presented at the Intermountain Native Plant Summit IV, 28-30 March 2006, Boise ID.

March 28. Interagency cooperation in collection, characterization, and storage of native plant germplasm. Mike Cashman, Tamra Putensen, R.C. Johnson, and Peggy Olwell. Poster presented at the Intermountain Native Plant Summit IV, 28-30 March 2006, Boise ID.

April 13. Invited speaker. R.C. Johnson. Agency Partnerships: Sound policy for native genetic resources, at the Joint USFS and BLM Botanist and Geneticist Meeting, Las Vegas, NV. 9-13 April 2006.

Management Applications:

This work on Taper-tip onion and other key Great Basin species is providing the research needed to develop adapted germplasm for restoration in the Great Basin. So far we have found clear differences in populations, suggesting important differences in adaptation across the Basin exist. In addition, long-term conservation and management of species needed for restoration are being maintained within the National Plant Germplasm System. This provides security back-up for native populations that may be lost.

Other Activities:

Genecology of Bluebunch Wheatgrass (Brad St. Clair, R.C. Johnson, and Nancy Shaw)

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. Many restoration projects using bluebunch wheatgrass rely upon the cultivars 'Goldar' and 'Whitmar', and to a greater extent on the newly available germplasms, Anatone and P-7. Another cultivar, 'Secar', was originally misidentified and released as bluebunch wheatgrass, but is now recognized as a separate taxon, Snake River wheatgrass. The cultivars and germplasms have proven useful over a wide range of environments, with different cultivars or germplasms being better adapted to different areas. Goldar and Whitmar are better adapted to uplands and mesic sites, whereas Secar is better adapted to lower and drier areas. However, no research has examined genetic variation in relation to environment across the Great Basin and the greater range of bluebunch wheatgrass in a large set of diverse populations. Genecology, that is, understanding genetic variation in relation to environmental variation, is a critical consideration when choosing germplasm for restoration on diverse sites.

In 2005, seed was collected from about eight western states including many locations in the Great Basin. In fall 2006, 127 diverse populations, each represented by two families, along with five cultivars, were established in common gardens at Pullman, WA, Central Ferry, WA, and at the USFS Lucky Peak Nursery northeast of Boise, ID. In-depth evaluation of these populations at each site for growth and development traits will be initiated in spring 2007. Results from this study will be used to develop guidelines and appropriate source material for revegetation and restoration in the northern Great Basin and adjacent areas.

Indian Ricegrass Common Gardens and Collections (Mike Cashman and R.C. Johnson)

Indian ricegrass [*Achnatherum hymenoides* (Roem. & Schult.) Barkworth] is among the most important species in the Great Basin. Current releases of Indian ricegrass are useful but we know of none derived specifically from and for the Great Basin. Information on how populations vary across the landscape and which may be most appropriate for a given area is lacking. Considering the importance of Indian ricegrass in the Great Basin plant community, germplasm specifically adapted to Great Basin environments appears to be critically needed.

Currently available at the Pullman gene bank are Indian ricegrass collections primarily from the eastern and southern regions of the Great Basin, extending into Colorado, Arizona, and New Mexico. In spring 2007, a diverse set of 120 populations of this material will be planted in a common garden at Central Ferry, WA for evaluation of key growth and developmental traits. Genecology studies to understand the variation in Indian ricegrass across a large area of the Western U.S. and to recommend germplasm best adapted for restoration will be conducted. Since additional material specific to the Great Basin is needed, additional collections are being made. These will form the basis of additional studies and will include families within collection locations to more fully assess genetic variation across the landscape. So far, 35 Indian ricegrass accessions have been collected and collection will continue in 2007.

Sandberg bluegrass (unfunded)

Sandberg bluegrass (*Poa secunda* Presl.) is a dominant perennial on much of the steppe vegetation in the Great Basin, providing cover and forage for livestock and wildlife. Yet current germplasms and cultivars of the Sandberg bluegrass complex, including Mountain Home, Reliable, 'Sherman' big bluegrass (*Poa ampla* Merr.), and 'Canbar' (*P. canbyi* Scribn.) were collected either on the fringe or completely out of the Great Basin. Material collected within the Great Basin proper may be better adapted and more suitable. Considering the importance of Sandberg bluegrass in the Great Basin plant community, source identified germplasm for the Great Basin is critically needed.

Collections of Sandberg bluegrass from diverse sites and ecological areas in the Great Basin were initiated in 2006 and will be continued in 2007. So far 29 populations have been collected, including families within collection locations. This material will be used to establish common garden studies in contrasting environments and measure numerous traits associated with growth and development. That data will be used to identify seed transfer zones along with complementary *in situ* conservation sites. Seed of adapted material will be available through the USDA-ARS Pullman gene bank.

Publications:

Adair, R., R.C. Johnson, B.C. Hellier, and W. J. Kaiser. 2006. Collecting taper-tip onion (*Allium acuminatum* Hook.) in the Great Basin using traditional and GIS methods. Native Plants Journal 7: 141-148.

Literature Cited

Evanno, G., S. Regnaut, and J. Goudet. 2005. Detecting the number of clusters of individuals using the software *STRUCTURE*: a simulation study. Molecular Ecology. 14: 2611-2620.

Johnson, G.R., F.C. Sorensen, J.B. St. Clair, and R.C. Cronn. 2004. Pacific Northwest seed zones: A template for native plants? Native Plants Journal 5: 131-140.

Li, G. and C.F. Quiros. 2001. Sequence-related amplified polymorphism (SRAP), a new marker system based on a simple PCR reaction: its application to mapping and gene tagging in *Brassica*. Theor. Appl. Genet. 103: 455-461.

Table 2. Expected timeline from collection to seed production for species needed for Great Basin restoration and under study at the Germplasm Testing and Research Unit, Pullman WA					
Species	**Collection completed**	**Genecology completed**	**Adapted populations identified†**	**Initial seed increase**	**Initial Seed production**
Allium acuminatum (Taper-tip onion)	2005	2007	2008	2009	2010
Achnatherum hymenoides (Indian ricegrass)	2005; additional completed 2007	1st study in 2008; 2nd study in 2009	2008 for 1st study; 2010 for 2nd study	2009, 1st study 2011, 2nd study	2010, 1st study 2012, 2nd study
Pseudoroegneria spicata (Bluebunch wheatgrass)	2005	2008	2009	2010	2011
			Others of interest (Unfunded)		
Poa secunda (Sandberg bluegrass)	2007	2010	2011	2012	2013
Leymus cinereus (Great Basin wildrye)	2008	Planning stage	Planning stage	Planning stage	Planning stage
Lupinus sp.	Planning stage	Planning stage	Planning stage	Planning stage	Planning stage
Achillea millefolium (Yarrow)	Planning stage	Planning stage	Planning stage	Planning stage	Planning stage

†Including potential *in situ* sites

Project Title: - Establishment and Maintenance of Certified Generation 1 (G1) Seed
- Propagation of Native Forbs
- Plant Display Nursery Evaluation
- Development of Technology to Improve the Diversity of Introduced Grass Stands

Project Location: USDA NRCS Aberdeen, ID Plant Materials Center

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Project Description:
Production of Certified Generation 1 (G1) seed of Maple Grove Germplasm Lewis flax, Anatone Germplasm bluebunch wheatgrass, Snake River Plains Germplasm fourwing saltbush, and Northern Cold Desert Germplasm winterfat to facilitate commercial seed production. Propagation of native forbs for evaluation and seed increase. Evaluation of display nursery near Boise, ID. Development of technology to improve the diversity of introduced grass stands by evaluating methods to introduce native species into established plant communities.

Project Status:
Seed Production: Maple Grove Germplasm Lewis flax: A new seed field (3.2 acres) was planted on May 24, 2006. The seed field established in 2005 (also 3.2 acres in size) was contaminated with 'Appar' blue flax so harvested seed could not be certified. This field is now being used to conduct herbicide tolerance trials in cooperation with the University of Idaho. The new field established in 2006 was also contaminated with Appar. It appears that the stock seed to plant both fields was contaminated with Appar. Approximately two-thirds of the new field was plowed out and the remaining plants will be rouged carefully to remove Appar plants. Seventy pounds of Certified seed was shipped to commercial growers in 2006.

Anatone Germplasm bluebunch wheatgrass: Currently 5.2 acres are in production. Estimated seed yield from the 2006 seed crop is 1,090 pounds. Three hundred fifty pounds of Certified seed was shipped to commercial growers in 2006.

Snake River Plains Germplasm fourwing saltbush: Estimated seed yield from the 2006 crop is 20 pounds. No seed was requested by commercial growers in 2006.

Northern Cold Desert Germplasm winterfat: Estimated seed yield from 2006 crop is 11 pounds. We shipped 5 pounds of Certified seed to commercial growers in 2006.

Propagation Studies: The original project plan in 2005 was to propagate 8,000 plants total of *Lomatium dissectum* (LODI) fernleaf biscuitroot, *Lomatium grayi* (LOGR) Grays biscuitroot, *Lomatium triternatum* (LOTR) nineleaf biscuitroot, *Eriogonum umbellatum* (ERUM) sulphurflower buckwheat, *Penstemon deustus* (PEDE) hotrock penstemon, *Penstemon acuminatus* (PEAC) sharpleaf penstemon, and *Penstemon speciosus* (PESP) sagebrush penstemon in the greenhouse. Approximately 1000 plants each of ERUM and LOTR were to be transplanted at the Plant Materials Center (PMC) and the remaining plants were to be made available to cooperators for transplanting at field sites. Due to no plant establishment of *Lomatium* species and minimal success with greenhouse propagation of *Penstemon* species, no plants were made available to cooperators. All plants that were successfully propagated in the PMC greenhouse were transplanted at the PMC during the 2005 growing season and direct dormant seeding of *Eriogonum*, *Lomatium* and *Penstemon* accessions was completed at the PMC in November 2005. Weed barrier fabric was installed to control weeds.

On June 13, 2006 and October 27, 2006 the plants that were direct-seeded the preceding fall were evaluated for survival (see table).

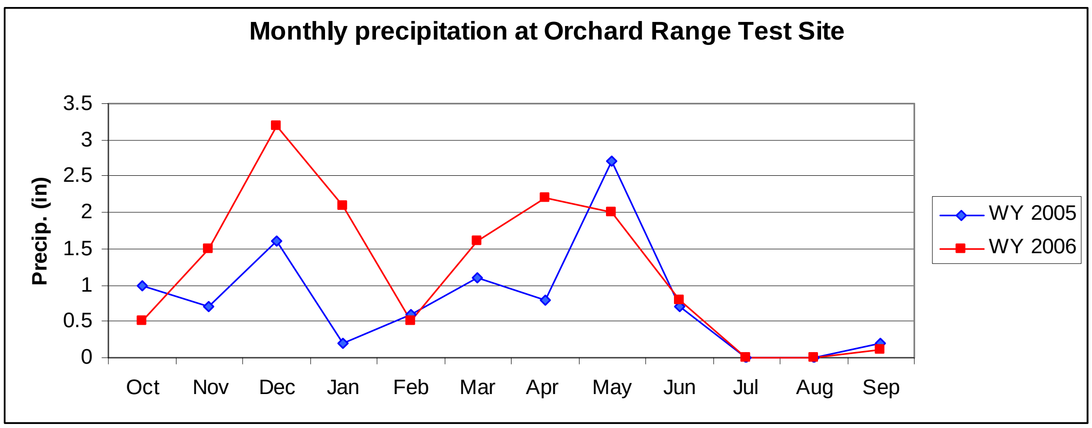
Species	6/13/06 Survival (percent)	10/27/06 Survival (percent)	10/27/06 Plant Height (cm)	Clean seed (grams)
ERUM	40	40	10-15	31.8
LODI	25	dormant		
LOGR	65	dormant		
LOTR	70	dormant		
PEAC	60	68	20-25	1362.0
PEDE	50	58	20-25	1180.0
PESP	60	60	10-20	0.0

The evaluation conducted in June was an estimate of survival and the October evaluation was an actual plant count. By early July, the *Lomatium* plants had gone completely dormant. There was no sign of green-up this fall, so survival of these plants is unknown and will be evaluated in the spring of 2007. Seed was harvested and cleaned from ERUM, PEAC and PESP.

Orchard Display Nursery Evaluation Summary

Introduction

The Orchard Display Nursery was planted on November 16, 2004 in cooperation with the Great Basin Native Plant Selection and Increase Project. The nursery contains 82 accessions of 27 native and introduced grass, forb and shrub species. Each accession was planted in 7 X 60 foot plots. See Tilley et al. (2005) for descriptions of the species and accessions planted. The remaining area was planted to a cover crop mix of 50% Anatone bluebunch wheatgrass, 20% Bannock thickspike wheatgrass, 20% Magnar basin wildrye and 10% Snake River Plains fourwing saltbush. The test site is located on a loamy 10-12 inch precipitation ecological site that historically supported a Wyoming big sagebrush/ bluebunch wheatgrass/Thurber's needlegrass plant community. Total precipitation at the Orchard Test Site for water year 2005 was 9.6 inches, and total accumulated precipitation for water year 2006 was 14.4 inches (USDA 2006).



The Bureau of Land Management (BLM) burned the site in the fall of 2002. The site was sprayed by the PMC staff in May 2003 and May 2004 with a Roundup and 2, 4-D herbicide mix to create a weed free seedbed. Due to limited breakdown of dead grass clumps that would inhibit proper seed placement with a drill and to ensure a clean seedbed, the decision was made to cultivate the site with a culti-packer just prior to seeding. Plots were evaluated for initial establishment on April 27 and May 5, 2005. During the first evaluation most plots contained high numbers of Russian thistle (*Salsola* sp.) and moderate amounts of bur buttercup (*Ranunculus testiculatus* Crantz) plants. Russian thistle plants were approximately 2 to 3 inches tall and bur buttercup had already flowered. At the time of the second evaluation, there was a heavy infestation of tumblemustard (*Sisymbrium altissimum* L.). Plots were consequently sprayed again on June 9, 2005 with 16 oz. 2, 4-D and 8 oz. Clarity per acre to control the mustard.

Materials and Methods

The first evaluation of the plots was conducted on April 27, 2005 using a frequency grid based on that described by Vogel and Masters (2001). The grid measured approximately 40 x 41 inches, having four 10-inch columns (to incorporate 1 drill row per column) and five rows, giving a total of 20 cells. The first grid was laid on the rows approximately two grid lengths (80 inches) into the plot. Counts were made of the cells that contained at least one plant. Grids were subsequently flipped and evaluated three more times giving a total of 80 evaluated cells.

Total area for one grid is approximately 1 m^2. Total area evaluated is therefore approximately 4 m^2. A conservative estimate of plant density (plants/m^2) is the total number of cells containing at least one plant divided by four. The second evaluation of 2005 occurred on May 25, 2005. The 2006 evaluation was conducted on May 30 using the methods describe above, except that the frame was evaluated five times for a total of 100 cells or 5 m^2. Total counts were then divided by five for approximate plants/m^2. Numbers for approximate plants/m^2 were divided by 10.8 to calculate approximate plants/ft^2. It is important to note that because cells with plants were counted and not the number of plants per cell, the best possible score is 100 hits per five frames which converts to 20 plants/m^2 or 1.85 plants/ft^2. Actual plant density may be higher than the numbers indicated below. All tables have been arranged with accessions ranked from highest plant density to the lowest at the time of the second evaluation in 2005. Data were not analyzed for significance.

Native Grasses

There were forty-seven accessions of native grasses planted. Overall the native grasses established well considering the limited amount of precipitation received over the winter and early spring of 2005. Especially good stands were seen in the bluebunch wheatgrass and Snake River wheatgrass plots during 2005. There was a marked decrease in plant density between the first and second evaluations with some notable exceptions. Seven of nine bluebunch wheatgrass accessions and three of four Snake River wheatgrass accessions increased in density from the first evaluation to the second. This is possibly due to 2.5 inches of precipitation during that period and/or from a lack of pressure by black grass bugs (*Labops* sp.). Most of the native grasses decreased in density from 2005 to 2006 with the exception of Covar sheep fescue and all of the Sandberg bluegrass accessions. These may have been plants that germinated late in the first growing season or, more likely, were too small to notice under the heavy growth of mustards and were more easily observed in 2006.

In 2005 the best performing Indian ricegrass accession was White River, with a plant density of 0.56 plants/ft^2 during the first evaluation and 0.17 plants/ft^2 during the second evaluation. By 2006 there were no plants of any Indian ricegrass accession observed in the evaluation grids and very few seen within their respective plots. In 2006, all squirreltail accessions had decreased in density. Fish Creek maintained the best plant density with 0.26 plants/ft^2. Bannock thickspike wheatgrass had a density of 1.04 plants/ft^2 and increased slightly to 1.07 plants/ft^2 at the second evaluation. In 2006 Bannock had dropped to nearly half of the original density to 0.58 plants/ft^2. Revenue and San Luis slender wheatgrass both had 0 plants/ft^2 in 2006. Pryor slender wheatgrass similarly dropped in density but had 0.02 plants/ft^2. The western wheatgrass accessions had less dramatic declines in density from 2005 to 2006, but still showed poor stands with Rodan having the highest density of 0.13 plants/ft^2.

The bluebunch wheatgrass accessions had the highest average densities of all the native grasses. All decreased slightly in density from 2005 to 2006, but still maintained good stands. P-12, Wahluke and Jim Creek all had densities over 1.00 plants/ft^2. Columbia, Anatone, P-7 and P-15 had densities between 0.50 and 1.00 plants/ft^2 while P-5 and Goldar both had low densities. The three Snake River wheatgrass accessions dropped to just over 0.50 plants/ft^2. The basin wildrye accession densities also decreased; U108-02 and Trailhead retained the highest densities at 0.24 and 0.26 plants/ft^2 respectively. Sheep fescue stands remained poor from 2005 to 2006 with Covar slightly increasing from 0.00 to 0.07 plants/ft^2. Thurber's needlegrass had no plants in the evaluated grids. All five of the Sandberg bluegrass accessions increased in density from 2005 to 2006. The best stands were observed in the High Plains and Mountain Home plots with respective stands of 0.54 and 0.35 plants/ft².

ORCHARD DEMONSTRATION AREA		**4/27/05**	**5/25/05**	**5/30/06**
Native Grass Species	**Name or accession**	**Plants/ft²**	**Plants/ft²**	**Plants/ft²**
Indian ricegrass	Rimrock	0.37	0.20	0.00
	White River	0.56	0.17	0.00
	Nezpar	0.42	0.17	0.00
	Ribstone	0.14	0.09	0.00
	Paloma	0.05	0.00	0.00
Squirreltail	Fish Creek	0.97	0.54	0.26
	Shaniko Plateau	0.81	0.52	0.06
	Sand Hollow	0.37	0.20	0.19
	Toe Jam Creek	0.58	0.17	0.00
	9019219	0.02	0.02	0.00
Thickspike wheatgrass	Bannock	1.04	1.07	0.58
	Critana	0.90	0.56	0.24
	Schwendimar	0.69	0.52	0.39
	Sodar	0.37	0.30	0.15
Slender wheatgrass	Revenue	1.00	0.93	0.00
	San Luis	0.60	0.69	0.00
	Pryor	0.30	0.30	0.02
Western wheatgrass	Rodan	0.28	0.35	0.13
	Rosana	0.05	0.20	0.04
	Arriba	0.16	0.15	0.06
Bluebunch wheatgrass	P-12	1.34	1.59	1.04
	Wahluke	0.97	1.26	1.02
	Columbia	1.30	1.23	0.84
	P-7	0.93	1.15	0.67
	Anatone	0.81	1.15	0.80
	Jim Creek	0.83	1.02	1.02
	P-15	0.60	0.93	0.54
	P-5	0.42	0.61	0.22
	Goldar	0.51	0.37	0.33
Snake River wheatgrass	Expedition	1.27	1.44	0.54
	Secar	1.00	1.11	0.76
	SERDP	1.02	0.94	0.67
	E-26	0.21	0.23	0.22
Basin wildrye	U108-02	0.56	0.57	0.24
	Trailhead	0.60	0.52	0.26
	U100-01	0.53	0.41	0.11
	U70-01	0.30	0.22	0.02
	Magnar	0.28	0.22	0.04
	Washoe	0.21	0.09	0.09
Sheep fescue	Initial Point	0.21	0.04	0.02
	Covar	0.16	0.00	0.07
Thurber's needlegrass	Thurber's	0.00	0.00	0.00
Sandberg bluegrass	High Plains	0.25	0.00	0.54
	Sherman	0.00	0.00	0.02
	Mountain Home	0.00	0.00	0.35
	Toole County, MT	0.00	0.00	0.04
	Hanford Source	0.00	0.00	0.19

Introduced Grasses

Although many of the introduced grass accessions had fair emergence, we noted an outbreak of black grass bugs at the time of the first evaluation in 2005. The infestation appeared limited to the introduced grass section of the nursery. Plants were covered with yellow spots making them appear yellow-green overall. Although most of the stands of the introduced grasses decreased from the first to the second evaluation, many stands had recovered and increased by 2006 indicating that many plants thought to be dead during the second evaluation in 2005 were still alive. However, the plants in the crested wheatgrass plots were very small when compared to the other wheatgrass accessions in the nursery and still appear to be recovering from black grass bug pressure.

In 2006 all of the crested wheatgrass accessions increased in density or remained approximately where they were in 2005. Ephraim rose from 0.28 to 1.23 plants/ft^2; however, many of the plants were small in size due to the 2005 black grass bug infestation. Both Siberian wheatgrass accessions similarly increased from 2005 to 2006, but the three pubescent wheatgrass accessions decreased with the highest density in 2006 coming from Manska at 0.28 plants/ft^2. Rush intermediate wheatgrass, along with Prairieland and Eejay Altai wildrye had zero plants in 2006. Pearl Altai wildrye had 0.02 plants/ft^2. The Russian wildrye accessions all increased in density with the exception of Tetracan, which decreased slightly. The best stand was recorded in the Bozoisky Select plot with 0.58 plants/ft^2.

ORCHARD DEMONSTRATION AREA		**4/27/05**	**5/25/05**	**5/30/06**
Introduced Grass Species	**Name or accession**	**Plants/ft^2**	**Plants/ft^2**	**Plants/ft^2**
Crested wheatgrass	Nordan	1.30	1.19	1.10
	Ephraim	0.65	0.28	1.23
	Hycrest	0.39	0.24	0.15
	CD-II	0.56	0.24	0.20
	Roadcrest	1.30	0.07	0.52
	Douglas	0.28	0.04	0.09
Siberian wheatgrass	Vavilov	0.65	0.20	0.61
	P-27	0.09	0.02	0.33
Pubescent wheatgrass	Manska	0.69	0.65	0.28
	Greenleaf	0.60	0.59	0.15
	Luna	0.79	0.54	0.13
Intermediate wheatgrass	Rush	0.60	0.56	0.00
Altai wildrye	Prairieland	0.56	0.39	0.00
	Eejay	0.16	0.28	0.00
	Pearl	0.35	0.15	0.02
Russian wildrye	Bozoisky Select	0.72	0.54	0.58
	Mankota	0.46	0.28	0.32
	Tetracan	0.42	0.20	0.17
	Syn-A (Bozoisky II)	0.21	0.13	0.24

Forbs and Shrubs

Despite some good stands in 2005, all of the forb and shrub accessions except for Eagle yarrow had zero plants during the 2006 evaluation. Eagle had 0.07 plants/ft^2 in the frequency grids along with a small stand of plants at one end of the seeded plot.

ORCHARD DEMONSTRATION AREA		4/27/05	5/25/05	5/30/06
Forb and Shrub Species	**Name or accession**	**Plants/ft²**	**Plants/ft²**	**Plants/ft²**
Western yarrow	Eagle	0.51	0.50	0.07
	Great Northern	0.19	0.09	0.00
Utah sweetvetch	Timp	0.14	0.02	0.00
Firecracker penstemon	Richfield Selection	0.02	0.02	0.00
Scarlet globemallow		0.00	0.00	0.00
Lewis flax	Maple Grove	0.42	0.15	0.00
Blue flax	Appar	0.90	0.26	0.00
Wyoming big sagebrush		0.02	0.02	0.00
Fourwing saltbush	Snake River Plains	0.00	0.00	0.00
	Wytana	0.00	0.00	0.00
	Rincon	0.00	0.00	0.00
Gardner's saltbush	9016134	0.00	0.00	0.00
Winterfat	Hatch	0.28	0.17	0.00
	Northern Cold Desert	0.00	0.00	0.00
	Open Range	0.00	0.00	0.00
Forage kochia	Immigrant	0.00	0.00	0.00

Cover Crop

The cover crop consisted of a four species mix which contained: 50% Anatone bluebunch wheatgrass, 20% Bannock thickspike wheatgrass, 20% Magnar basin wildrye and 10% Snake River Plains fourwing saltbush. Four grids were examined during the first evaluation in 2005, one on each side of the nursery, and five grids were evaluated at the time of the second evaluation in 2005 and the 2006 evaluation. Total plant density was estimated at 0.37 plants/ft^2 at the first evaluation and 0.57 plants/ft^2 at the second evaluation. In 2006 the cover crop density was 0.13 plants/ft^2.

Discussion

Despite large amounts of Russian thistle, native and introduced grasses had fair to good emergence and plant density during the establishment year. Germination and emergence might have been increased with more precipitation during March and April, 2005 but emergence was good with the rain that was received. The majority of the plots showed decreased stands from 2005 to 2006. The low precipitation at the site, especially the lack of moisture in July and August of 2005, seems to have eliminated many of the less drought tolerant accessions. One concern is the effect of black grass bugs on the introduced grasses. Plants subjected to black grass bug are normally affected by decreased seed yield and a reduction in palatability. Infestations rarely result in the death of established plants, but in low water years establishing plants may be under enough stress to kill the establishing seedlings (Hammon and Peairs 2001). The second evaluation in 2005 indicated a loss in plant densities; however it appears that many of the plants survived, although stunted, through 2006. Future evaluations will provide more information on plant establishment, persistence and longevity. The PMC staff will continue to evaluate plant performance at the site.

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Develop Technology to Improve the Diversity of Introduced Grass Stands

The PMC assisted Brigham Young University (BYU), Provo, UT and the Agricultural Research Service (ARS), Burns, OR in developing technology to improve the diversity of introduced grass stands by evaluating methods to introduce native species into established introduced plant communities. In 2005 the PMC modified a Truax Rough Rider range drill, mixed the seed and rice hull mixtures and completed the first year of seedings at the sites in Utah and Oregon.

In 2006 modified seed drop boots by the manufacturer were installed on the Truax drill. The Utah sites (Skull Valley and Lookout Pass) were seeded the week of October 24 and the Oregon site (Burns) was seeded the week of October 31, 2006. Twelve and a half acres were seeded at each location. In addition to these seedings, the PMC also seeded drill comparison trials (approximately 30 acres total) at two locations near Elko, NV during the week of November 6, 2006 on recently burned rangeland to compare the Truax drill to the Kemmerer drill, a standard range drill used by BLM. While seeding these projects, the PMC technicians met with Jim Truax (drill manufacturer) to demonstrate the modifications to the drill under field conditions.

The Truax drill is designed to both broadcast and drill seed in the same pass so species that require broadcasting or very shallow planting depth were broadcast and the deeper seeded species were drill seeded in alternating rows. The following table lists the seed and rice hull mixtures:

Utah Broadcast Mix

Species	Pounds PLS/acre	Pounds bulk seed/acre
Wyoming big sagebrush	0.20	0.94
Rubber rabbitbrush	0.25	0.75
Eagle yarrow	0.20	0.24
“OR” Sandberg bluegrass	0.75	0.95
Rice hulls		7.41

Utah Drill Mix

Species	Pounds PLS/acre	Pounds bulk seed/acre
Fourwing saltbush	1.00	3.48
Appar blue flax	0.75	0.83
Munro globemallow	0.50	0.84
Anatone bluebunch wheatgrass	3.00	3.16
Sanpete bottlebrush squirreltail	2.00	2.82
Nezpar Indian ricegrass	2.00	2.13
Rice hulls		4.58

Oregon Broadcast Mix

Species	Pounds PLS/acre	Pounds bulk seed/acre
Wyoming big sagebrush	0.20	1.33
Rubber rabbitbrush	0.25	2.06
Eagle yarrow	0.20	0.26
Mtn. Home Sandberg bluegrass	0.75	1.18
Rice Hulls		4.90

Oregon Drill Mix

Species	Pounds PLS/acre	Pounds bulk seed/acre
Fourwing saltbush	1.00	2.28
Appar blue flax	0.75	1.00
Munro globemallow	0.50	0.61
Anatone bluebunch wheatgrass	3.00	3.52
Toe Jam bottlebrush squirreltail	2.00	2.17
Nezpar Indian ricegrass	2.00	2.08
Rice hulls		4.74

Drill Comparison Broadcast Mix

Species	Pounds PLS/acre	Pounds bulk seed/acre
Wyoming big sagebrush	0.20	1.33
Rubber rabbitbrush	0.25	0.65
Eagle yarrow	0.20	0.21
Mtn. Home Sandberg bluegrass	0.75	0.91
Rice hulls		7.01

Comparison Drill Mix

Species	Pounds PLS/acre	Pounds bulk seed/acre
Fourwing saltbush	0.69	1.15
Appar blue flax	0.65	0.75
Munro globemallow	0.50	0.59
Anatone bluebunch wheatgrass	3.00	3.54
Bottlebrush squirreltail	1.90	2.06
Nezpar Indian ricegrass	2.00	2.13
Rice hulls		5.05

The drill comparison trials were seeded at rates of 75 and 125 percent of the rates listed in the table above in order to be able to compare effectiveness of the two drills.

Cover crop mixes were also prepared and seeded at the drill comparison trial sites to provide perennial cover around the plots. Approximately 8 acres of cover crop were seeded at each site and the mixes are listed below:

East Humboldt Cover Drill Mix

Species	Pounds PLS/acre	Pounds bulk seed/acre
Hycrest crested wheatgrass	2.50	2.78
Bozoisky Russian wildrye	1.50	1.83
Vavilov Siberian wheatgrass	3.00	3.24
Rice hulls		6.11

Gopher Fire Cover Drill Mix

Species	Pounds PLS/acre	Pounds Bulk Seed/acre
Ladak alfalfa	0.50	0.54
Hycrest crested wheatgrass	1.00	1.11
Bozoisky Russian wildrye	1.00	1.22
Rimrock Indian ricegrass	1.50	1.55
Secar Snake River wheatgrass	2.00	2.51
Bannock thickspike wheatgrass	2.00	2.44
Rice hulls		5.37

The drill comparison trial will be repeated in fall of 2007. Location of the trial will be determined based on areas that burn during the 2007 fire season in the northern Great Basin.

Project Title: Native Plant Genetics, Ecophysiology, Plant Materials Development, and Seed Increase

Project Location: USDA-ARS Forage and Range Research Laboratory, Logan, UT

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Project Description:
Jones' funding was designated for seed increase of pending germplasm releases, germplasm development, and needle-and-thread germplasm collection. Johnson's funding was designated for collection and evaluation of basalt milkvetch. Peel's funding was designated for development of improved germplasms of globemallows, particularly *Sphaeralcea grossulariifolia* and *S. munroana*. Larson's funding was designated for genetic (DNA) analysis of bluebunch wheatgrass, *Leymus* wildryes, squirreltail, Indian ricegrass, and Utah

sweetvetch. These funds partially covered the costs of research itemized in this report with remaining costs covered by ARS funds.

Project Status:

North American Grasses

- Rattlesnake Germplasm bottlebrush squirreltail (*E. elymoides* ssp. *elymoides*), developed from material collected in Elmore Co., ID, was approved for release and is awaiting signatures. A seed-increase block was established. (Jones)
- Cycles of selection were completed for populations of diploid bluebunch wheatgrass (4), tetraploid bluebunch wheatgrass (2), and thickspike wheatgrass (2). (Jones)
- Selection blocks were established for populations of bottlebrush squirreltail (*E. elymoides* ssp. *californicus*) (1), Snake River x thickspike wheatgrass (1), diploid bluebunch wheatgrass (1), tetraploid bluebunch wheatgrass (1), and a Snake River x (thickspike x slender) wheatgrass hybrid (1), basin x beardless wildrye (1), and salina wildrye (1). (Jones)
- An evaluation of nine bluebunch wheatgrass populations from the Owhyee Plateau indicated that T-1561 (SW Marsing, ID) has the greatest potential.
- Greenhouse and field trials of 36 accessions of bottlebrush squirreltail ssp. *brevifolius* race C from Idaho and Oregon allowed evaluation of seedling traits and mature-plant phenology. (Jones)
- A seed-increase block of E-21 Snake River wheatgrass was established to prepare for possible release. (Jones)
- An evaluation of 42 accessions of needle-and-thread from southern Idaho and northeastern Oregon was established at Cornish Farm. (Jones)
- An evaluation of 15 accessions of Thurber's needlegrass from southwestern Idaho and southeastern Oregon was established at Blue Creek Farm. (Jones)
- A nursery of *Festuca idahoensis* X *F. roemeri* hybrids was established to evaluate pollen fertility to clarify the taxonomic relationship between these two taxa. (Jones and Larson)
- Data analysis of squirreltail taxa evaluated under a precipitation gradient in a rainout shelter has been completed, and a manuscript is being prepared. Data collection of a similar study for bluebunch wheatgrass was also completed. In 2006, the squirreltail data sets were statistically analyzed and a manuscript first draft was written. New data were generated by analyzing leaf N and leaf C:N ratio, and these data were compared to biomass production and carbon isotope discrimination in squirreltail taxa. A second manuscript was started that focuses on leaf-level gas exchange (photosynthesis) of both perennial grasses. (Monaco, Jones, Johnson).

Basalt Milkvetch (*Astragalus filipes*)

- Six rhizobial strains isolated by the Nitragin Company were tested in two greenhouse studies for their effectiveness at nitrogen fixation with six different collections of basalt milkvetch. The six rhizobial strains were compared with no-nitrogen and nitrogen treatments to identify the rhizobial strain resulting in the greatest nitrogen fixation, plant growth, and nitrogen pools. Rhizobial strain I-49 was the best strain and will be used by the Nitragin Company to produce a commercial rhizobial inoculant for basalt milkvetch. (Johnson)

- Plants of 67 accessions of basalt milkvetch were evaluated in common garden studies at Evans Farm and Millville in northern Utah for their morphological characteristics, plant vigor, forage yield and quality, seed yield, and regrowth after defoliation during the summer of 2006. Data from 2005 and 2006 were statistically analyzed, and two manuscripts are being prepared. (Johnson)
- Kishor Bhattarai, an M.S. student at Utah State University, is being supported from funds on this project. He is preparing his thesis from the basalt milkvetch research and is planning to defend his thesis during spring 2007. (Johnson)
- Transplants of the top-performing basalt milkvetch accessions were planted at Hyde Park in northern Utah in spring 2006 and will be used in the development of a selected class pre-variety germplasm of basalt milkvetch. (Johnson)
- DNA was extracted for informative AFLP DNA primer pairs in North American collections of basalt milkvetch. These data will be used to obtain estimates of genetic diversity for 1,200 AFLP markers. (Johnson)
- Collaborations are continuing with Jim Cane at the USDA-ARS Bee Biology and Systematics Lab at Logan to study pollination and seed predation in basalt milkvetch. (Johnson)
- A GIS data extraction tool with 11 data layers was constructed, and a web-based version was made available through Utah State University's GIS and Remote Sensing Laboratory website to characterize collection sites in the lower 48 states. This tool will allow collection sites across the U.S. to be characterized for annual precipitation, annual minimum and maximum temperatures, ecoregion levels, topographic characters, soils features, and land ownership. This tool could be used as a basis for delineating seed zones for rangeland plant species. (Johnson)

Genetic Diversity Analyses

- In cooperation with Mike Peel and Shaun Bushman, we prepared and submitted a manuscript describing DNA variation within and between 21 *Hedysarum boreale* accessions (384 plants), including two accessions from the USFS Shrub Sciences Laboratory and 10 accessions from the UDWR Great Basin Research Center. We acknowledged the financial support of the U.S. Department of the Interior-Bureau of Land Management Great Basin Native Plant Selection and Increase Project, the U.S. Department of Agriculture-Forest Service Rocky Mountain Research Station, the Utah Division of Wildlife Resources – Pittman / Robertson Big Game Habitat Restoration Project W-82-R, and the U.S. Department of Agriculture –Agricultural Research Service. (Larson)
- Supported a research assistantship for Utah State University graduate student Catherine Mae Culumber, who analyzed chloroplast *psbA-trnH* intergenic spacer sequences, chloroplast *trnK-rps16* intergenic spacer sequences, and nuclear 18S-5.8S-26S ribosomal DNA internal transcribed spacer (ITS) sequences for 335 *Leymus* wildrye accessions including 304 North American accessions (nine species) and 31 Eurasian accessions (nine species). The *Leymus* germplasm included 55 GBRC collections, four Berta Youtie collections, and 61 new FRRL wildland seed collections from 2004. Results of this genetic diversity study are described in her M.S. thesis,

which will be defended and submitted for publication in the spring 2007. Mae also helped collect *Lepidium montanum* herbarium specimens and DNA samples from 30 collection sites (ID, NV, OR, UT, and WY), which provided crucial reference specimens used for genetic diversity studies of *Lepidium papilliferum* and *L. montanum*. Although, the *Lepidium* work was primarily funded by ARS, we intend to acknowledge U.S. Department of the Interior-Bureau of Land Management Great Basin Native Plant Selection and Increase Project in the *Leymus* and *Lepidium* reports. (Larson)

- Supported research assistantship for Utah State University graduate student Parminder Kaur, who is genetically mapping genes and comparing gene expression profiles related to adaptive trait variation (growth habit) in North American *Leymus* wildryes. Parminder also began testing 1,800 PCR primer pairs flanking simple-sequence repeats (SSR) detected in a library of 28,632 expressed gene sequence tags (ESTs) of *Leymus*. (Larson)

<u>Globemallows (*Sphaeralcea* spp.)</u>

- In spring 2006, progenies of 21 half-sib families of *S. munroana* were established at Utah State University's Blue Creek Research Farm. This material will be evaluated during the 2007 growing season for growth habit, leaf type, persistence, vigor and particularly seed production. (Peel)
- It is expected that desirable plant types from this cycle of selection will be used to generate seed for testing and eventual germplasm release. (Peel)
- Following evaluation of *S. coccinea* in 2006, 18 lines were selected for further characterization. It was the intent to start this material in the greenhouse during the 2006/2007 winter for transplanting to the field in spring 2007. However, serious seed quality issues and a very small number of plants have been successfully started. (Peel)
- It is anticipated that seed from the *S. coccinea* material will be harvested again in 2007 and a second attempt will be made the following year at successful establishment. (Peel)

Products:

Four M.S. and two Ph.D. students have been supported in part through project funds.

The release of Rattlesnake Germplasm bottlebrush squirreltail makes seed of this competitive early-seral species from the Lower Snake River Plain available for the first time.

Submitted chloroplast *psbA-trnH* intergenic spacer sequences, chloroplast *trnK-rps16* intergenic spacer sequences, and nuclear 18S-5.8S-26S ribosomal DNA internal transcribed spacer (ITS) sequences for 335 *Leymus* wildrye accessions including 304 North American accessions (nine species) and 31 Eurasian accessions (nine species). These materials included 55 GBRC collections, four Berta Youtie collections, and 61 new FRRL wildland seed collections from 2004.

Management Applications:

Collections of bottlebrush squirreltail, Indian ricegrass, bluebunch wheatgrass, thickspike wheatgrass, Snake River wheatgrass, salina wildrye, needle-and thread, Idaho fescue, and

Roemer's fescue were made and are being evaluated in this project. Data collected in these evaluation studies will form the basis for identifying the most promising collections of these species for eventual germplasm releases for use in revegetation and restoration efforts on rangelands of the western U.S. Releases of these species will allow land managers greater flexibility in meeting plant materials needs for western rangelands.

Globemallow and basalt milkvetch are species that are drought and heat tolerant, winterhardy, and survive well in semiarid environments. When included in seed mixtures with adapted grasses, plants of these species will be of value in stabilizing degraded rangelands, revegetating disturbed areas, and beautifying roadsides. These native forb species may be used where introduced species are not desired. Their attractive foliage and flowers make them excellent choices for use in wildflower seed mixtures.

The molecular genetics information generated from this project will be used to genetically characterize collections of important Great Basin plant species. These molecular data will allow identification of optimal germplasm releases to most effectively represent existing genetic variation in key plant species. Molecular data will also be useful in identifying specific gene sequences associated with growth habit, seed-shattering, seed dormancy and other functionally important traits related to seed production, plant establishment, plant adaptation, forage quality, and other conservation uses. These SSR and other EST DNA markers will provide a valuable new resource for breeding and genetic diversity studies of North American *Leymus* wildryes used in rangeland revegetation, agriculture, and other conservation uses.

Squirreltail and bluebunch wheatgrass populations were previously delineated based on morphological and genetic characteristics. Our studies showcase the functional importance of variation in drought response between these populations. Populations capable of maintaining favorable water balance, photosynthesis, and productivity under low water availability may have an advantage when competing with invasive annual grasses in late spring, when soil resources typically become limiting within the Great Basin.

Publications:

Bushman, S.B., S.R. Larson, M.D. Peel, and M.E. Pfrender. 2007. Population structure and genetic diversity in North American *Hedysarum boreale*. Nutt. Crop Science (in press).

Jones, T.A., and T.A. Monaco. 2007. A restoration practitioner's guide to the Restoration Gene Pool Concept. Ecol. Restor. 25: 12-19.

Jones, T.A., M.G. Redinbaugh, Y. Zhang, S.R. Larson, and B.D. Dow. 2007. Polymorphic Indian ricegrass populations result from overlapping waves of migration. W. North Amer. Nat. 67: (accepted 9/7/06).

Larson, S.R., X. Wu, T.A. Jones, K.B. Jensen, N.J. Chatterton, B.L. Waldron, J.G. Robins, S.B. Bushman, and A.J. Palazzo. Growth habit, height, and flowering QTLs reveal footprints of speciation between North American *Leymus* wildryes. Crop Science. (submitted).

Technology Transfer:
A presentation was made by Tom Jones at the Red Brome Symposium in April 2006 (Gilbert, AZ).

A presentation was made by Tom Jones at the Grass Breeders' Conference in July 2006 (Ames, IA).

Poster abstract was presented at Plant and Animal Genome XV Meetings, January, 13-17, 2007. Kaur, P., I. W. Mott, S. Bushman, S.R. Larson. Comparison of gene expression in *Leymus* tiller and rhizome meristems using heterologous Affymetrix wheat and barley gene chips.

Presentations were made by Tom Jones and Doug Johnson at the GBNPSIP Symposium at the 2007 SRM Annual Meeting in February 2007 (Reno, NV).

Project Title: Agronomic and Cultural Care of Wildland Plants, and Seed Yield Losses in Forbs (Asteraceae) Due to Fruit Flies (Tephritidae)

Project Location: Brigham Young University, Provo, UT

Principal Investigators and Contact Information:

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Project Description:
Four projects were carried out in 2006.

1. Seeding depth studies: The seeding depth study is designed to determine optimal planting depth. This greenhouse study compares planting depths at 1, 1/2, 1/4, 1/8, and 0 inches in a clay-loam and sandy soil.
2. Spacing and production methodology development: This project investigates the effect of within row spacing at 6, 12, and 18 inches on seed production as well as the influence of mulch. Mulch treatments include weed fabric, paper, plastic, and bare ground.
3. Manipulations of wild bitterbrush and sagebrush stands: Another way to increase seed production is to manage wildland stands of important species. This study investigates methodologies to increase seed production in wildland stands of bitterbrush and Wyoming big sage. A combination of treatments was applied including: removal of competing vegetation, fertilization, and pruning. The long-term effect of beating versus hand stripping was also examined.
4. Seed yield losses due to tephritid fruit flies in Asteraceae: Understanding the extent of seed yield losses by seed predators in wild forb populations will help predict the

potential seed loss of native forbs under cultivation. This project looks at seed loss occurring in four yellow composite species at three different sites, the insect composition of flower visitors, and the effect of spraying the pesticide imidachloprid for controlling seed predation.

1. Seeding Depth

Project Status: A new set of species was provided by the U.S. Forest Service Shrub Sciences Laboratory. Four species were planted in a replicated block design in two soil types, watered, and cold stratified for six weeks. Those species were *Crepis intermedia*, *Crepis acuminata*, *Balsamorhiza sagittata*, and *Perideridia bolanderi*. Soil types were clay-loam, and sand. We hope to replicate this study in 2006.

2. Spacing and Production Methodology

Project Status: Evaluations of *Sphaeralcea* were completed in 2005. *Sphaeralcea coccinea* died out over the winter so production data were collected on *S. grossulariifolia* and *S. munroana*. The condition of the remaining two species was generally fair to poor, indicating a possible short-lived perennial status for *Sphaeralcea* on heavy soils. A rust fungus was prevalent throughout the population and where the plant crown produced abundant stems the previous year, 2006 stem production was severely reduced. In 2005, a single harvest was employed cutting the stems with a harvester and air-drying the plant material on tarps before threshing. Yields were significantly reduced over the previous year, an effect of lower production but also an artifact of different harvest techniques. Seed was hand harvested the previous year over an extended period maximizing seed capture. The single machine harvest completed at mid seed ripening missed some early shatter and was premature for some plants. The machine harvest does, however, fit into a more realistic yield model for large-scale agricultural production.

Where spacing was significant the first season, it no longer displayed significance in 2006 (Fig.1). This was in part due to the fact that the 6 inch-spaced plants had higher mortality, equalizing the spacing to some extent. Mulch was not significant in 2006.

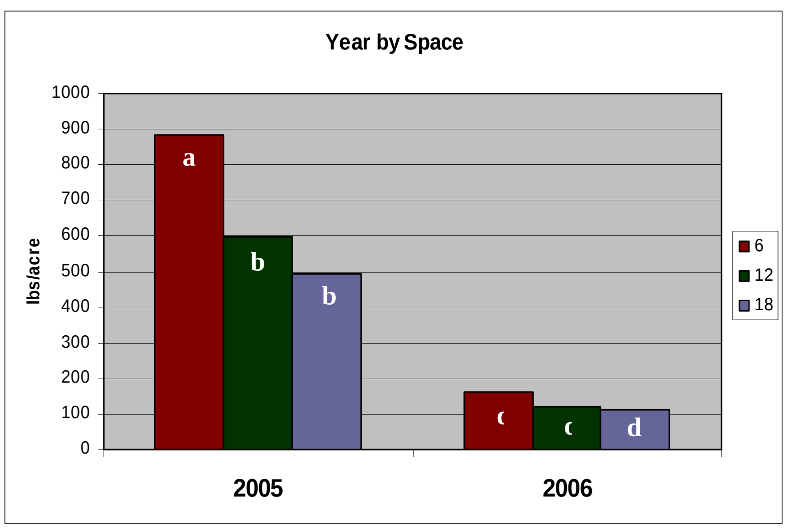

Figure 1. Seed yield (lbs/acre) of *Sphaeralcea* by row spacing (6, 12, or 18 inches).

Four additional plant species were introduced into the experiment in 2006. The same spacings were used, but paper mulch was removed as a mulch treatment. *Lupinus argenteus, Crepis intermedia,* and *Agoseris glauca* were planted

3. Manipulations of wildland bitterbrush and sagebrush stands:

Project Status: Annual herbicide application for the competition removal treatment on bitterbrush was repeated in April of 2006. Two treatments were applied this year. The first was in April and the second in late May. Below freezing temperatures over Memorial Day weekend of this year froze the flowers at the Utah site. Due to complications with the unpredictable seed shatter, we decided to sub-sample the plants by wrapping individual reproductive stems with a fine mesh fabric to capture the seed rain, thus avoiding the necessity of seed harvest at precisely the right time. Seed bags were made of 1/8th inch mesh cut into 2 ft^2 sections and wrapped on three randomly selected branches on each plant. Seed bags were placed on the shrubs at the "blood stage" of seed ripening. This task was accomplished first at the Idaho site and continued through the third week of June. By the first week of July an insect infestation at the Nevada site was so severe that the majority of seed at this site was lost.

Because two sites failed in seed production we modified our data point from seed production to potential seed production and implemented a new collection protocol based on the number of spurs, length, and number of leaders per unit area. Since a single spur represents one reproductive unit, we could estimate the potential seed production based on a plants reproductive potential. A one square meter quadrat was built with intersecting wires to create 25 individual points and 16 nested frames from which to randomly collect data. Attributes of the nearest spur-to-point and the number of spurs per nested frame were recorded. For analysis, all data were extrapolated to a square meter basis. Since current year's growth and the previous year's growth are easily distinguishable, the same data were collected for the previous season.

Across all sites, competition removal was the only treatment that showed a positive effect on spur production (Fig.2). On the Utah site, browse was shown to have a negative effect (Fig. 3). We attribute this to the fact that the Utah site was the only site to receive browsing during the last two years. It is part of a sheep allotment while the other two sites are part of a cattle allotment and were not grazed during the time of our study.

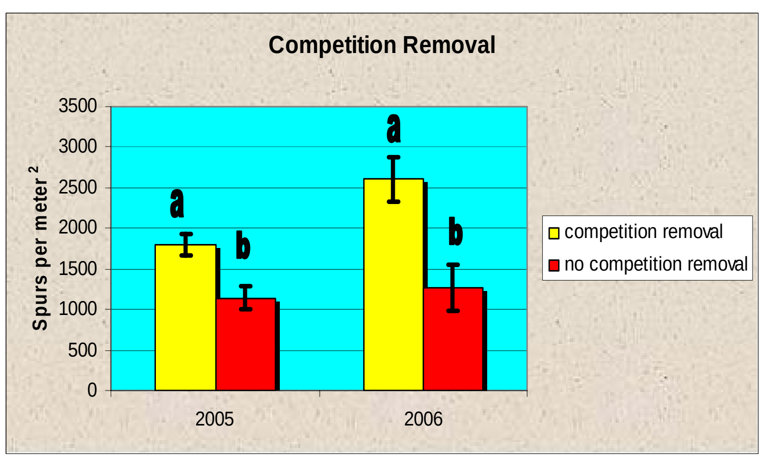

Figure 2. Antelope bitterbrush spurs m^{-2} with competition present or removed in 2005 and 2006.

In spring 2006, herbicide was applied to the sagebrush treatments designated for competition removal. Starting in October we began monitoring the flowering at all sites. After flowering (approx. late October to early November) we used nylon stockings to "bag" a sub-sample of the inflorescences on each of 80 plants in the sample population. We bagged individual inflorescences and secured the bags at the bottom with nylon zip-ties. We did this to eliminate the problem of uneven seed ripening and shatter that were encountered in 2005. In early December, the seed bags were collected and brought back to the lab for processing. Data will be analyzed and reported in 2007.

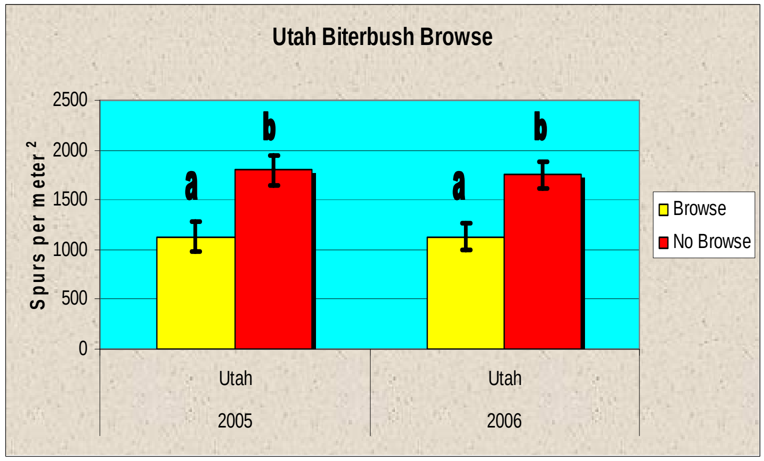

Figure 3. Antelope bitterbrush spurs m^{-2} with or without browsing in 2005 and 2006 at the Utah site.

4. Seed yield losses due to tephritid fruit flies in Asteraceae

Project Status: In 2006, three sites each for *Balsamorhiza sagittata*, *Wyethia amplexicaulis*, *Crepis acuminata*, and *Agoseris glauca*, were selected for 2 years of monitoring. Some of these sites remained from the previous season, and some were newly located to obtain a compliment of three sites/species. In addition to the standard seed predation rate evaluations begun in 2005, random plants from each population were selected for pesticide application. Imidachloprid was used on half the sample population as a soil drench applied early in the season, and as a spray on the other half at the flower bud stage just prior to flowering. Capitula of random samples from treated and untreated plants were collected and placed in cups for rearing. Emerged insects were counted and the capitula dissected to determine the extent of seed damage (Figs. 4-6). Additionally, plant populations were swept to quantify the composition of flower visiting insects. Contents of each sweep sample were aspirated and placed in 70% ethanol. A late freeze decimated the developing flowers at all our of our *Balsamorhiza* sites in 2006.

In all cases the application of imidachloprid significantly reduced infestation rates. The soil drench performed better than the spray, and in some cases reduced seed predation to near zero.

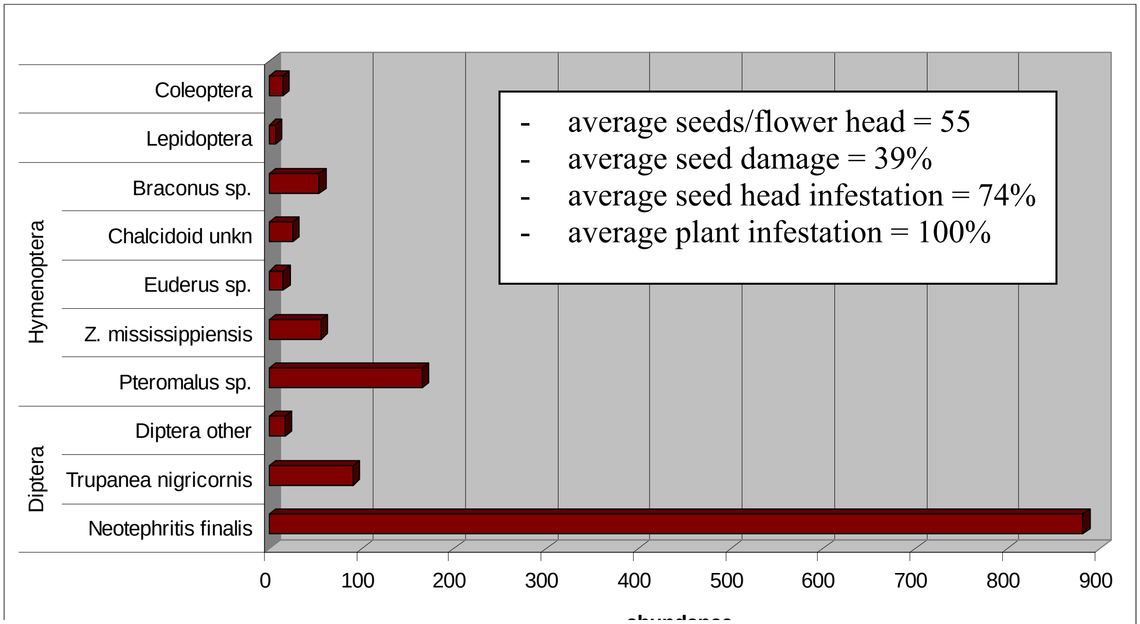

Figure 4. Composition of reared insects for *Wyethia amplexicaulis*. Fruit flies were the most dominant seed predator.

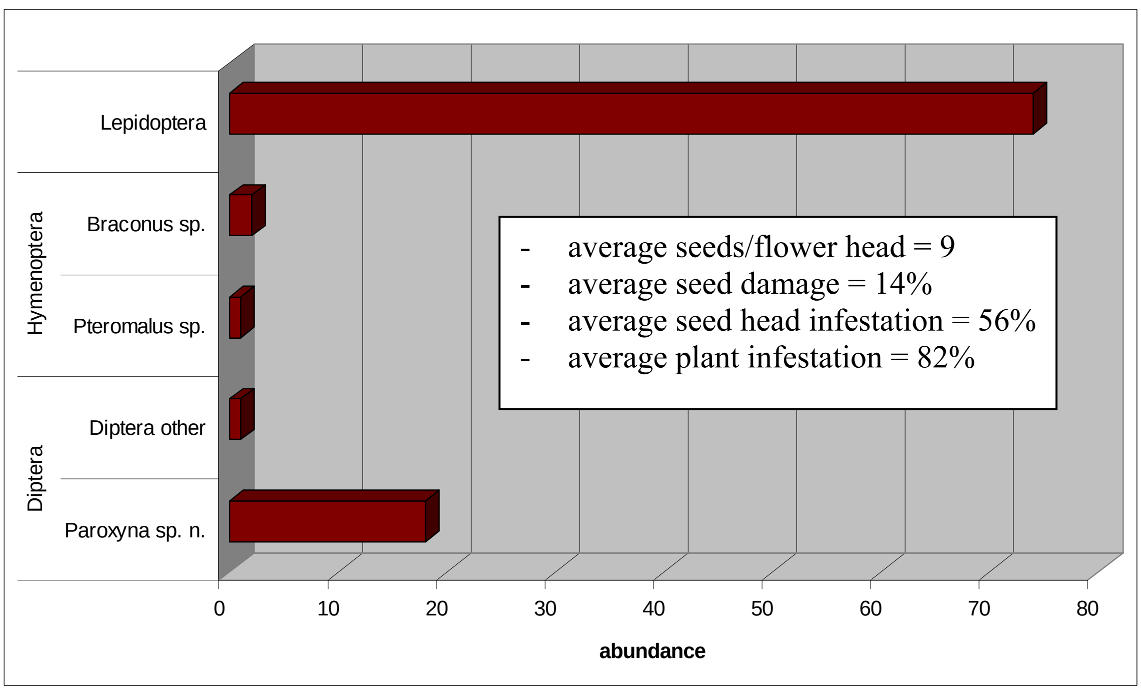

Figure 5. Composition of reared insects for *Agoseris glauca*. Fruit flies were the dominant seed predator.

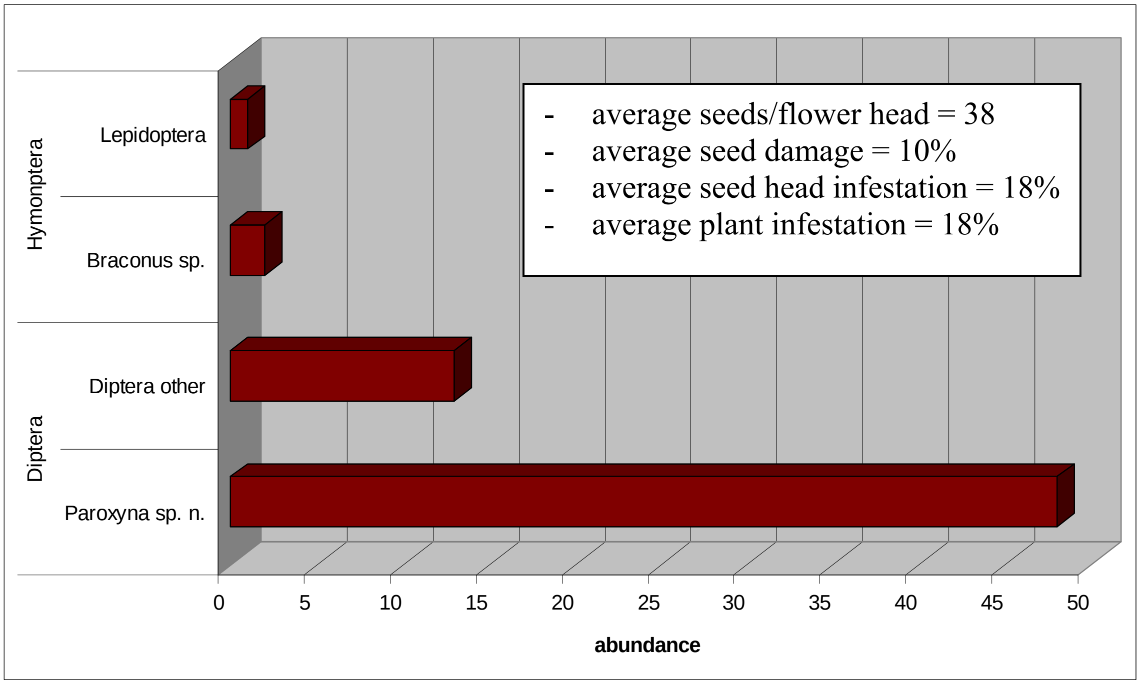

Figure 6. Composition of reared insects for *Crepis acuminata.* Moths were the dominant seed predator.

Technology transfer:

The following presentations were given in 2006.

Johnson, R. L., V. J. Anderson. 2006. Estimates of seed production loss in wild plants populations by capitivorous fruit flies (Diptera: Tephritidae). 90th annual meeting for Pacific Branch Entomological Society of America. Maui, Hawaii.

Johnson, R.L., V.J. Anderson. 2006. Reduction in seed yields of forbs from native stands due to seed predation by fruit flies (Diptera: Tephritidae). 2006 Society for Range Management Annual Meeting. Abstract 198. Vancouver, British Columbia.

Taylor, B. G., R. L. Johnson, V. J. Anderson, B. A. Roundy. 2006. Two year evaluation of cultural practices on seed production of select native forbs. 2006 Society for Range Management Annual Meeting. Abstract 353. Vancouver, British Columbia.

Voss, J., V. J. Anderson, R. Johnson. 2006. Effect of three rates of five different herbicides on seven native forbs at various growth stages. 2006 Society for Range Management Annual Meeting. Abstract 371. Vancouver, British Columbia.

Roberts, L. V. J. Anderson, R. Johnson. 2006. Shrub stand manipulations to improve seed production in antelope bitterbrush in Idaho, Nevada, and Utah. 2006 Society for Range Management Annual Meeting. Abstract 308. Vancouver, British Columbia.

Armstrong, J., V. J. Anderson, R. Johnson. 2006. Shrub stand manipulations to improve seed production in Wyoming big sagebrush in Idaho, Nevada, and Utah. 2006 Society for Range Management Annual Meeting. Abstract 9. Vancouver, British Columbia.

Management Applications:

The following take-home messages have management application:

- The single limiting factor for increased seed production of bitterbrush and Wyoming big sage in wildland stands is water. Removal of plants competing for that resource can increase potential seed yield.

- Productive stands of bitterbrush designated for seed harvesting should be protected from grazing.

- The first season's seed production of *Sphaeralcea* has the best yield potential. This is when plants are most vigorous and healthy. Seed production is expected to decrease after the first year on heavy soils unless practices are employed to decrease mortality and disease.

- The first season's seed production is highest for plants planted at a 6-inch within row spacing. This density may, however, contribute to increased plant mortality and disease in subsequent years.

- Mulch type seems to have no affect on seed yield in *Sphaeralcea* compared to no-mulch. Any realized benefit may be in reduced weed control costs.

- Overall seed yield loss in wild populations averaged between 10-39% (depending upon the species) due to pre-dispersal seed predators. The range of damage was much higher depending upon the site. Higher losses in seed yield could be expected in agricultural production in monoculture systems.

- Imidachloprid proved affective at controlling seed predators, but an alternative, non-systemic, insecticide would be required in agricultural production to prevent impacting pollinators.

Project Title: Seed Production of Native Forbs Shows Little Response to Irrigation in a Wet Year

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

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Project Description:
Native forb seed is needed to restore rangelands of the Intermountain West. Commercial seed production is necessary to provide the quantity of seed needed for restoration efforts. A major limitation to economically viable commercial production of native forb seed is stable and consistent seed productivity over years. Variations in spring rainfall and soil moisture result in highly unpredictable water stress at seed set and development. Excessive water stress during seed set and development is known to compromise yield and quality of other seed crops. Native forbs are not competitive with crop weeds. Both sprinkler and furrow irrigation promote seed production, but risk encouraging weeds. Furthermore, sprinkler and furrow irrigation can lead to the loss of plant stand and seed production to fungal pathogens. By burying drip tapes at 12-inch depth, and avoiding wetting of the soil surface, we hope to assure flowering and seed set without encouraging weeds or opportunistic diseases. This trial tested the effect of three irrigation intensities on the seed yield of seven native forb species.

Materials and Methods:

Plant Establishment
Seed of seven Great Basin forb species (Table 1) was received in late November 2004 from the USFS Rocky Mountain Research Station (RMRS) in Boise. 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 2005. To ensure germination the seed was submitted to a cold

stratification treatment. The seed was soaked overnight in distilled water on January 26, 2004. After soaking, the water was drained and the seed soaked for 20 minutes in a 10% by volume solution of 13% bleach in distilled water. The water was drained and the seed placed in a thin layer in plastic containers. The plastic containers had lids with holes drilled to allow air movement. The seed containers were placed in a cooler set at approximately 34^0 F. Every few days the seed was mixed and, if necessary, distilled water added to maintain moisture. In late February, seed of *Lomatium grayi* and *Lomatium triternatum* had started sprouting.

Table 1. Forb species planted at the Malheur Experiment Station and their origins.

Species	Common name	**Origin**	**Year**
Eriogonum umbellatum	Sulfur buckwheat	Shoofly Road (ID)	2004
Penstemon acuminatus	Sand penstemon	Bliss Dam (ID)	2004
Penstemon deustus	Hotrock penstemon	Blacks Cr. Rd. (ID)	2003
Penstemon speciosus	Royal or sagebrush penstemon	Leslie Gulch (OR)	2003
Lomatium dissectum	Fernleaf biscuitroot	Mann Creek (ID)	2003
Lomatium triternatum	Nineleaf desert parsley	Hwy 395 (OR)	2004
Lomatium grayi	Gray's lomatium	Weiser R. Rd. (ID)	2004

In late February, 2005, drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth between two rows (30 inch rows) of a Nyssa silt loam. The drip tape was buried on 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.

The trial was conducted in a field of Nyssa silt loam with a pH of 8.3 and 1.1% organic matter. 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 per foot of row. The *E. umbellatum* and *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*, *L. 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 using the drip system. A total of 3.73 inches of water was applied with the drip system from June 24 to July 7. Thereafter the field was not irrigated.

Plant stands for *E. umbellatum*, all 3 *Penstemons*, *L. triternatum*, and *L. grayi* were uneven. *Lomatium dissectum* did not emerge. None of the species flowered in 2005. In early October, 2005, RMRS provided additional seed for replanting. The *E. umbellatum* and *Penstemon* spp. plots had the empty lengths of row replanted by hand. 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, plant stand of the replanted species was excellent, except for *P. deustus*.

Irrigation for seed production

In April, 2006, the field was divided into plots 30 feet long. Each plot contained 4 rows of each of the 7 forb species. The experimental design was a randomized complete block with 4 replicates. The three irrigation treatments were: a non irrigated check, one inch per irrigation for a total of 4.8 inches, and 2 inches per irrigation for a total of 8.7 inches. Four irrigations were applied approximately every 2 weeks starting on May 19. The amount of water applied to each plot was measured by a water meter for each plot and recorded after each irrigation (Table 2). At the first irrigation on May 19, *P. acuminatus* had ended flowering, *P. deustus* and *P. speciosus* were flowering, and *E. umbellatum* had just initiated flowering.

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

Eriogonum umbellatum flowering started on May 19, peaked on June 24, and ended on July 28. *Penstemon acuminatus* flowering started on May 2, peaked on May 10, and ended on May 19. *Penstemon speciosus* flowering started on May 10 and peaked on May 19. *Penstemon deustus* flowering started on May 10, and peaked on May 22.

The *E. umbellatum* and *Penstemon* spp. plots produced seed in 2006, probably because they had emerged in the spring of 2005. In these plots, only the lengths of row that had consistent stand and seed production were harvested. The plant stand for *P. deustus* was too poor to result in reliable seed yield estimates. The middle two rows of each plot were harvested using a Wintersteiger Nurserymaster small plot combine. *Penstemon acuminatus* was harvested on July 7, *P. speciosus* was harvested on July 13, E. *umbellatum* was harvested on August 3, and *P. deustus* was harvested on August 4.

Eriogonum umbellatum seeds did not separate from the flowering sructures in the combine. Unthreshed *E. umbellatum* seed was taken to the U.S. Forest Service Lucky Peak Nursery and run through a dewinger to separate seed. The seed was further cleaned in a small clipper seed cleaner.

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

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

Results and Discussion:

Precipitation in 2005 and 2006 was higher than normal at the Malheur Experiment Station (Figure 1). Precipitation from October 2004 through June 2005 totaled 11.1 inches and from October 2005 through June 2006 totaled 15.9 inches. The 62 year average precipitation for October through June is 9.2 inches. The wet weather could have attenuated the effects of the irrigation treatments. The actual amount of water applied for each irrigation treatment was relatively close to the planned amounts (Table 2). The soil volumetric water content responded to the irrigation treatments (Figures 2, 3, and 4).

There was no significant difference in seed yield between irrigation treatments for *P. acuminatus*, *P. deustus,* and *P. speciosus* (Table 3). *Eriogonum umbellatum* showed a trend for increasing seed yield with increasing irrigation, with the 2 inch irrigation rate resulting in higher seed yield than the 1 inch irrigation rate or the non-irrigated check. Compared to the *Penstemon* spp., *E. umbellatum* flowered later, at about the same time as the start of the irrigation treatments. *Penstemon acuminatus* had ended flowering at the start of the irrigation treatments. *Penstemon speciosus* and *P. deustus* were in mid-flowering at the start of the irrigation treatments. The later reproductive stage of *E. umbellatum* might explain the response to the irrigation treatments.

The lack of seed yield response to irrigation of the *Penstemon* species in this trial is consistent with substantial rainfall over the winter and spring of 2006 and consistent with the rangelands showing vigorous growth of native plants in the spring of 2006.

Improvements in the planned experimental protocol for 2007 are to deliver irrigation water more closely to the flowering and seed formation stages for each forb species.

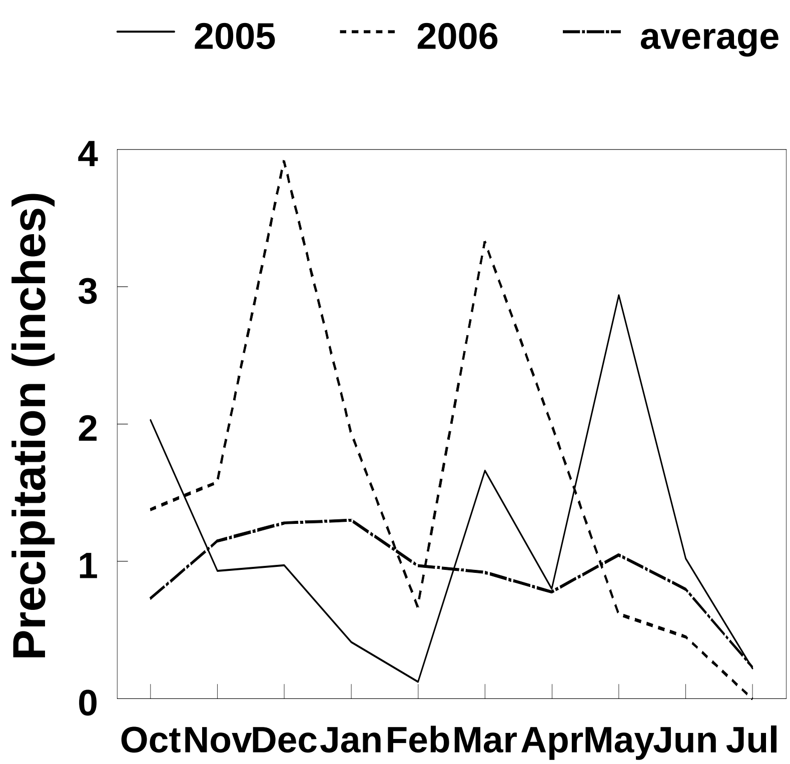

Figure 1. Monthly precipitation from October of the previous year through July for the displayed years. Malheur Experiment Station, Oregon State University, Ontario, OR, 2006.

Table 2. Irrigation treatments and actual amounts of water applied to native forbs. Malheur Experiment Station, Oregon State University, Ontario, OR, 2006.

	Irrigation rates (inches per irrigation)	
Date	Planned	Actual
May 19	2	2.2
	1	1.3
June 2	2	2.2
	1	1.2
June 20	2	2
	1	1.2
June 30	2	2.3
	1	1.1
Total	8	8.7
	4	4.8

Table 3. Native forb seed yield response to irrigation rate. Malheur Experiment Station, Oregon State University, Ontario, OR, 2006.

Total irrigation applied	*Eriogonum umbellatum*	*Penstemon acuminatus*	*Penstemon deustus**	*Penstemon speciosus*
inches	--------------------------------	lb/acre	-----------------------------------	
8.7	371.6	544.0	1,068.6	213.6
4.8	214.4	611.1	1,200.8	285.4
0	155.3	538.4	1,246.4	163.5
LSD (0.05)	92.9	NS	NS	NS

*Yields might overestimate potential commercial yields due to small areas harvested.

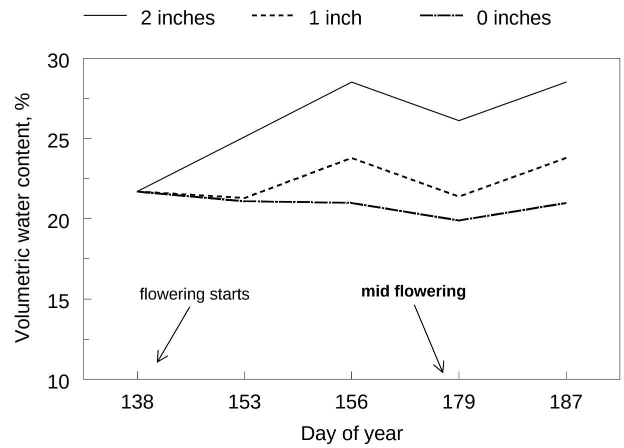

Figure 2. Soil volumetric water content for *Eriogonum umbellatum* over time. Soil volumetric water content is the combined average at the 8, 20, and 32 inch depths. *Eriogonum umbellatum* was harvested on August 3 (day 215). Malheur Experiment Station, Oregon State University, Ontario, OR, 2006.

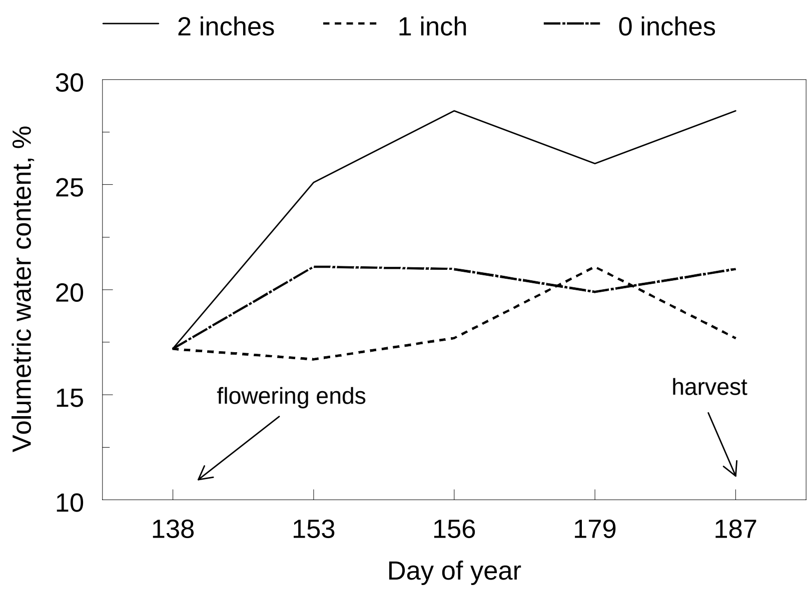

Figure 3. Soil volumetric water content for *Penstemon acuminatus* over time. Soil volumetric water content is the combined average at the 8, 20, and 32 inch depths. Malheur Experiment Station, Oregon State University, Ontario, OR, 2006.

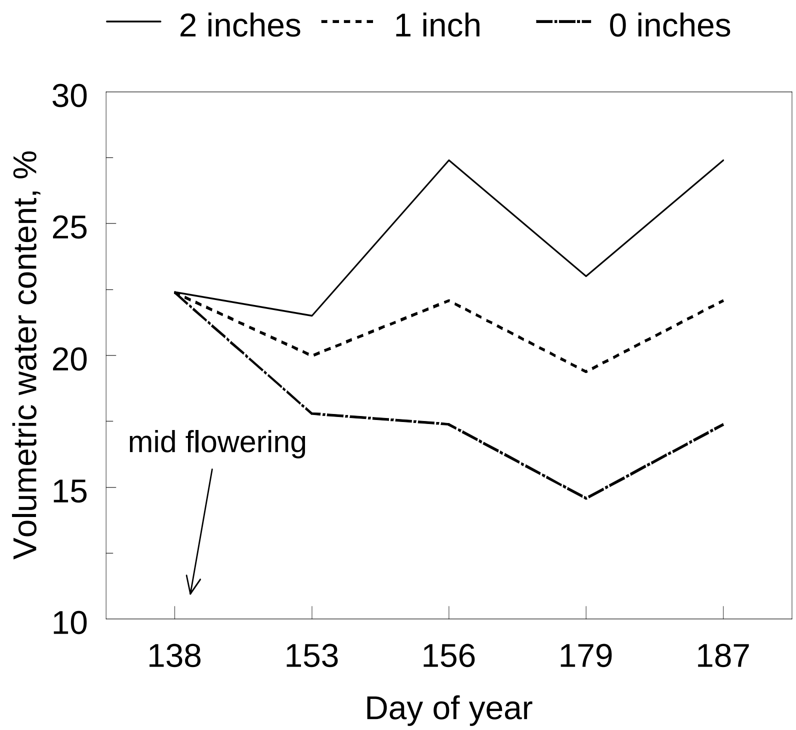

Figure 4. Soil volumetric water content for *Penstemon speciosus* over time. Soil volumetric water content is the combined average at the 8, 20, and 32 inch depths. *Penstemon speciosus* was harvested on July 13 (day 194). Malheur Experiment Station, Oregon State University, Ontario, OR, 2006.

Table 4. Soil volumetric water content for native forb species submitted to 3 irrigation intensities.

	18-May			2-Jun			5-Jun			28-Jun			6-Jul		
Depth	2 inches	1 inch	0 inches	2 inches	1 inch	0 inches	2 inches	1 inch	0 inches	2 inches	1 inch	0 inches	2 inches	1 inch	0 inches
							Eriogonum umbellatum								
0.2 m	16.4	16.4	16.4	17.9	15.6	14.1	22.3	19.1	14.0	19.8	13.6	12.4	21.0	14.7	5.1
0.5 m	24.5	24.5	24.5	28.7	24.2	25.4	32.1	26.6	25.3	29.7	22.8	24.1	30.1	24.2	16.4
0.8 m	24.2	24.2	24.2	28.6	24.1	23.7	31.1	25.6	23.7	28.8	27.7	23.1	29.3	26.2	22.5
Average	21.7	21.7	21.7	25.1	21.3	21.1	28.5	23.8	21.0	26.1	21.4	19.9	28.5	23.8	21.0
							Penstemon acuminatus								
0.2 m	11.2	11.2	11.2	17.9	10.7	14.1	22.3	11.7	14.0	19.6	16.1	12.4	21.5	12.8	7.0
0.5 m	19.0	19.0	19.0	28.7	18.7	25.4	32.1	20.5	25.3	30.5	23.7	24.1	32.2	22.5	17.2
0.8 m	21.3	21.3	21.3	28.6	20.7	23.7	31.1	20.8	23.7	27.9	23.6	23.1	28.6	21.8	21.0
Average	17.2	17.2	17.2	25.1	16.7	21.1	28.5	17.7	21.0	26.0	21.1	19.9	28.5	17.7	21.0
							Penstemon speciosus								
0.2 m	13.1	13.1	13.1	12.1	13.7	9.8	18.0	17.0	9.5	13.6	13.2	7.3	17.3	14.6	7.1
0.5 m	30.3	30.3	30.3	25.2	22.6	22.1	32.4	25.1	21.5	26.8	22.4	18.1	29.5	23.2	17.4
0.8 m	23.9	23.9	23.9	27.4	23.6	21.6	31.8	24.1	21.2	28.7	22.8	18.4	29.8	23.1	17.8
Average	22.4	22.4	22.4	21.5	20.0	17.8	27.4	22.1	17.4	23.0	19.4	14.6	27.4	22.1	17.4

*inches of water per irrigation

Project Title: Tolerance of Seven Native Forbs to Preemergence and Postemergence Herbicides

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

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Project Description:

Native forb seed is needed to restore rangelands of the Intermountain West. Commercial seed production is necessary to provide the quantity of seed needed for restoration efforts. A major limitation to economically viable commercial production of native forb seed is weed competition. Weeds are adapted to growing in disturbed soil, and native forbs are not competitive with these weeds. There is a considerable body of knowledge about the relative efficacy of different herbicides to control target weeds, but few trials have tested native forbs for their tolerance to commercial herbicides.

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

Materials and Methods:

Plant Establishment

Seed of seven Great Basin forb species (Table 1) received in October 2005 was planted November 1, 2005. The field had been disked, ground hogged, and marked out in rows 30 inches apart. The seven forb species were planted in individual rows 435 feet long 30 inches apart. Planting depths were similar to those used in the irrigation trial and varied by species. The crop preceding forbs was wheat. Prior to planting, one drip tape was inserted 12 inches deep equidistant between pairs of rows to be planted. The drip tape was supplied with irrigation water using filtration and other common drip irrigation practices (Shock et al., 2005)

Preemergence Treatments

The weather was wet and windy delaying the application of preemergence herbicide treatments. The field was staked out to make 5-ft wide plots perpendicular to the forb rows, crossing all seven species using the upper 200 feet of the field. Eight treatments (Table 2) including the untreated check were replicated four times, in a randomized complete block design. Treatments were applied 5 January 2006 at 30 psi, 2.63 mph, in 20 gal/ac using 8002 nozzles with three nozzles spaced 20 inches apart.

By early January the planted area had volunteer wheat and blue mustard. Roundup UltraMax at 1.01 lb ai/ac was sprayed 6 January 2006 over the entire area to control the volunteer wheat and other weeds that had emerged. The Roundup was applied at 30 psi, 2.63 mph, in 20 gal/ac using 8002 nozzles with three nozzles spaced 20 inches apart.

On 16 March there was good emergence of the *Lomatium* species. The forbs were cultivated April 13. Cultivation of adjoining areas damaged part of the *Eriogonum umbellatum* that had emerged. Starting April 17 emerged plants were counted in 6 inches of row. Plants were evaluated subjectively for injury on a scale of 0 = no injury and 100 = plants dead.

Postemergence Treatments

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

General Considerations

The focus of the evaluations was forb tolerance to the herbicides, not weed control. Therefore, weeds were removed as needed. In 2006 the trial was irrigated very little using the drip irrigation system because of ample rainfall.

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

Table 1. Forb species planted at the Malheur Experiment Station and their origins.

Species	Common name	**Origin**	**Year**
Eriogonum umbellatum	Sulfur buckwheat	Shoofly Road (ID)	2004
Penstemon acuminatus	Sand penstemon	Bliss Dam (ID)	2004
Penstemon deustus	Hotrock penstemon	Blacks Cr. Rd. (ID)	2003
Penstemon speciosus	Royal or sagebrush penstemon	Leslie Gulch (OR)	2003
Lomatium dissectum	Fernleaf biscuitroot	Mann Creek (ID)	2003
Lomatium triternatum	Nineleaf desert parsley	Hwy 395 (OR)	2004
Lomatium grayi	Gray's lomatium	Weiser R. Rd. (ID)	2004

Results and Discussion:

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

Eriogonum umbellatum (Sulfur Buckwheat)

Sulfur buckwheat had no statistical differences to the preemergence treatments (Table 2) due to the considerable cultivation injury. Very few of the plants that survived cultivation injury survived the preemergence treatment with Outlook or Lorox. Plant stunting was observed in plants where the soil was treated with Kerb and Outlook. None of the sulfur buckwheat plants receiving Kerb preemergence survived.

Sulfur buckwheat was subject to foliar burn and chlorosis (yellowing) with several postemergence herbicides (Table 3). The buckwheat was sensitive to postemergence applications of Buctril, Goal, Caparol, and Lorox as evidenced by statistically significant foliar damage.

Table 2. Tolerance of *Eriogonum umbellatum* to preemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

	Treatment	Rate	Plant stand			Injury		
			4/26	5/31	6/15	5/31	6/15	7/5
		lb ai/ac	----- counts -----		%	----------- % -----------		
1	Untreated check	--	14.5	14	46	0	0	0
2	Prefar 4.0 EC	5.0	25.5	20	65	0	10	10
3	Kerb 50 WP	1.0	0	0	0		No plants	
4	Treflan HFP	0.375	23.5	20.5	52.5	0	20	17.5
5	Prowl 3.8 SC	0.75	11	10	37.5	0	0	5
6	Balan 60 DF	1.2	25	24	80	0	0	0
7	Outlook 6.0 EC	0.656	2.5	2.5	2	0	35	22.5
8	Lorox 50 DF	1.0	1	1	1	0	0	20
	Mean		12.9	11.4	34.8	0	10.8	10.8
	LSD (0.05)		NS	NS	NS	NS	NS	NS

Table 3. Tolerance of *Eriogonum umbellatum* to postemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

	Treatment	Rate	Plant stand %	Injury %		
		lb ai/ac	5/24	5/31	6/15	6/30
1	Untreated	--	70	0	0	0
2	Buctril 2.0 EC	0.125	60	36.3	37.5	23.8
3	Goal 2XC	0.125	62.5	67.5	42.5	23.8
4	Select 2.0 EC + Herbimax	0.094 + 1% v/v	52.5	2.5	2.5	16.3
5	Prowl H_2O 3.8 C	1.0	85	6.3	7.5	0
6	Caparol FL 4.0	0.8	55	40	33.8	28.8
7	Outlook 6.0 EC	0.656	48.8	0	0	3.8
8	Lorox 50 DF	0.5	70	33.8	33.8	27.5
	Mean		63.0	24.0	20.3	16.0
	LSD (0.05)		NS	18.7	12.7	17.4

Penstemon acuminatus (Sand penstemon)
Plant stands of sand penstemon were reduced by preemergence treatments of Prefar, Kerb, Prowl and Balan (Table 4). Where Kerb or Prowl was applied preemergence, almost all sand penstemon plants died during the first growing season. Plant stands were best where Treflan, Outlook, and Lorox were applied. Scattered areas of stunted plants occurred in several treatments. Foliar damage was minimal by July 5 where Treflan or Lorox had been applied.

Few negative effects were noted on sand penstemon from most of the herbicides used as postemergence applications (Table 5). Symptoms of damage were yellowing and leaf burn. Leaf burn and plant stunting occurred with Caparol, a photosynthetic inhibitor. Less dramatic and temporary leaf damage was noted following the application of Buctril.

Penstemon deustus (Hotrock penstemon)
Hotrock penstemon plant stands were reduced by all the products tested except Treflan (Table 6). No hotrock penstemon plants were observed where the soil was treated with Kerb. The most common damage symptoms were yellowing and stunting.

Hotrock penstemon plant stands were reduced by post emergence applications of Caparol and Outlook (Table 7). Plants treated with Select and Prowl had no phytotoxic symptoms. Burnt and yellowing foliage was common with Caparol, Lorox, Buctril, and Goal. Burnt and stunted symptoms on plants persisted to June 30 following the application of Caparol and Lorox.

Table 4. Tolerance of *Penstemon acuminatus* to preemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

	Treatment	Rate	Plant stand			Injury		
			4/26	5/31	6/15	5/31	6/15	7/5
		lb ai/ac	----- counts -----		%	----------- % -----------		
1	Untreated check	--	21.5	20.5	20.0	0	0	0
2	Prefar 4.0 EC	5.0	5	3.5	8.3	31.3	25	0
3	Kerb 50 WP	1.0	0.3	0.3	0.5	0	0	no plants
4	Treflan HFP	0.375	17.8	18.3	43.7	13.3	10	3.3
5	Prowl 3.8 SC	0.75	3	0.75	0.75	87.5	95	no plants
6	Balan 60 DF	1.2	7.8	7.5	22.5	17.5	10	3.3
7	Outlook 6.0 EC	0.656	17.3	15.5	61.7	25	28.8	17.5
8	Lorox 50 DF	1.0	15.5	12.8	40.0	22.5	15	3.8
	Mean		11.0	9.9	23.1	23.1	20.6	5.3
	LSD (0.05)		12.0	11.2	43.0	27.5	29.6	NS

Table 5. Tolerance of *Penstemon acuminatus* to postemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

	Treatment	Rate	Plant stand %	Injury %		
		lb ai/ac	5/24	5/31	6/15	6/30
1	Untreated	--	83.8	0	0	0
2	Buctril 2.0 EC	0.125	81.3	18.8	5	0
3	Goal 2XC	0.125	77.5	7.5	0	0
4	Select 2.0 EC + Herbimax	0.094 + 1% v/v	46.3	2.5	0	0
5	Prowl H_2O 3.8 C	1.0	77.5	5	5	0
6	Caparol FL 4.0	0.8	71.3	35	55	50
7	Outlook 6.0 EC	0.656	65	0	0	0
8	Lorox 50 DF	0.5	67.5	6.3	7.5	0
	Mean		71.25	9.375	9.0625	6.25
	LSD (0.05)		NS	8.4	6.6	2.1

Table 6. Tolerance of *Penstemon deustus* to preemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

	Treatment	Rate	Plant stand			Injury		
			4/26	5/31	6/15	5/31	6/15	7/5
		lb ai/ac	----- counts -----		%	----------- % ----------		
1	Untreated check	--	37.3	25	68.8	0	0	0
2	Prefar 4.0 EC	5.0	3	2.5	5.0	0	0	7.5
3	Kerb 50 WP	1.0	0	0	0	No plants		
4	Treflan HFP	0.375	27.8	20.3	59.3	0	12.5	0
5	Prowl 3.8 SC	0.75	6.3	4.3	15.3	0	23.3	20
6	Balan 60 DF	1.2	4.8	4.3	10.8	0	16.3	12.5
7	Outlook 6.0 EC	0.656	2	1.5	1.8	0	53	70
8	Lorox 50 DF	1.0	0.8	0.5	1.0	0	20	10
	Mean		10.2	7.3	20.2	0	17.3	13.9
	LSD (0.05)		21.2	14.8	30.6	NS	NS	22.5

Table 7. Tolerance of *Penstemon deustus* to postemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

	Treatment	Rate	Plant stand %	Injury %		
		lb ai/ac	5/24	5/31	6/15	6/30
1	Untreated	--	98.8	0	0	0
2	Buctril 2.0 EC	0.125	82.5	32.5	11.3	10
3	Goal 2XC	0.125	83.8	21.3	13.8	7.5
4	Select 2.0 EC + Herbimax	0.094 + 1% v/v	91.3	0	0	0
5	Prowl H_2O 3.8 C	1.0	95	0	0	0
6	Caparol FL 4.0	0.8	56.3	48.8	55	42.5
7	Outlook 6.0 EC	0.656	70	0	0	0
8	Lorox 50 DF	0.5	86.3	38.8	48.8	42.5
	Mean		83.0	17.7	16.1	12.8
	LSD (0.05)		24.5	11.2	17.7	19.5

Penstemon speciosus (Royal or Sagebrush penstemon)
Royal penstemon plant stands were not affected by Treflan, Balan, or Outlook, among others (Table 8). Phytotoxic effects of most herbicides were moderate and diminished with time. Prowl and Balan applied preemergence had significant negative effects, and marked stunting with Prowl. No royal penstemon survived to 2007 where Kerb was applied preemergence.

None of the postemergence herbicides tested reduced the stands of royal penstemon (Table 9). Royal penstemon was sensitive to Lorox and extremely sensitive to Caparol. Symptoms of Caparol damage included yellowing, yellow-purple foliage, and plant death. Where other products damaged plants, symptoms were yellowing, stunting, and leaf burn.

Lomatium dissectum (Fernleaf biscuitroot)
Fernleaf biscuitroot had a very brief growing season, so observations on the effects of preemergence herbicides were ended on May 31. No significant decreases in plant counts were noted due to preemergence herbicides (Table 10); however, phytotoxic symptoms on the foliage were commonly noted. Prefar had significantly more foliar symptoms that the untreated check on April 17, while Kerb, Outlook, Prowl, and Lorox had significantly more symptoms that the untreated check on both April 17 and May 31. None of the herbicides applied preemergence appeared to be totally safe at the rates used in this trial.

Observations of the postemergence herbicides were begun in late May and continued until June 30. The postemergence herbicides had no significant effects on plant stands at the rates tested (Table 11). In contrast to the negative phytotoxic effects observed with the preemergence herbicide applications, none of the herbicides applied postemergence had significant phytotoxic effects on fernleaf biscuitroot at the rates tested.

Table 8. Tolerance of *Penstemon speciosus* to preemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

	Treatment	Rate	Plant stand, counts		Injury %		
			4/26	5/31	5/31	6/15	7/5
		lb ai/ac	----- counts -----		---------- counts ----------		
1	Untreated check	--	22.5	20.3	0	0	0
2	Prefar 4.0 EC	5.0	10.3	9	11.7	6.7	0
3	Kerb 50 WP	1.0	0.3	0	------------ No plants ------------		
4	Treflan HFP	0.375	26.3	24.8	20	12.5	8.3
5	Prowl 3.8 SC	0.75	8.8	7	73.8	57.5	41.7
6	Balan 60 DF	1.2	20	20	30	26.3	8.3
7	Outlook 6.0 EC	0.656	19.5	17.3	18.8	7.5	0
8	Lorox 50 DF	1.0	19.8	16.3	2.5	2.5	0
	Mean		15.9	14.3	22.8	16.5	7.6
	LSD (0.05)		NS	15.2	32.2	24.4	16.5

Table 9. Tolerance of *Penstemon speciosus* to postemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

	Treatment	Rate	Plant stand %	Injury %		
		lb ai/ac	5/24	5/31	6/15	6/30
1	Untreated	--	71.3	0	0	0
2	Buctril 2.0 EC	0.125	82.5	7.5	7.5	5
3	Goal 2XC	0.125	83.8	3.8	2.5	2.5
4	Select 2.0 EC + Herbimax	0.094 + 1% v/v	92.5	3.8	0	2.5
5	Prowl H_2O 3.8 C	1.0	92.5	2.5	0	10
6	Caparol FL 4.0	0.8	83.8	45	83.3	81.3
7	Outlook 6.0 EC	0.656	76.3	0	0	0
8	Lorox 50 DF	0.5	73.8	25	28.8	33.8
	Mean		82.0	10.9	15.3	16.9
	LSD (0.05)		NS	12.1	7.4	9.6

Table 10. Tolerance of *Lomatium dissectum* preemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

Treatment		Rate	Plant Stand, counts		Injury %	
		lb ai/ac	4/17		4/17	5/31
1	Untreated check	--	18.5		0	0
2	Prefar 4.0 EC	5.0	19.8		18.8	15
3	Kerb 50 WP	1.0	13.5		38.8	46.3
4	Treflan HFP	0.375	16		11.3	20
5	Prowl 3.8 SC	0.75	16		20	32.5
6	Balan 60 DF	1.2	16		13.8	20
7	Outlook 6.0 EC	0.656	9.5		35	41.3
8	Lorox 50 DF	1.0	14.8		15	27.5
	Mean		15.5		19.1	25.3
	LSD (0.05)		NS		13.9	26.5

Table 11. Tolerance of *Lomatium dissectum* to postemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

Treatment		Rate	Plant stand %	Injury %		
		lb ai/ac	5/24	5/31	6/15	6/30
1	Untreated	--	96.3	0	0	0
2	Buctril 2.0 EC	0.125	100	3.8	5	2.5
3	Goal 2XC	0.125	95	12.5	7.5	5
4	Select 2.0 EC + Herbimax	0.094 + 1% v/v	97.5	3.8	7.5	8.8
5	Prowl H_2O 3.8 C	1.0	96.3	5	10	7.5
6	Caparol FL 4.0	0.8	90	0	7.5	7.5
7	Outlook 6.0 EC	0.656	100	5	2.5	0
8	Lorox 50 DF	0.5	100	2.5	2.5	5
	Mean		96.9	4.1	5.3	4.5
	LSD (0.05)		NS	NS	NS	NS

Lomatium triternatum (Nineleaf desert parsley)
Plant counts of nineleaf desert parsley were not affected by the preemergence herbicides at the rates tested (Table 12). Outlook caused significant foliar damage compared to the untreated check at all four observation dates. Symptoms included leaf burn, stunting, and plant death. Leaf burn and stunting were also noted for the plants with preemergence Lorox.

None of the postemergence herbicides reduced plant stands as of May 24 (Table 13). Burnt plants and plant death occurred where Buctril was applied postemergence. Other than the very marked damage observed with Buctril, none of the other postemergence herbicides had significant amounts of foliar damage except the observations on June 30 of the plants treated with Prowl.

Lomatium grayi (Gray's lomatium)
Plant counts of Gray's lomatium were not affected by the preemergence herbicide treatments (Table 14). Stunting and plant death were severe where Kerb was applied preemergence. For the other preemergence treatments, mild stunting was noted, not significantly different from the untreated check treatment.

Just like the other two Lomatiums, none of the postemergence herbicides reduced plant stands as of May 24 (Table 15). Like nineleaf desert parsley, Gray's lomatium showed significantly more damage following postemergence application of Buctril. Buctril resulted in burnt foliage. Some significant foliage symptoms followed postemergence applications of Goal, Caparol, and Lorox, but the symptoms were significantly less than those observed with Buctril.

Table 12. Tolerance of *Lomatium triternatum* to preemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

Treatment		Rate	Plant stand, counts		Injury %			
		lb ai/ac	4/18		4/18	5/31	6/15	7/5
1	Untreated check	--	48.5		0	0	0	5
2	Prefar 4.0 EC	5.0	42.5		0	7.5	1.3	0
3	Kerb 50 WP	1.0	37.5		10	10	5	8.8
4	Treflan HFP	0.375	42.5		7.5	10	6.3	7.5
5	Prowl 3.8 SC	0.75	39.8		3.8	5	0	0
6	Balan 60 DF	1.2	48.8		6.3	3.8	6.3	0
7	Outlook 6.0 EC	0.656	41.3		30	40	35	38.8
8	Lorox 50 DF	1.0	43.8		10	11.3	11.3	11.3
	Mean		43.1		8.4	10.9	8.1	8.9
	LSD (0.05)		NS		10.4	14.8	13.7	14.1

Table 13. Tolerance of *Lomatium triternatum* to postemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

	Treatment	Rate	Plant stand %	Injury %		
		lb ai/ac	5/24	5/31	6/15	6/30
1	Untreated	--	93.8	0	0	0
2	Buctril 2.0 EC	0.125	96.3	28.3	73	82.5
3	Goal 2XC	0.125	87.5	2.5	2.5	6.3
4	Select 2.0 EC + Herbimax	0.094 + 1% v/v	98.8	0	2.5	3.8
5	Prowl H_2O 3.8 C	1.0	96.3	2.5	5	15
6	Caparol FL 4.0	0.8	98.8	2.5	0	3.8
7	Outlook 6.0 EC	0.656	97.5	2.5	0	3.8
8	Lorox 50 DF	0.5	100	0	0	3.8
	Mean		96.1	4.8	10.4	14.8
	LSD (0.05)		NS	9.8	9.6	11.7

Table 14. Tolerance of *Lomatium grayi* to preemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

	Treatment	Rate	Plant stand, counts		Injury %			
		lb ai/ac	4/18		4/18	5/31	6/15	7/5
1	Untreated check	--	30.8		0	0	0	0
2	Prefar 4.0 EC	5.0	28.3		7.5	11.3	11.3	8.8
3	Kerb 50 WP	1.0	29.8		28.8	42.5	38.8	42.5
4	Treflan HFP	0.375	30		7.5	7.5	5	12.5
5	Prowl 3.8 SC	0.75	26.3		2.5	8.8	5	6.3
6	Balan 60 DF	1.2	35.3		6.3	0	0	0
7	Outlook 6.0 EC	0.656	30.5		11.3	6.3	5	6.3
8	Lorox 50 DF	1.0	29.8		10	11.3	6.3	8.8
	Mean		30.1		9.2	10.9	8.9	10.6
	LSD (0.05)		NS		12.7	19.5	20.4	24.7

Table 15. Tolerance of *Lomatium grayi* to postemergence herbicides screened at the Malheur Experiment Station, Oregon State University, Ontario, Oregon, 2006.

	Treatment	Rate	Plant stand %	Injury %		
		lb ai/ac	5/24	5/31	6/15	6/30
1	Untreated	--	100	0	0	0
2	Buctril 2.0 EC	0.125	98.8	22.5	37.5	30
3	Goal 2XC	0.125	92.5	10	7.5	5
4	Select 2.0 EC + Herbimax	0.094 + 1% v/v	96.3	5	0	0
5	Prowl H_2O 3.8 C	1.0	96.3	5	2.5	2.5
6	Caparol FL 4.0	0.8	90	10	7.5	7.5
7	Outlook 6.0 EC	0.656	95	2.5	2.5	3.8
8	Lorox 50 DF	0.5	98.8	8.85	6.3	6.3
	Mean		95.9	8.0	8.0	6.95
	LSD (0.05)		NS	5.3	7.2	15.1

Spring of 2007

By March 30, 2007, it was difficult if not impossible to distinguish any effects of the 2006 postemergence herbicide applications on any of the seven forb species. Preemergence herbicide effects from 2006 were no longer visible on the *Lomatium* species. Where preemergence herbicides hurt or killed most of the sulfur buckwheat or penstemon plants, the negative effects were permanent. These observations suggest that some degree of phytotoxic damage may be acceptable in establishing native forb seed fields if effective weed control is achieved.

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

Project Location: USDA-FS National Seed Laboratory, Dry Branch, GA

Principal Investigators and Contact Information:

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Project Description:
The USDA Forest Service, National Seed Laboratory (NSL) is collaborating with other members of the Great Basin Native Plant Selection and Increase Project to develop seed cleaning and testing protocols for research species. Seed cleaning protocols involve using screens, aspirators, debearders and other equipment to separate seed from other material collected. Seed testing work includes determination of AOSA minimum purity weight recommendations and protocols for germination and purity determinations. The seed testing work is essential for eventual development of AOSA rules if seeds are going to be marketed. Seed test results are important to buyers and sellers for product labeling, to growers for plant production and to seed control officials for enforcement of state and federal seed laws. Seed testing rules for these species will be necessary as these seeds enter the market.

Project Status:
The NSL has received collections of five species for seed cleaning protocols, *Balsamorhiza hookeri*, *Chaenactis douglasii*, *Crepis acuminata*, *Erigeron pumilis*, and *Penstemon deustus*. Guidelines and recommendations for cleaning collections of these species have been developed and will be posted on the NSL website, www.nsl.fs.fed.us/great_basin_native_plants.html, and at the Native Plant Program website, www.nativeplants.for.uidaho.edu/network.

Species and number of collections received in 2004 from cooperators for seed testing protocols include: *Agoseris glauca* 4, *Astragalus filipes* 30, *Crepis acuminata* 3, *Eriogonum umbellatum* 18, *Lomatium dissectum* 23, *L. grayi* 10, *L. triternatum* 7, *Penstemon acuminatus* 36, *P. deustus* 35, and *P. speciosus* 20. In 2005 these additional species and lots were received: *Agoseris glauca* 5, *Lomatium dissectum* 19, *L. grayi* 4, *L. triternatum* 4, *Balsamorhiza sagittata* 1, *Crepis acuminata* 2, *Astragalus eremiticus* 2, *Aristida purpurera* 1, *Eriogonum heracleoides* 1, *E. umbellatum* 5, *Penstemon acuminatus* 5, and *P. deustus* 11.

Seed counts and recommended minimum purity test weights have been developed. Information is available on the NSL website and will be available at the Association of Official Seed Analysts (AOSA) website for Species without Seed Testing Procedures, www.aosaseed.com/reference.htm.

The first round of germination trials for all collections was completed in 2004. Seed was tested with and without prechill, with and without light, and using two sets of temperatures for germination, 15-25 ^oC. and 20-30 ^oC., two temperature regimes common at many seed laboratories. Results indicate that further trials are needed with varying lengths of prechill and with lower temperature regimes for germination. The second round of testing indicated that cool germination temperatures were better, and many seeds germinated in the dark of the chilling room at 3 ^oC. A third round of tests used the following temperatures mostly in the dark and with and without stratification: 5-10, 5-20, 5-30, 15, 15-25, 20, 30 ^oC. Light was applied at 5-10 ^oC. (When two numbers are given for temperature, the first is for 16 hours and the second is for 8 hours. A single number indicates a constant temperature. When light is used it is used for 8 hours and at the higher temperature if alternating.)

Preliminary data is available on *Lomatium*. *Lomatium grayi* appears to germinate well without stratification at 5-10 ^oC or constant 5 ^oC. Light does not seem to help or hinder. Even at 15 ^oC germination requires stratification. A cold night (16 hours) does not give germination if temperature is warm during the day as 5-20 ^oC and 5-30 ^oC gave no germination. *Lomatium dissectum* appears to need about 4 weeks of stratification to germinate at 5 and 10 ^oC, while *L. triternatum* needs an even longer stratification as it did not germinate at the apparent optimum temperature even with the stratification. Results are summarized in Fig. 1.

Seed weight work continues with each year's collection to improve the estimates made in the first year.

As greater quantities of seed become available for a particular species, ring tests can be conducted between a few AOSA and research laboratories. Rule proposals developed and submitted to AOSA will be based on this ring test data.

The NSL will continue to work with AOSA to promote the standardization of seed testing methods for native species. The NSL is a member of the AOSA Native Species Seed Task Force formed in 2005 and will continue working with this group in 2007, participating in a Native Seed Workshop at Omaha, NE and at the AOSA annual conference at Indianapolis, IN.

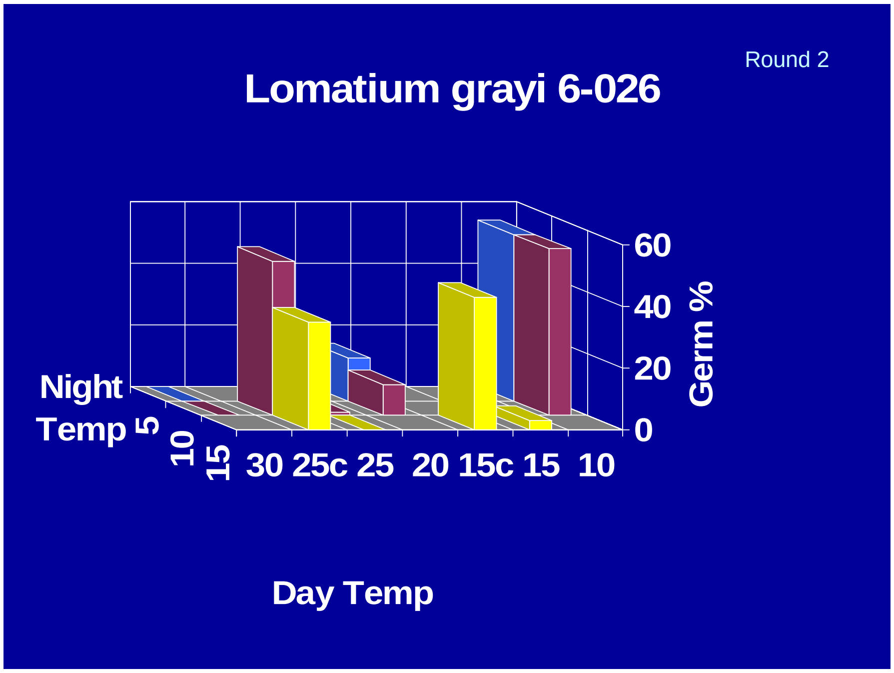
Products

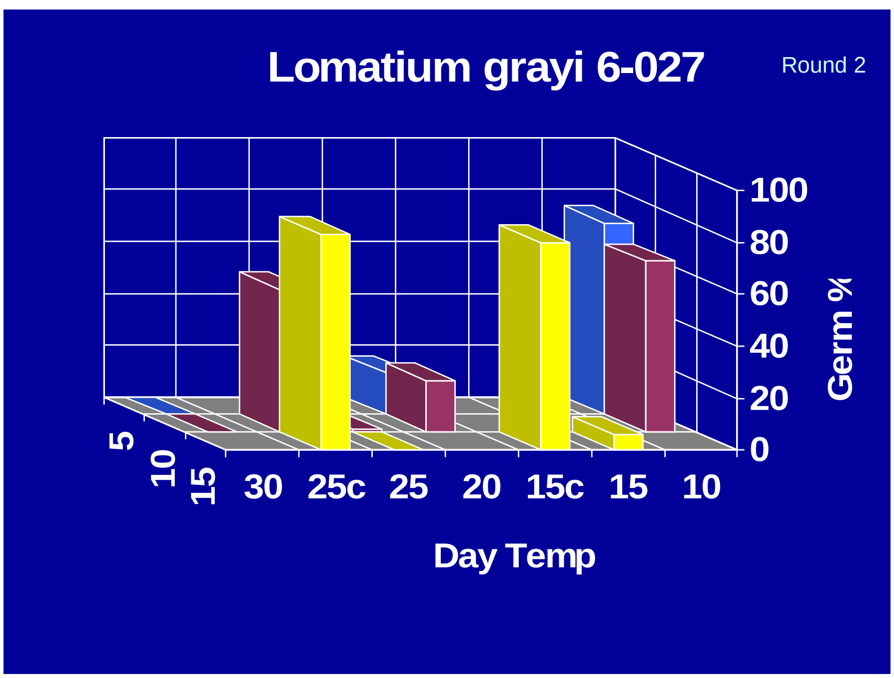
Presentations:
R.P. Karrfalt, V.G. Vankus, and J.R. Barbour. Germination, seed weight, purity, and seed cleaning protocols for Great Basin native plants. Society for Range Management 60th Annual Meeting, February 15, 2007.

Technology Transfer:
Attended the Association of Official Seed Analysts (AOSA) annual meeting in June 2006. Discussions at the conference related to GBNPP work with other seed testing laboratories with continued participation in the Native Species Seed Task Force to address the issue of standardization of seed testing and reporting procedures at seed testing laboratories which met in Nebraska in 2006.

As they becomes available, data are posted to the internet at:
www.nsl.fs.fed.us/great_basin_native_plants.html and www.nativeplants.for.uidaho.edu/network

Figure 1. Germination data from two lots (6-026, 6-027) of *Lomatium grayi* seeds. A "c" with the temperature indicates the seeds were chilled at 3 °C for 4 weeks prior to germination. Daytime temperatures above 10 °C suppressed germination unless the seed was chilled prior to germination.





Project Title: Establishment of Native Plants Through Improved Propagation Techniques and Seedling Disease Control

Project Location: **Brigham Young University and USDA FS** Shrub Sciences Laboratory, Provo, Utah

Principal Investigators and Contact Information:

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Project Description:

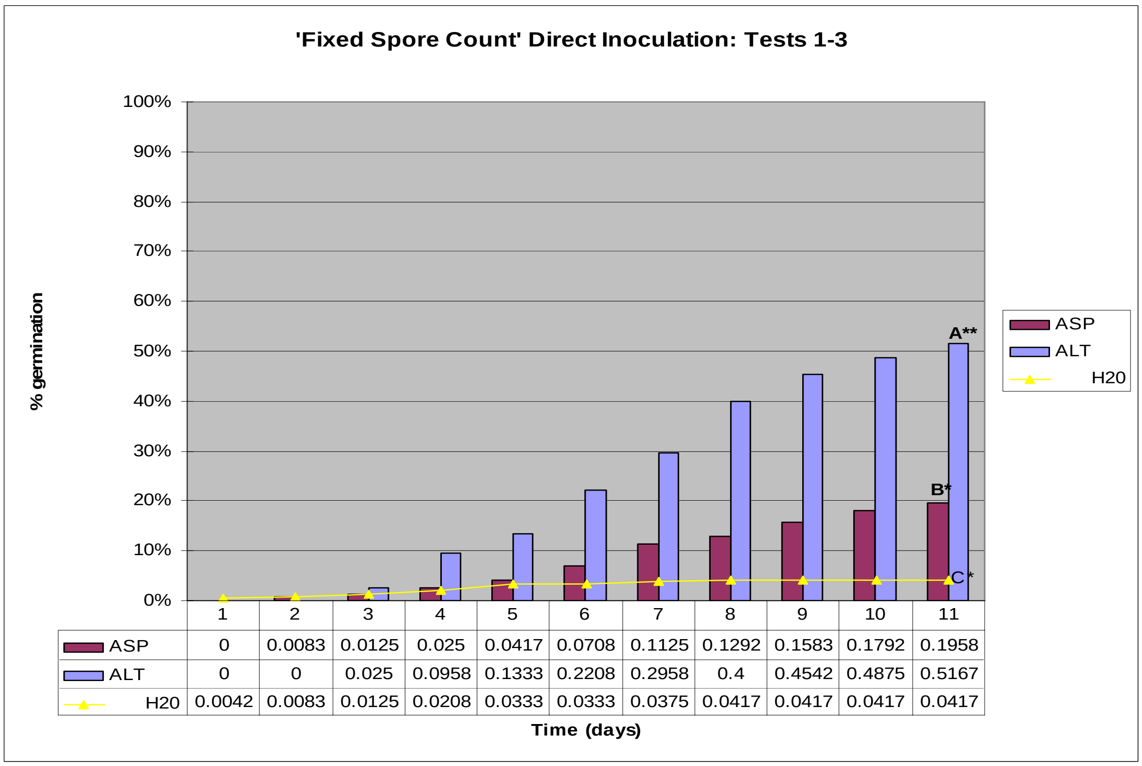
Increase seed germination by inoculation with Aspergillus and Alternaria fungi. Hard seeded dormancy of *Astragalus utahensis* prevents germination under optimal moisture conditions even after scarification with 98% H_2SO_4. Seeds inoculated with *Aspergillus* spp. (Asp) and *Alternaria* spp. (Alt) germinate rapidly (83% and 28%) over H_2O (6%). Physical manipulation by the fungi show elevated response in seed coat removal. Pin pricking responses are similar to soaking the seeds in broth where the fungi have been grown but are removed. Future research in consortium tests (use of 4 filtrates in combination with mechanical scarification) will likely show strong correlation to the direct inoculation tests. Grass species were also inoculated with *Aspergillus* and *Alternaria*. Trials are just beginning to determine efficacy of the fungi on other plant seed.

Native plant seedling disease control. Many of the seedlings from *Astragalus utahensis* die shortly after emergence. Isolation and fungicide/bactericide tests were conducted to determine if the seedling mortality is due to biotic stresses or abiotic stresses.

Improved propagation techniques to increase seedling survivability. High frequencies of seedling mortality occur after the first two true leaves appear on *Lupinus* species. Studies indicated that the cause of death is not due to biotic organisms like fungi or bacteria, but are due to physiological issues within the plant. Seedling fertility may be an abiotic stress that is influencing mortality, therefore seedlings will be fertilized with liquid fertilizers to determine if seedling survival can be increased.

Project Status:
Increase seed germination by inoculation with Aspergillus and Alternaria fungi.
Germination of *Astragalus utahensis* increased significantly (P $\leq$ 0.05) when seeds were inoculated with *Aspergillus* and *Alternaria* (Fig. 1). *Alternaria* inoculated seeds had significantly more germination at 11 days than the *Aspergillus* treated seeds, and the *Aspergillus* treatment was significantly better than the water control. Identical inoculation studies were conducted again but the seeds were planted in potting soil and grown in a growth chamber and in a greenhouse. In both growing areas, the seeds inoculated with *Aspergillus* and *Alternaria* had significantly ($P < 0.05$) higher germination than did the water control (Figs. 2 and 3). *Aspergillus* treated seeds tended to have higher germination, but it was not significantly different from that of the *Alternaria* treated seeds.

Figure 1. Germination response in-vitro of *Astragalus utahensis* seeds inoculated with *Aspergillus* or *Alternaria*.



	1	2	3	4	5	6	7	8	9	10	11
ASP	0	0.0083	0.0125	0.025	0.0417	0.0708	0.1125	0.1292	0.1583	0.1792	0.1958
ALT	0	0	0.025	0.0958	0.1333	0.2208	0.2958	0.4	0.4542	0.4875	0.5167
H20	0.0042	0.0083	0.0125	0.0208	0.0333	0.0333	0.0375	0.0417	0.0417	0.0417	0.0417

Figure 2. Germination response of *Astragalus utahensis* seeds inoculated with *Aspergillus* or *Alternaria* in soil in a growth chamber.

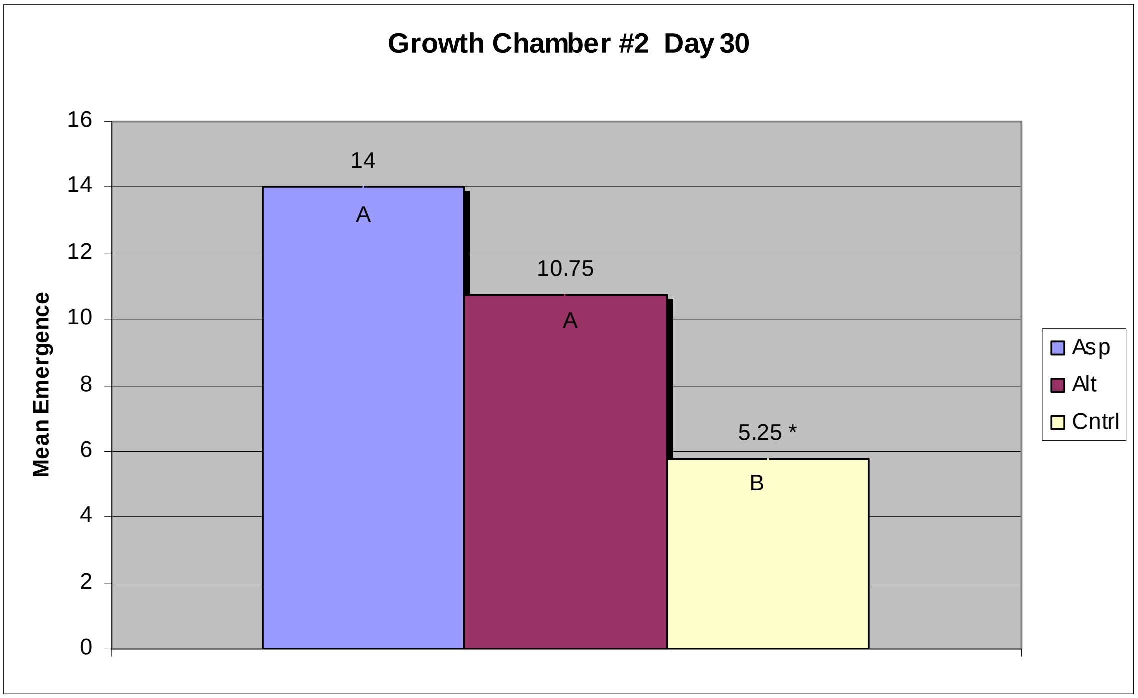
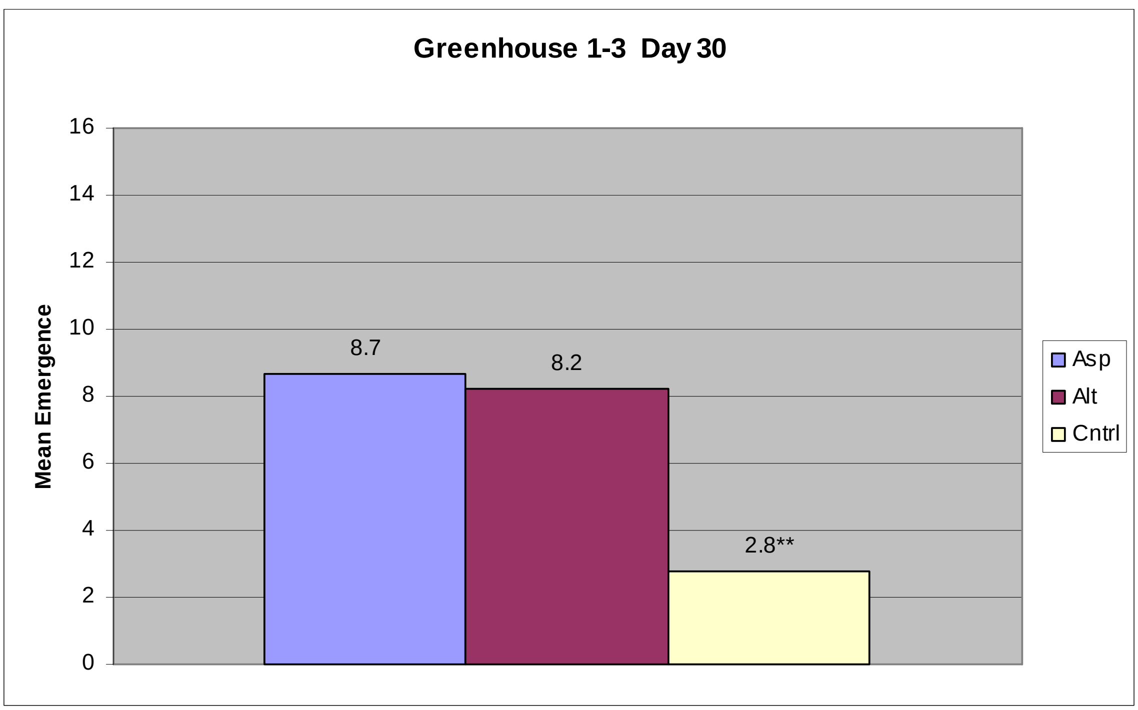


Figure 3. Germination response of *Astragalus utahensis* seeds inoculated with *Aspergillus* or *Alternaria* in soil in a greenhouse.



Studies looking at *Aspergillus* and *Alternaria* influence on grass seed germination are also being conducted. From preliminary data collected thus far from in-vitro studies it appears that *Aspergillus* and *Alternaria* increase germination over water controls. Data are not presented here because the study is on-going.

Native plants seedling disease control.
Lupinus seeds were planted in potting soil and then removed from the soil on timed intervals of 3, 5, 7, 9, and 11 days. Seeds were then surface sterilized in a 10% bleach solution, cut in half and placed on potato dextrose agar. Many different fungi and bacteria grew from the seeds. One fungus that was of interest that could cause seedling damping off was *Fusarium*. A number of bacteria genera were identified. Most were of the genus *Agrobacterium*, 15 isolates were *Erwinia*, 5 were *Pseudomonus*, and 4 were *Xanthamonas*. A number of the bacteria could be pathogenic, however, when isolations were made from dying seedlings most did not have any fungi or bacteria grow out on the potato dextrose agar. The dying seedlings were also stained with lanolin blue to identify any fungi, but no fungal infections could be identified.

To further test if the seedlings were dying due to fungi or bacteria, four different species of *Lupinus* (LUSE, LUAR, LUPO, LUCA) seeds were treated with various fungicides and bacteriacides. None of the seed treatments were significantly ($P < 0.05$) better that the untreated control seeds (Table 1). Two treatments (PCNB and Mancozeb) had significantly lower germination, most likely due to a phytotoxic effect on the seedlings from the chemicals. A number of fungicides and bacteriacides were used to minimize phytotoxic effects from the chemicals and to target specific fungi or bacteria since all chemicals do work equally well on different microorganisms.

Table 1. Germination percentages for *Lupinus* seeds (data combined for all four species) treated with different fungicides and bacteriacides.

Seed treatments	Germination percentage	Significance
Arpon	60.3	A
Maxim	59.1	A
Dynasty	56.6	A
Streptomyacin	55.9	A
Control	53.5	AB
Captan	32.3	BC
PCNB	28.7	C
Mancozeb	27.7	C

Observations of many seedlings that were dying once the cotyledons were out showed that roots were not forming. The shoot from which the cotyledons were produced was the only portion of the plant emerging from the seed. This observation strongly suggested that seedling death was due to a physiological condition within the plant/seed, or the scarification methods used to break dormancy were causing detrimental effects on the seedling. The lack of fungi identified within dying plants, the number of fungi and bacteria (with no predominating organism) isolated from the seeds, and no beneficial influence from the fungicides or bacteriacides suggest that seed mortality is due to an abiotic stress upon the plant.

Seeds that do produce roots are still dying but it may be from a lack of nutrients. Therefore, this study is continuing by germinating seedlings in nutrient poor media and then applying liquid nutrients to determine if seedling survival can be increased.

Improved propagation techniques to increase seedling survivability.
Fertility studies, as mentioned above, are on going to determine if seedling survivability can be improved. Along with the fertility is the use of *Rhizobium* inoculations made to the seeds to determine if the symbiotic relationship between the seedling and the bacteria stimulate *Lupinus* growth and survival. Commercial inoculates of *Rhizobium* are being used as well as *Rhizobium* taken from wild plants, which was collected and cultured. All types will be added to seeds to determine if the *Rhizobium* can increase survival and growth.

Technology Transfer:

Oral presentations with abstracts:
Eldredge, S., B. Geary, J. Gardner, and S. Jensen. 2006. Viability of an accelerated germination response of fungal inoculated *Astragalus utahensis* seed in soil. 51st Annual Meeting of the Agronomy – Soil – Crop Science Society of America, Nov. 12-16, Indianapolis, IN.

Eldredge, S., B. Geary, S. Jensen and J. Gardner. 2006. Mechanisms of accelerated germination of *Astragalus utahensis* with *Aspergillus* and *Alternaria* fungi. American Phytopathological Society, July 29-Aug. 2, Quebec, Canada. Phytopathology 96: S32.

Poster presentation with abstract:
Eldredge, S., B. Geary, S. Jensen, and J. Gardner. 2005. Increased germination of *Astragalus utahensis* with the fungi *Alternaria* and *Aspergillus*. 69th Annual Meeting Crop Science Society of America. Nov. 6-10, Salt Lake City, Utah.

Project Title: Pollinator and Seed Predator Studies

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

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Project Description:

Native bees and/or honey bees are proving to be beneficial or necessary to pollinate nearly all of the wildflower species considered for Great Basin 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 species attracts and is 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.

Concurrently, drilled wooden nesting blocks are placed in these habitats to acquire captive populations of one or more promising cavity-nesting pollinators. Currently managed bee species (alfalfa leaf-cutting bees, blue orchard bees, alkali bees, honey bees) are being evaluated for their pollination prowess with each of the target plant species as well, using our common gardens or managed stands maintained by BLM and USFS collaborators on this proposal. Practical management protocols and materials will be developed to sustainably manage pollinators on-farm.

In addition, any prevalent floral herbivores and seed predators are being collected, reared and identified, as they subtract from the potential seed production initiated by pollinators. Lastly, pollination information is being disseminated to collaborators and growers, and if need be, populations of native cavity-nesting pollinators acquired, increased and distributed to growers with guidance for the bees' management.

Project Status:

Additional systematic censuses of bees (as individuals per 100 flowering plants) were sampled at *Lomatium dissectum*, *Balsamorhiza sagittata, Astragalus filipes* and *Lupinus argenteus* in states not before sampled, with new bee surveys started for two globemallows (*Sphaeralcea).* In addition, an efficient unbiased large-scale method was developed and tested for future use in characterizing the response of bee communities to ecological perturbations (esp. fire, cheatgrass invasion). Basically, it allows pairwise comparison of passively sampled bee communities and net-collected floral guilds within and beyond the perturbed area, with a quick estimate of density of sagebrush and the target forb species.

We prepared raised, irrigated seed beds for this coming year's experimental plantings of *Sphaeralcea* and *Lomatium*. We also transplanted greenhouse seedlings of *Lomatium triternatum* and *L. grayi,* and transplanted 100 more taproots of *Lomatium dissectum*. Deer have been excluded with an 8' perimeter fence that we built.

Pollinators, particularly bees, will be needed for seed production at most of the native forbs chosen for this project from the Great Basin flora. In 2006 we focused our studies of breeding biologies on established plants of 3-yr-old *Dalea ornata* and 2-yr-old *D. searlsiae* growing in our 20' x 20' common garden plots. Deer depredation cost us our *Lomatium dissectum* pollination experiments.

For both *Dalea ornata* and *D. searlsiae*, autopollination on caged racemes yielded dismal seed production (3-4% of available flowers set a seed, and 80-97% of those seeds were small and of questionable viability). Hence, pollinators are essential to seed production by these two prairie-clovers. Manual self-pollination of *Dalea ornata* yielded no more seed than autopollination, but manual outcrossing yielded a 50% seed set, 1/3 of the seeds being large. At *D. searlsiae,* self-pollination gave 14% seed set and outcrossing only 20% seed set. Because all plants were within a cage, we could not compare with free pollination by bees. For 2007 experiments, we have built individual cages to repeat pollination treatments on *D. searlsiae,* and evaluate both species for their attractiveness to bees and bees' resultant pollination service. At *D. purpurea*, bees outperformed us, doubling the percentage of seeded pods and large seeds per pod, so we expect similarly good pollination by bees with these two Great Basin prairie-clovers. We are also expecting that the plants, being a year older, will be more robust.

In general, it appears that bees are the essential pollinators for the selected wildflower species. Studies of the pollination needs of *Hedysarum boreale* Nutt. have recently been completed by graduate student Katharine Swoboda. They are illustrative and detailed here. Her manual pollinations showed that *H. boreale* is self-compatible; however, *H. boreale* did not produce fruits or seeds in the absence of bee visitors because the flowers are mechanically incapable of autopollination. Manual selfing yielded more seedless pods and more small seeds than outcrossing. Conversely, bee pollination of *H. boreale* flowers yielded abundant large, viable seed, the quantities being intermediate between that of selfing via geitonogamy and out-crossing (xenogamy). Hence, bee pollination apparently yields a mix of selfing and outcrossing.

Cultivated *H. boreale* flowers abundantly, producing four million new flowers daily per acre. Flowers produce abundant pollen (50,000 grains per flower) and nectar (1-2 liters per acre of nectar with 60% sugar content). Diverse bee species in the families Apidae and Megachilidae were found in surveys at *H. boreale* flowers. Female bees often collect both nectar and pollen from *H. boreale* for provisioning their progeny. In general, *Osmia* species are an important component of *H. boreale* pollinator faunas. Three solitary, cavity-nesting candidate *Osmia* species were chosen and evaluated for their management potential as *H. boreale* pollinators. All three reproduced and could increase with *H. boreale* as their only pollen and nectar source. Nesting success by *O. lignaria* Say was limited, however, by the mismatch of the bee's early natural emergence date and the later bloom of *Hedysarum*. Later flying *O. lignaria* from colder climates could be used to pollinate *H. boreale* flowering earlier in warmer climes. Nesting results from the other two *Osmia* species, *O. bruneri* Cockerell and *O. sanrafaelae* Parker, were more encouraging. In cages, both species provisioned enough daughters to increase in subsequent years. Comparable increases were obtained with *O. sanrafaelae* that we flew in a 2-acre production field of *H. boreale* managed by Rick Dunne near Lander, WY. Their nesting habits are known from earlier publications. Both species proved to be effective and consistent pollinators of *H. boreale* flowers, their foraging behaviors compensating for a seeming size-mismatch with the flowers. Experimental estimates of seed yield per forager were compromised by an outbreak of rust on the sweetvetch grown in the pollination cages. Honeybees were mediocre pollinators of *H. boreale* compared to other species, but they could serve in some agricultural settings to pollinate *H. boreale*. Populations of the two promising *Osmia* are currently being increased for commercial pollination of *H. boreale*.

Systematic samples of bee faunas continue, targeting six floral hosts sampled at 40 locations in the heart of the Great Basin and adjacent Snake River Plains. We focused on extending field sampling of bee faunas at *A. filipes* this year, systematically sampling at sites all across Nevada, southern Idaho and eastern Oregon. Species of the bee genus *Osmia* were numerous and diverse at flowers of *A. filipes* and *Balsamorhiza*, whereas bees were always exceptionally sparse at *Lupinus argenteus.* Once again, only ground-nesting *Andrena* bees were found at *Lomatium* (*L. dissectum, L. triternatum*), that generalization now extending from western WY to southcentral ID to northern Utah and northern and central Nevada.

Managed populations of several pollinator species are increasing**,** primarily at our trial gardens in Logan. We are able to increase populations of the native bees *O. bruneri, O. lignaria, O. sanrafaelae*, and *Hoplitis albifrons*, even when restricted to foraging at flowers of our target forb species.

The *Hoplitis* was a surprise, for although they abundantly visit and pollinate *H. boreale,* general experience with this genus is that emerging adults disperse rather than nest in provided nesting substrates. In large field cages, all three species of *Hoplitis* bees that we evaluated as manageable pollinators for *H. boreale* happily foraged at sweetvetch, provisioning nest cells with its pollen and producing progeny. Preliminary single-visit pollination experiments reveal that they are good pollinators. Emerging females of two of the species were prone to disperse away from provided nesting materials, but *Hoplitis albifrons* remained and increased in our wooden nesting blocks. We will progress with its pollination evaluation and population increase.

Native herbivorous insects have the potential to become pests of seed production on each of the wildflower species studied to date. Seed weevils and their kin have been found attacking maturing seeds of four of the forb genera studied to date. This year I found weevils attacking maturing pods of globemallows. Our primary focus will be on establishing life histories for these and other herbivorous species that attack buds, flowers and seeds (adults are needed for ID). We will continue to evaluate their abilities to travel and reproductively cycle in dried seed, which so far has not been a problem for the species that we have found. As needed, I will help Bob Hammon at Colorado State University to develop practical, safe and effective means of avoiding, excluding or treating each of these insects for future use when these wildflowers are grown in row crop agriculture.

Products:
A practical, affordable nesting shelter for managing cavity-nesting bees for pollination on farm has been developed and successfully field trialed in 3 states with 4 species of cavity-nesting bees. The shelter is adapted from laminate tubs manufactured for the US Postal Service. The metal support bracket, which quickly bolts to a T-post, was developed with a manufacturer of grape arbor equipment, Quiedan, Inc. They now manufacture the brackets on demand. One complete unit costs less than $25.

Four *Osmia* bee species and one *Hoplitis* species that effectively pollinate are being increased at the Logan labs for eventual distribution to seed growers. With our guidance, one of these, *O.*

sanrafaelae, is also being successfully increased at Wind River Farm for pollination of sweetvetch.

Publications:

Cane, J.H. 2006. An evaluation of pollination mechanisms for purple prairie-clover, *Dalea purpurea* (Fabaceae: Amorpheae). Amer. Midl. Natur. 156: 193-197.

Cane, J.H. 2006. The Logan Beemail shelter: a practical, portable unit for managing cavity-nesting agricultural pollinators. American Bee Journal. 146(7): 611-613.

Cane, J.H. 2007. Pollinating bees crucial to farming wildflower seed for U.S. habitat restoration. *in* Bee Pollination in Agricultural Ecosystems (eds. R.R. James and T. Pitts-Singer). Univ. Chicago Press. (accepted December 2006). 26 ms pages + 3 figures.

Cane, J.H., T.G. Griswold and F.D. Parker. Substrates and materials used for nesting by North American *Osmia* bees. Ann. Entomol. Soc. Amer. (in print). 24 ms pages + 1 plate + 3 page table.

K.A. Swoboda. 2006. The pollination ecology of *Hedysarum boreale* and evaluation of its pollinating bees for restoration seed production. Thesis, Utah State University.

Technology Transfer:
Invited symposium presentation entitled: “Bees and the seeds that their pollination breeds”. Intermountain Native Plant Summit IV, Boise, Idaho, 2006.

Invited seminar entitled: “Pollinating and growing desert wildflowers for seed for ecological restoration”. Plant Ecology Institute, University of Uppsala, Sweden, 2006.

Invited restoration symposium presentation entitled: “Pollinating Great Basin forbs for seed to rehabilitate western rangelands”. Society for Rangeland Management, Reno, Nevada, scheduled for February 2007.

Research was highlighted by Kevin Hacket, USDA ARS National Program Leader, at the October 2006 meeting of the North American Pollinator Protection Campaign in Washington, DC.

Project Title: Insect Pests of Selected Grass and Forb Species in the Great Basin

Project Location: Colorado State University Cooperative Extension, Tri-River Area, Grand Junction, CO

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Project Description:
Many insects affect seed production of native plants. These include specialist insects that feed on the plants in their native habitat and generalist crop pests that move into monocultures planted as seed increase plots. We need to know as much as possible about insect life histories before management techniques can be developed. This project is designed to learn the natural history of insects that affect field-collected and field-grown seed associated with the Great Basin Native Plant Selection and Increase Project. Fields and collection sites were surveyed for insect pests, and when problems were found, specimens were forwarded to the Grand Junction, Colorado Extension office for identification. In addition, seed increase fields of project species located in southwestern Colorado were monitored for pests.

Samples submitted for diagnosis were photographed and placed into a secure collection for future reference and educational programming. Species that needed further taxonomic work were forwarded to specialists for identification. Specimens are currently stored at the Tri-River Cooperative Extension Office in Grand Junction, CO, the USDA-ARS Bee Biology and Systematics Lab in Logan, UT, or with the taxonomist responsible for identification of the particular taxa.

Project Status:
A summary of insect pests collected from wildland sites and field plantings associated with the project is provided in Table 1. Two previously unknown insects were added to the list in 2005, with two more added in 2006. A previously undescribed species of *Acanthosceliedes* was discovered feeding on *Hedysarum boreale* in Utah, and an unidentified tephritid fly was discovered feeding on *Lupinus argenteus* in Colorado in 2005. An undescribed pyralid moth was discovered attacking *Lupinus sericeus* seeds near Hotchkiss, Colorado, and an *Aphis* sp. aphid was discovered attacking the foliage of *Dalea purpurea* near

Figure 1. The larvae of this small undescribed moth were found destroying seed of *Lupinus sericeus* at Hotchkiss, CO.

Logan, Utah in 2006. In addition, samples taken from small seed increases in southern Idaho and southern Colorado have shown that *Lygus* bugs are a significant seed production pest on many species of forbs, especially *Penstemon* and *Hedysarum*. A management strategy for these generalist feeders will have to be developed for each seed increase site.

Seed increase fields of *Hedysarum boreale*, *Linum lewisii*, *Sphaeralcea coccinea*, *Bromus marginatus*, *Hesperostipa comata*, *Elymus elymoides*, *Leymus cinereus*, *and Poa secunda* were established during 2005 and 2006 at the Western Colorado Research Center at Rogers Mesa, near Hotchkiss, Colorado (Delta County) as part of the Uncompahgre Plateau Project. These fields will be utilized in the future for pest management research, which will be utilized by seed growers, associated with both projects.

Table 1. Insect and disease pests identified from Great Basin Native Plant Selection and Increase Project.

Plant species	**Pest**	**Order: Family**	**Attacks:**	
Astragalus filipes	*Acanthoscelides* sp	Coleoptera: Bruchidae	Seeds	**Cane & Johnson 2004**
Astragalus filipes	*Acanthoscelides pullus*	Coleoptera: Bruchidae	Seeds	**Cane & Johnson 2004**
Astragalus filipes	*Acanthoscelides fraterculus*	Coleoptera: Bruchidae	Seeds	**Cane & Johnson 2004**
Astragalus filipes	*Acanthoscelides aureolus*	Coleoptera: Bruchidae	Seeds	**Cane & Johnson 2004**
Astragalus filipes	*Tychius tectus* leConte	Coleoptera: Curculionidae	Seeds	**Cane 2004**
Astragalus filipes	*Tychius semisquamosus*	Coleoptera: Curculionidae	Seeds	**Cane 2004**
Balsamorhiza sagittata	*Trupanea jonesi*	Diptera: Tephritidae	Head/seed	**Hammon 2004**
Balsamorhiza sagittata	*recepticle feeding fly*	Diptera: Ceciomyiidae	Receptacle	**Hammon 2004**
Crepis acuminata	Rust		Whole plant	**Hammon & Shaw 2004**
Crepis acuminata	*Seed feeding fly*	Diptera:Tephritidae	Head/seed	**Hammon & Shaw 2004**
Dalea ornata	*Acanthoscelides oregonensis*	Coleoptera: Bruchidae	Seeds	**Cane & Johnson 2004**
Dalea ornata	*Acanthoscelides daleae*	Coleoptera: Bruchidae	Seeds	**Cane & Johnson 2004**
Dalea ornata	*Apion* spp	Coleoptera: Brentidae	Seeds	**Cane 2004**
Dalea ornata	*Lycaeides melissa*	Lepidoptera:Lycaenidae	Flowers	**Cane 2004**
Dalea ornata	*Acanthosceliedes* sp.	Coleoptera: Bruchidae	Seeds	**Cane & Johnson 2004**
Eriogonum umbellatum	Seed feeding caterpillar	Lepidoptera	Seeds	**DeBolt 2004**
Hedysarum boreale	*Acanthoscelides fraterculus*	Coleoptera: Bruchidae	Seeds	**Hammon, Johnson 1991**
Hedysarum boreale	*Acanthoscelides* sp.	Coleoptera: Bruchidae	Seeds	**Cane 2006**
Hedysarum boreale	*Lycaeides melissa*	Lepidoptera:Lycaenidae	Flowers	**Hammon 2006**
Hedysarum boreale	*Filatima xanthuris*	Lepidoptera:Gelechiidae	Foliage	**Cane & Lee**
Lomatium dissectum	*Smicronyx* sp.	Coleoptera: Curculionidae	Seeds	**Cane 2004**
Lomatium dissectum	*Depressaria multifidae*	Lepidoptera: Oecophoridae	Flowers	**Cane 2004**
Lomatium dissectum	*Aphis heraclella*	Homoptera: Aphididae	Heads	**Cane 2004**
Lupinus argenteus		Diptera:Tephritidae	Seeds	**Hammon 2006**
Lupinus sericeus	*Pima* sp.	Lepidoptera: Pyralidae	Seeds	**Hammon 2006**
Penstemon sp.	*Kushelinea barbarae*	Coleoptera:Chrysomelidae	Foliage	**Hammon & DeBolt 2004**
Penstemon sp.	*Hesperobaris ovulum* ??	Coleoptera: Curculionidae	Stems/crown	**Hammon & O'Brien**
Penstemon sp.	*Penstemona* sp.	Lepidoptera: Sessidae	Seems/crown	**Hammon & Cane**
Leymus cinereus	Seed fly	Diptera: Ottididae	Seeds	**Hammon & Young**
Leymus cinereus	*Crambus* sp.	Lepidoptera: Pyralidae	Seeds	**Hammon 2004**

Project Title: Diversification of Crested Wheatgrass Stands

Project Location: Brigham Young University, Provo, UT

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Reporting for work funded, in part, by both the USDI Bureau of Land Management Great Basin Native Plant Selection and Increase Project and undergraduate mentoring funds, Brigham Young University.

Project Description:
This work is designed to determine effective ways to control crested wheatgrass and establish native species while minimizing weed invasion. We will report on progress for 2006 and state directions for 2007.

Crested wheatgrass diversification:
Two sites in Tooele Co., Utah were selected for large-scale manipulation of crested wheatgrass stands. The Skull Valley site, which borders the U.S. Army Dugway Proving Ground, is at an elevation of 1524 m, receives 200-254 mm of precipitation annually and has Medburn fine sandy loam soils. The Lookout Pass site is approximately 45 miles southeast of the Skull Valley site and located on the eastern side of the Onaqui Mountains. It is slightly higher in elevation (1676 m) and precipitation (254-305 mm) than the Skull Valley site and has Taylor's flat loamy soil. Both sites were seeded to crested wheatgrass monocultures more than 10 years ago following wildfires. Prior to treatment, the crested wheatgrass stand at Skull Valley was not as vigorous as the Lookout Pass site and had an abundance of cheatgrass.

The study is replicated in both time (year 1 = 2005; year 2 = 2006) and space and is set up as a randomized block split plot design with 5 blocks. Within each block, 1-acre (0.4-ha) main plots were either left undisturbed or received a mechanical (1-way or 2-way disking) or herbicide treatment (16 oz/ac. or 44 oz/ac. [1.1 L/ha or 3.2 L/ha] Roundup Original Max) to reduce (partial control) or eliminate (full control) crested wheatgrass. Following wheatgrass control, main plots were divided into 0.5-ac (0.2-ha) subplots that were either seeded or unseeded. In both 2005 and 2006, herbicide treatments were applied in late May while mechanical treatments were applied in early June. Plots were seeded with a Truax Rough Rider rangeland drill in October 2005 and 2006. The drill was specially configured to drill or broadcast seed in alternating rows with the goal of drilled species being planted no deeper than 1.3 cm. Brillion packer wheels placed immediately after the drop tubes pressed broadcast species into the soil. With the exception of 'Appar' flax, all species used in the seed mix are native and where possible collected or grown in proximity to the study sites. The Utah Division of Wildlife Resources supplied all seed for the study except for Eagle western yarrow.

Table 1. Crested wheatgrass diversification study seed mix.

Drill Mix

SPECIES	PLS lbs/acre	Bulk lbs/acre
Bluebunch wheatgrass – Anatone	3.00	3.16
Squirreltail - SID Sanpete	2.00	2.82
Indian ricegrass - 'Nezpar'	2.00	2.13
Fourwing saltbush	1.00	3.48
Lewis flax - 'Appar'	0.75	0.83
Munro globemallow	0.50	0.84
Total	**9.25**	**13.26**

Broadcast Mix

SPECIES		PLS lbs/acre	Bulk lbs/acre
Sandberg bluegrass - SID OR		0.75	0.95
White-stemmed rabbitbrush		0.25	0.75
Wyoming big sagebrush		0.20	0.94
Western yarrow – Eagle		0.20	0.24
	Total	**1.40**	**2.88**

Data Collection Methods:
In each subplot, five transects were established and six quadrats were placed along each transect for a total of 30 samples per subplot or 1500 samples per site. Both transects and quadrats were placed in a stratified random manner by selecting a random starting point and then placing both the transects and quadrats at consistent intervals. At Lookout Pass, transects were spaced every 12 meters beginning at meter 13 and quadrats were spaced every 3 meters along the transect beginning at meter 8. At Skull Valley, transects were spaced every 8 meters beginning at meter 7.5 while quadrats were spaced every 3 meters along the transect beginning at the 6 meter mark. In 2007, data will be collected from both year 1 and year 2 plots for a total of 3000 quadrats per site.

Data were collected in June 2006 using $0.25m^2$ quadrats. Within each $0.25m^2$ quadrat, density was determined for all species including those that were seeded. Percent cover for crested wheatgrass, cheatgrass, Sandberg bluegrass, and all other perennial species was estimated ocularly using modified Daubenmire cover classes. Nested frequency was used for cheatgrass, annual weeds, and crested wheatgrass seedlings. The number of mature crested wheatgrass seedheads and average length per frame was also measured.

We collected soil in June 2006 to determine the potential seedbank for our study sties. Within each block we took ten, 1-in^3 soil samples in each treatment, grew the samples in a greenhouse and counted the number of seedlings that emerged. This will be repeated in June 2007.

Data Analysis:
Data relating to crested wheatgrass control were analyzed separately from data relating to revegetation success. Crested wheatgrass control variables included: mature crested wheatgrass (density, cover, number of seed heads, average length in centimeters of seed heads, and the number of seed heads X length of average seed heads); crested wheatgrass seedling (density and frequency); mature Sandberg bluegrass (density and cover); residual perennial grasses, not including Sandberg bluegrass (density and cover); cheatgrass (density, frequency, and cover); and annual weeds, including cheatgrass (density and frequency). Mature Sandberg bluegrass was analyzed as a separate variable within the crested wheatgrass control analysis due to the quantity found at the sites. Revegetation success variables were based on density of seeded species which included: drill seeded grasses, broadcast seeded Sandberg bluegrass, drill seeded grasses plus broadcast seeded Sandberg bluegrass, total forbs, total seeded grasses plus total forbs, total shrubs, and total seeded species.

We used Proc Mixed in SAS (SAS Institute 1996) to determine significant treatment effects and interactions. The analysis factors were site (Lookout Pass vs. Skull Valley), block (1-5), treatments (undisturbed, partial control mechanical, full control mechanical, partial control herbicide, full control herbicide), and seeding (seeded vs. unseeded), with site considered fixed and both block and treatment considered random affects. Data were arcsin transformed to normalize the data. Differences were considered significant at $P \leq 0.05$.

Project Status:

Results

Crested wheatgrass control. Mechanical treatments were more effective than herbicide in reducing mature crested wheatgrass cover (Fig. 1A). Compared to control plots, two-way disking (full control mechanical) decreased wheatgrass cover by 66.5% while one-way disking (partial control mechanical) decreased wheatgrass cover by 49.1% ($P < 0.05$). Compared to the control plots, full control herbicide (3.2 L/ha) reduced mature crested wheatgrass cover by 43.3% while the partial control herbicide (1.1 L/ha) reduced mature crested wheatgrass cover by only 3.7%. Differences between the full vs. partial control herbicide treatments on mature crested wheatgrass cover were significant ($P < 0.05$; Fig. 1A).

The treatments were not significantly different ($P>0.05$) in reducing mature crested wheatgrass density at the Lookout Pass site. However, at the Skull Valley site, full control mechanical reduced mature crested wheatgrass density by 57% compared to its density on undisturbed plots ($P < 0.05$; Fig. 1B). Herbicide treatments did not reduce mature wheatgrass density at either site.

Crested wheatgrass seedling density was similar in all treatment plots at the Skull Valley site ($P > 0.05$; Fig. 1C). At the Lookout Pass site, partial control herbicide reduced seedling density 7.5% compared to its density on undisturbed plots. The full control herbicide increased seedling density 32.6% compared to seedling density on the undisturbed plots.

Weed invasion. Skull Valley had an abundance of cheatgrass when the study began. Following treatment, cheatgrass comprised 92% of the total weed composition at Skull Valley and only 11% at Lookout Pass. There appeared to by a trend of greater weed invasion at both sites in the mechanical treatments where disturbance was high (Fig. 1D). Areas treated with herbicide had lower densities of annual weeds relative to mechanically treated plots; however, these differences were only significant between partial control herbicide treatments compared to the partial or full mechanical treatments at Skull Valley.

Revegetation success. None of the crested wheatgrass control treatments affected seeded species emergence (Fig. 1E). There was greater emergence of seeded species at Lookout Pass compared to Skull Valley. This is likely due to higher precipitation at Lookout Pass. At both sites, seeded grasses had greater emergence than either forbs or shrubs (Fig.1F). Species encountered most frequently were drill-seeded grasses. Of the species that were broadcast, Sandberg bluegrass and Lewis flax were most common. Shrubs were encountered rarely during data collection in June but seedlings of Wyoming big sagebrush and western yarrow were noted in the plots in October.

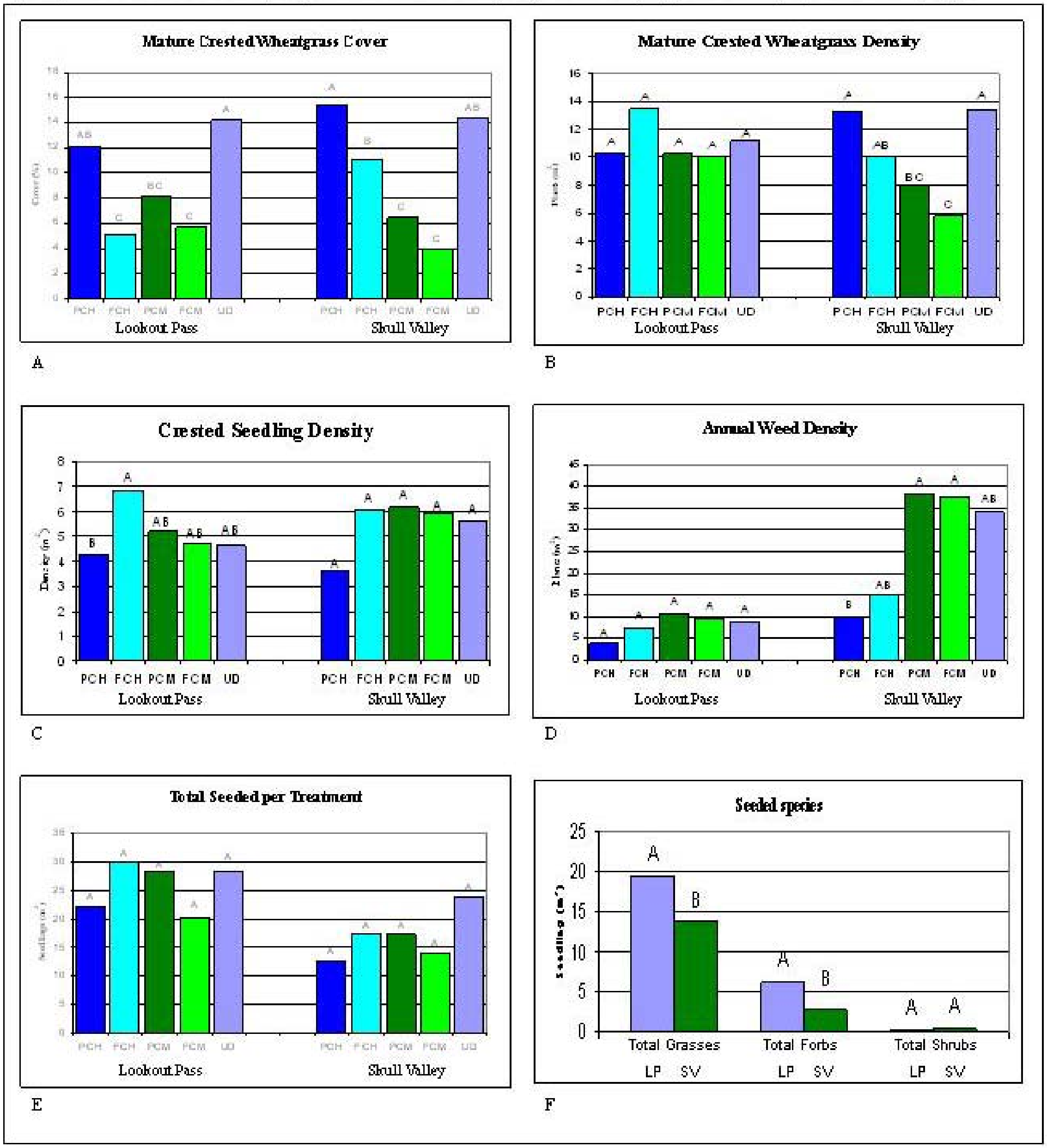
Timeline

Data will be collected in June of 2007 on year 1 and year 2 blocks. Data collected will be as described for 2006.

Technology Transfer:
Hulet, A., B.A. Roundy, B. Jessop, J. Coleman. 2007. Diversification of crested wheatgrass stands in Utah. Society for Range Management Annual Meeting, 10-15 February, Reno/Sparks, NV.

Management Applications:
This research will help land managers to identify and implement effective ways to control crested wheatgrass and establish native species while minimizing weed invasion. Managers will also be provided with germination and survival rates of native species used in this study which will help in developing successful seed mixes.

Figure 1. Crested wheatgrass diversification study, Year 1 results collected June 2006. Partial Control Herbicide (PCH), Full Control Herbicide (FCH), Partial Control Mechanical (PCM), Full Control Mechanical (FCM), Undisturbed (UD), Lookout Pass (LP), and Skull Valley (SV).



Time Period: Calendar year 2006

Project Title: Wet Thermal Time Modeling of Seedling Establishment

Project Location: **Brigham Young University, Provo, UT**

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Reporting for work funded, in part, by both the USDI Bureau of Land Management Great Basin Native Plant Selection and Increase Project and undergraduate mentoring funds, Brigham Young University.

Project Description:

Seedling emergence can be broken down into four temperature influenced stages: 1) dormancy loss, 2) germination, 3) pre-emergence growth, 4) emergence (Vleeshouwers and Kropff 2000). Much research has been done on dormancy loss of range species and is not included in this study (Allen et al. 2007). Temperature and presence of moisture are the most important environmental conditions causing germination, pre-emergence growth and emergence. Germination, pre-emergence growth and emergence models using thermal accumulation have been successfully developed for many weed and crop species (Vleeshouwers and Kropff, 2000; Grundy 2003; Forcella 2000). Thermal accumulation is based on the assumption that the plant or seed requires a certain amount of time (measured in degree days) above a base temperature and below a maximum temperature where enzymatic activity ceases in order to reach a certain life stage (Trudgill et al. 2005). Models that have assumed that the seed progresses towards germination and emergence only when water is available have been more accurate in predicting emergence than strictly thermal models (Forcella et al. 2000).

Models based on temperature and a soil moisture threshold will be used to predict the germination rate, pre-emergence growth and survivability of 11 different species or cultivars commonly used for fire rehabilitation seeding, in addition to 3 collections of the invasive weed, *Bromus tectorum*. Each wet thermal accumulation model was based on germination rates determined through constant temperature germination trials. These germination rates were used to predict species germination with three fluctuating-temperature regimes based on spring soil temperatures in sagebrush-dominated communities of Tintic Valley, Utah. In addition, seedbags of 6 of the 14 species/cultivars (Table 1) were buried in a randomized block design at two sites in central Utah (Fig.1). Seedbag germination was compared to model predicted germination using hourly seedbed temperatures and water potentials measured on site. Small plots at the field sites were also seeded with these species (Table 1). Predicted and actual germination were compared to emergence and survival data in the small plots.

Project Status:

Germination

Model Development:

Percent and rate of germination are the main factors in determining percent and rate of emergence in non-dormant seeds (Forcella 2000; Vleeshouwers and Kropff 2000). In order to determine the field germination rate, we first determined the relationship between germination and temperature for each species by conducting germination trials at seven constant temperatures (5, 10, 15, 20, 25, 30 and 35°C) in incubation chambers. We created thermal accumulation models of 14 species/cultivars: *Linum perenne*, *Linum lewisii*, *Lupinus argenteus*, *Enceliopsis nudicaulis*, *Agropyron desertorum*, *Achillea millefolium* (Eagle and white), *Elymus elymoides*, *Agropyron cristatum*, *Pseudoroegneria spicata* (Anatone), *Elymus wawawaiensis* (Secar), and *Bromus tectorum*. Populations of *Bromus tectorum* were collected from Spanish Fork, Skull Valley and Lookout Pass, UT. The time non-dormant seeds of each species required to reach 25% and 50% germination was determined for each constant temperature. We computed the hourly germination rate each temperature produced from the number of days to 25% and 50% germination. The germination rate is the slope of a curve that best fits the 1/days to 25% or 50% germination. Curves were generated three different ways: a part linear and part polynomial curve, simple polynomial and Table Curve 2D-generated (a curve-fitting program) polynomial models. These curves were the basis of the thermal accumulation model.

Germination rates were found to be highest at 25°C for most species. *Bromus tectorum* populations experienced the fastest germination rates at 20°C. Highly variable results were obtained for all of the species at the 35°C constant temperature trial and so these data were not included in the thermal accumulation model.

Model Verification:
Diurnal Curves:
Incubation chambers were programmed with 3 different fluctuating temperature curves based on spring temperatures in sagebrush-dominated communities in Tintic Valley, Utah. Analysis comparing the predicted with actual germination rate is not yet complete for all 8 species, but the thermal accumulation model seemed to slightly overestimate the time to 50% germination for each curve.

Seedbags:
The wet thermal model was tested in the field at two sites located in north-central Utah, near White Rocks and the Cedar Mountains in Toole County. Skull Valley is located at 5000' with annual precipitation ranging from 8 to 12" and slope of about 0%. The average annual air temperature is 8-10°C. Soils are a Medburn fine sandy loam. The Lookout Pass site has an elevation of 5500' and slope of about 0%. The annual average for precipitation and air temperature is 10-12" and 7-11°C. Soils are classified as a Taylors flat loam. Both sites were dominated by crested wheatgrass (*A. cristatum*). Sagebrush communities originally dominated these areas.

Four small blocks were established at each site. Each of these small blocks was divided into two blocks for the each year replication. Each year replication had an area designated for seedbag burial and seeded plots. Thermocouples measuring soil temperature and gypsum blocks measuring soil moisture were buried at three depths (1-3, 15-16 and 28-30 cm deep) in each small block. These sensors were attached to microloggers that calculated their hourly averages. Precipitation and air temperature were also measured on site.

Table 1. Species seeded in seedbags and small plots.

Species	Common Name	Cultivar	Source	Year Collected	PLS Seeding Rate (lb/ha)	Bulk Seeding Rate (lb/ha)
Linum perenne	blue flax	Appar	UDWR-commercially grown	2003	33	36
Achillea millefolium	eagle yarrow	N/A	Eastern Washington	2003	33	50
Agropyron cristatum	hycrest crested wheatgrass	Hycrest		2003	33	47
Pseudoroegneria spicata	bluebunch wheatgrass	Anatone	UDWR-commercially grown	2003	33	36
Elymus elymoides	squirreltail	Sanpete	Sanpete Co., UT	2003	33	47
Bromus tectorum	cheatgrass	N/A	Skull Valley, UT	2005	38	
Bromus tectorum	cheatgrass	N/A	Lookout Pass, UT	2005	38	

Table 2. Seedbag burial and retrieval dates.

Buried:	Retrieved:
10/15/05	12/6/05
	1/19/06
2/27/06	3/16
	3/28
	4/11
	4/25
	5/10 & 5/11
3/28/06	4/11/06
4/11/06	4/25/06
10/24/06	11/9/06
	11/30/06
	2/21/07
2/21/07	

Nylon mesh seedbags of each species were buried in fall 2005 (Table 2). we only seeded and buried seed that had been collected from that site. At least one seedbag per species was collected from each block during a retrieval. After retrieving the seedbags, the percent of germinated seeds was compared to the model-predicted percent germination (50% or 25%) based on the surface soil moisture and water potential.

Eighteen seedbag retrievals were planted in 2005. By the first retrieval date (12/6/05), all species (except *A. millefolium*) reached 50% germination, so only 2 retrieval dates were analyzed from this planting. The second was done to see the affects of overwintering on germination. Five seed bag retrievals were planted when the ground thawed during February of the following year. Two more retrievals were planted that spring. So far, nine seedbag retrievals have been compared with model predictions.

Our thermal accumulation model assumed that seeds accumulated degree days only when the soil was wet, or when the gypsum block read the soil water potential as above -1.5 MPa. We analyzed two different methods of accumulating degree-days for each seedbag retrieval: (1) thermal accumulation started over each wet period or (2) thermal accumulation was summed for all wet periods.

At Lookout Pass, summed and individual wet period thermal accumulations were equally accurate in predicting germination. At both sites, the model was able to predict whether seedbags would reach 25% or 50% germination for all species except *A. millefolium*. We conducted a light requirement experiment and verified that *A. millefolium* has a light requirement that would not have been fulfilled in the seedbags. *Bromus tectorum* germination on both sites was accurately predicted in every retrieval. Only one seedbag retrieval, 2/27/06-4/16/06, was inaccurately predicted by the model for the other species at Lookout Pass.

At Skull Valley, (a drier and warmer site), *B. tectorum* and *P. spicata* germination was predicted with 100% accuracy by both thermal accumulation methods. In *A. cristatum*, *E. elymoides* and *L. perenne*, summed thermal accumulation was more accurate to predict germination than individual wet period thermal accumulation. The thermal accumulation model underestimated germination during the time that the area experienced freezing temperatures. When the data were closely examined, short freezing periods when the gypsum blocks read the soil as dry, were responsible for much of this inaccuracy. When summed thermal accumulation was inaccurate as well, it showed the same trend that was seen in the incubation diurnal trials. This suggests that fluctuating temperatures not only accelerate dormancy and priming of seeds (Allen et al. 2007; Vleeshouwers and Kropff 2000; Forcella et al. 2000) but can also increase germination rate.

Emergence and Survival:

Model Development:

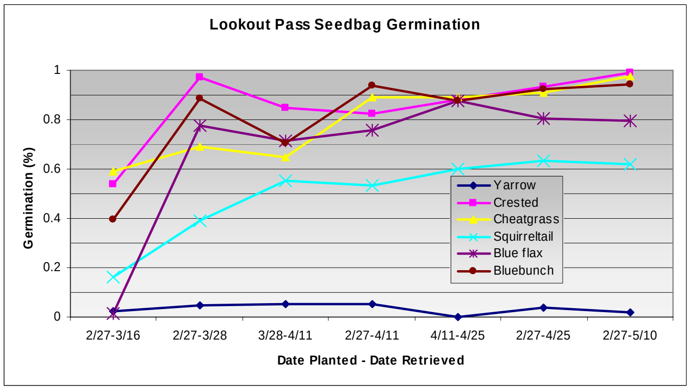
Root growth experiments to predict pre-emergence growth and survival capability of the different species will be conducted in spring 2007.

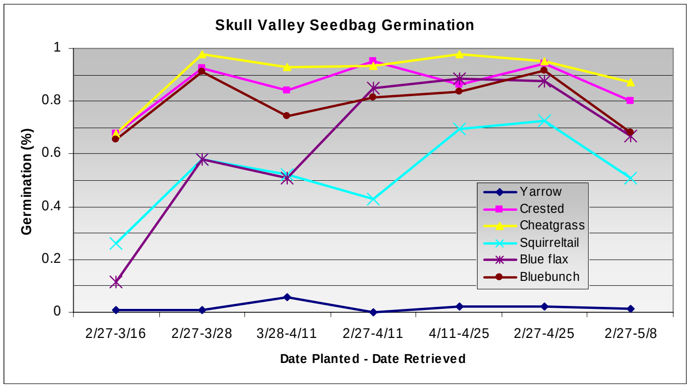
Model Verificiation:

Each small block contained three rows of 6 (1 plot for each species) 1.2 x 1.8m plots. Each row was given one of three crested wheatgrass control treatments: (1) full control herbicide, (2) partial control herbicide and (3) undisturbed. Round-up was applied at a rate of 44 oz/ac. for the full control and 16 oz/ac. for the partial control treatment. Small plots were seeded on Oct 15, 2005 and on Oct 24 (Skull Valley) and 25 (Lookout Pass) in 2006. Seedling density and survival were monitored in spring and summer 2006.

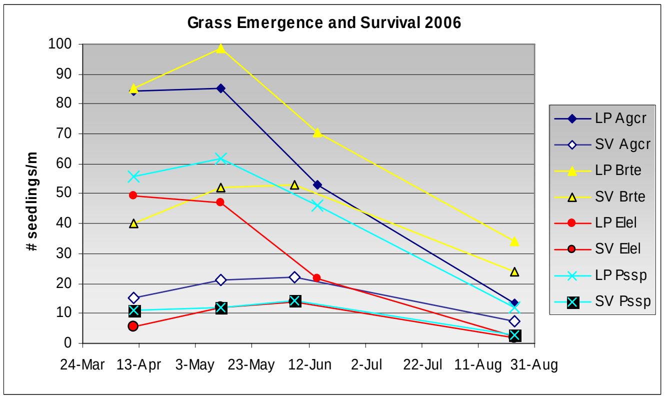
High germination rates (Figs. 2, 3) and emergence numbers (Fig. 4) occurred on both sites. Seedling mortality was higher for perennial grasses (68%-96%) than for *B. tectorum* (55%-65%). Almost all forbs seeded on both sites died (94-99%). *Agropyron cristatum* (85% and 68%) had slightly less mortality than the native grasses (*P. spicata* 80% and 79%, *E. elymoides* 96% and 69%).

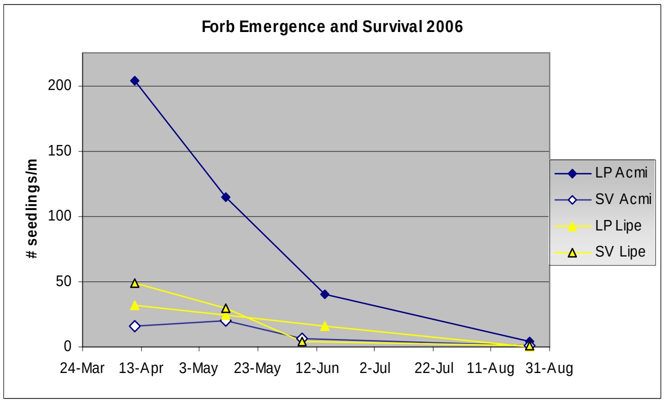
Figure 2 & 3. Percent germination in spring 2006 seedbag retrievals.





Figures 4 & 5. Number of live seedlings per m of row recorded after notable emergence began (mid- March 2006) to the end of summer.





Higher mortality rates occurred at Lookout Pass for all species due to lack of precipitation events in July and August.

Research 2007:
This coming year, data related to thermal accumulation models for species not seeded in seedbags or small plots will be analyzed. Pre-emergence growth will be modeled by conducting root-growth experiments at the seven constant temperatures and the three different diurnal curves for all species and cultivars. Model predictions of the three diurnal curves of all species will be reanalyzed using the models created by Table Curve 2D. Soil moisture and temperature data for Fall 2006 and Spring 2007 will be downloaded and used to compare predicted and actual germination. Seedbag retrievals will continue throughout this spring. Seedling density counts in spring and summer of 2007 will be conducted on small plots of both years. A model converting air temperature and precipitation data to soil moisture and temperature will be developed. Fluctuating and cold temperature germination experiments of the six seeded species will be conducted.

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Management Applications:
For many range species, the environmental conditions required to germinate, establish and survive have not been quantified. Many laboratory studies have been able to predict different aspects of seedling establishment based on environmental conditions (Forcella, 1993; Vleeshouwers 1997; Roman et al. 2000), but there are few that have validated their models with actual field observations (Vleeshouwers and Kropff 2000; Forcella et al. 2000; Wang et al. 2006). Determining the relationship between environmental conditions and a species' development and survival rate will allow managers to better select range species that will establish in a revegetation site. Models predicting the development rate of different weed species would cue managers to the best time to seed or apply herbicide (Masin et al. 2005; Grundy 2003; Vleeshouwers and Kropff 2000). Non-chemical control methods (mechanical

treatments) could be timed when weed species are most vulnerable (Grundy 2003; Vleeshouwers and Kropff 2000). Reduced emergence of seeded species due to weed competition for a site could be estimated based on weed versus seeded species emergence timing (Vleeshouwers and Kropff 2000). Both 2005 and 2006 were relatively wet years and the model was able to predict the high germination and subsequent emergence that occurred. The high mortality of those seedlings shows that selecting species for areas that fulfill their germination and emergence requirements does not guarantee their establishment. But the thermal accumulation model can be used to compare the potential emergence of different revegetation species under a range of actual seedbed temperature and moisture conditions. This should help avoid seeding species with little likelihood of success and also help to select plant materials that have the highest probability to emerge. A model that can predict their survivability in summer temperature and moisture conditions is also needed.

Project Title: Reestablishing Native Plant Diversity in Crested Wheatgrass Stands in the Great Basin

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

Principal Investigator and Contact Information:

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Cooperators:

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USDA-NRCS, Aberdeen Plant Materials Center, P.O. Box 296
Aberdeen, ID 83210

Project Description:

This project investigates the feasibility of increasing native plant diversity in established crested wheatgrass stands in the Great Basin. The study location is 80 km south of Burns, OR, on the Malheur National Wildlife Refuge in a stand of crested wheatgrass approximately 25 years old. Objectives include: 1) determine the effect of crested wheatgrass control methodologies and revegetation on crested wheatgrass density and cover, 2) determine the effect of crested wheatgrass control methodologies and revegetation on establishment of native species, 3) determine the effect of crested wheatgrass control methodologies and revegetation on cheatgrass density and cover, and 4) determine the effects of crested wheatgrass control methodologies and native plant establishment on the seed bank and on soil nitrogen and water content.

Procedures included varying the method and intensity of crested wheatgrass control, followed by seeding a mix of native shrubs, grasses, and forbs. Control strategies were tested in a randomized block, split-plot design with control strategy and intensity as whole plots and seeded vs. unseeded as split-plots. Control methods included mechanical (disking), chemical (glyphosate application), or undisturbed (no crested wheatgrass control). Control intensity was varied by the number of passes with the disk (partial = one pass, full = two passes) and the rate of glyphosate application (partial = quarter rate, full = full rate). Half the plot was seeded and half the plot was left unseeded following control treatment. The five treatments (full mechanical control, partial mechanical control, full chemical control, partial chemical control, undisturbed) were replicated across five blocks each year on 0.4-ha (1-acre) plots for a total of approximately 10 ha (25 acres) treated annually (5 ha (12.5 acres) seeded, 5 ha unseeded). Control and seeding treatments were applied 2005 and 2006.

Surface soil and litter are being collected in the spring and fall of each year and bioassayed for seed bank potential of crested wheatgrass, native residuals, seeded species, and cheatgrass. Soil sampling occurs twice each year (April and September). Cover and density of unseeded and seeded species will be collected in June for 2 years on plots established in 2005 and for 1 year on plots established in 2006.

Project Status:

Accomplishments 2006

Control treatments

Chemical control treatments were applied May 3-8, 2006. Glyphosate was applied at 4.8 l/ha (44 oz. per acre) for full control or 2.4 l/ha (10 oz. per acre) for partial control using an ATV-mounted boom sprayer, delivering 95 l/ha (10 gal/a) water. Conditions were 10.5-16.7 ˚C, wind 0-10 km/h, and 1-37% relative humidity. Mechanical control treatments were applied May24-25, 2006 using a tractor-mounted 4.2-m (14-feet) off-set disk with 50-cm (20-inch) disks.

Seed bank and soil sampling

Seed bank and soil was collected in Year 1 and Year 2 plots. The seed bank was sampled on May 10-11, 2006. Five-50-cm^3 sub-samples were collected from the top 2-cm of soil in each plot. Seed bank samples were spread in trays containing sterilized sand in a greenhouse at the Eastern Oregon Agricultural Research Center and monitored for seedling emergence for 6 weeks. At the end of 6 weeks, a 1000 ppm solution of gibberrellic acid was added to stimulate germination of any remaining seeds. Seedling numbers were recorded. Soil was sampled for nitrogen and gravimetric water content by collecting 2-cm-diameter soil cores, 15-cm deep. Five sub-samples were collected and composited to make one sample per plot. Year 1 plots were sampled on April 17 and Year 2 plots were sampled on May 10, 2006. Soil samples were weighed before and after drying to determine gravimetric water content and were then sent to Central Analytical Lab at Oregon State University for analysis of nitrate-nitrogen and ammonium-nitrogen.

Vegetation sampling

The following data were collected on June 19-28, 2006, for Year 1 plots (i.e. seeded in fall 2005): 1) density of crested wheatgrass adult plants, cheatgrass, seeded species, any weedy species phenologically competitive with the seeded species, and any other species present; 2) cover of crested wheatgrass adult plants, cheatgrass, any significant weedy species, any other perennial species that was not seeded, bare ground, litter, and rock; 3) nested frequency of crested wheatgrass seedlings, cheatgrass, and any significant weedy species, and 4) number of crested wheatgrass seed heads arising from culms of adult plants and average length (cm) of seed heads.

Vegetation was sampled along five 18-m long transects placed 10-m apart and perpendicular to the seeded rows. Along each transect, 0.25-m^2 (0.5-m x 0.5-m) frames were used to sample vegetation. Percent cover was visually estimated using the Daubenmire cover class method and density of individuals was counted in 10 frames, 2-m apart, along each transect for a total of 50 frames per plot. The point at which to begin sampling on along transects was randomly determined. Distinction between bluebunch wheatgrass, Indian ricegrass, and bottlebrush squirreltail was difficult and therefore these three species were grouped into seeded perennial grasses. The other seeded species could be identified and thus were recorded individually.

Several weeks following sampling (at seed head maturity), samples of adult crested wheatgrass were collected across Year 1 plots. The length and number of seeds per seed head were recorded. This information was coupled with the number of crested seed heads arising from culms at the time of sampling (see 4 above) and used to estimate aerial seedbank of crested wheatgrass within each plot in seeds/ha by regressing number of seed heads per cm of seed head against average length of seed head.

<u>Seeding</u>

Year 2 plots were seeded on October 30-31, 2006. Plots were seeded using a modified Truax Rough Rider no-till drill. Two seed mixes were used (same seed as in 2005), one large-seeded and the other small-seeded. Because of a potential seed quality issue (4% germination TZ), new Wyoming big sagebrush seed was purchased and added to the seed mix. Large seeds were put in a cool-season box while small seeds were put in a fluffy seed box. Alternating drops were used from the cool-season and fluffy boxes. The cool-season box fed the seeding disks, and the fluffy box dropped seeds onto the soil surface where they were rolled over by Brillion wheels. The large-seeded mix included four-wing saltbush, Lewis flax, Munro globemallow, bluebunch wheatgrass, bottlebrush squirreltail, and Indian ricegrass. The small-seeded mix included Wyoming big sagebrush, white-stemmed rabbitbrush, western yarrow, and Sandberg bluegrass. Species, kind/variety, commercial source and seeding rates are listed in Table 1. Seeding conditions were approximately 15˚C, sunny, breezy, and dry.

<u>Data analysis/Preliminary Results</u>

Vegetation data from Year 1 plots was entered into Excel, compiled, and analyzed with SAS statistical software using a split-plot analysis of variance (ANOVA). Control treatments generally did not decrease density of crested wheatgrass below that of the untreated control (Fig. 1). The full mechanical control resulted in an increase in crested wheatgrass (Fig. 1). Seeded species density was highest in those plots that received mechanical control (Fig. 2). Cheatgrass density increased when subjected to the partial control mechanical treatment (Figure 3).

Plans for 2007

<u>Sampling</u>

Vegetation cover and density of Year 1 and Year 2 plots will be sampled during June using the same methods as in 2006. Seed bank and soil nitrogen and gravimetric water content will be sampled using the same methods as in 2005 and 2006. Seed bank and soil samples will be collected in April and September.

Data analysis

Vegetation, seed bank, and soil nitrogen and gravimetric water content data will be entered into Excel, compiled, and analyzed using SAS.

Final report

The final report, master's thesis, and a manuscript for journal submittal will be prepared following sampling and data analysis.

Management Applications:

Information obtained from this study will provide land managers with best practices for restoring native plant diversity in existing crested wheatgrass monocultures. Results will also further our understanding of the feasibility of using "assisted succession" for restoring landscapes currently dominated by cheatgrass.

Products:

Publications — Mangold, J. 2006. Restoring native plant diversity in crested wheatgrass stands. Malheur Musings 3(2):4.

Presentations — Increasing native diversity in crested wheatgrass stands. Invited presentation at Society for Range Management—Idaho Chapter. Boise, ID. January 17, 2007.

Technology Transfer — None at this time.

Table 1. Seeded species, including their origin and commercial source, and seeding rates.

Species	**Kind/ Variety**	**Commercial Source**	**Seeding Rate (lb. PLS/acre)**
Wyoming big sagebrush (*Artemisia tridentata wyomingensis*)		Maple Leaf	0.20
Fourwing saltbush (*Atriplex canescens*)		L&H Seed	1.0
White-stemmed rabbitbrush (*Chrysothamnus nauseosus albicaulis*)		Maple Leaf	0.25
Lewis flax (*Linum lewisii*)	'Appar'	Maple Leaf	0.75
Western yarrow (*Achillea millefolium*)	Eagle	Landmark Seed	0.20
Munro globemallow (*Sphaeralcea munroana*)		Maple Leaf	0.50
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	Anatone	Landmark Seed	3.0
Sandberg bluegrass (*Poa secunda*)	Mountain Home	Landmark Seed	0.75
Squirreltail (*Elymus elymoides californica*)	Toe Jam Creek	Landmark Seed	2.0
Indian ricegrass (*Achnatherum hymenoides*)	'Nezpar'	Landmark Seed	2.0

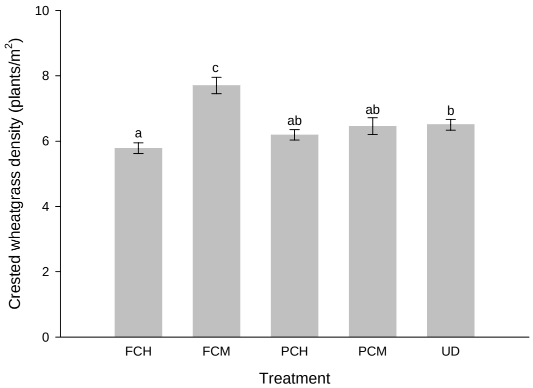

Figure 1. Treatment effect on density of crested wheatgrass. FCH = full control herbicide, FCM = full control mechanical, PCH = partial control herbicide, PCM = partial control mechanical, and UD = undisturbed control. Error bars represent ±1 SE.

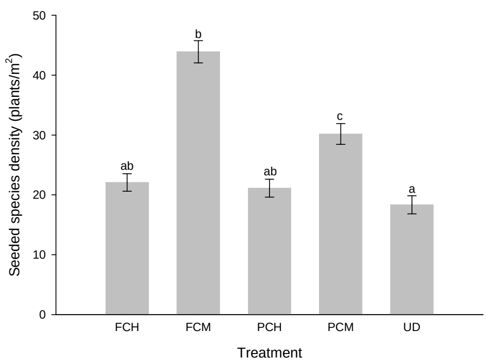

Figure 2. Treatment effect on density of seeded species. FCH = full control herbicide, FCM = full control mechanical, PCH = partial control herbicide, PCM = partial control mechanical, and UD = undisturbed control. Error bars represent ±1 SE.

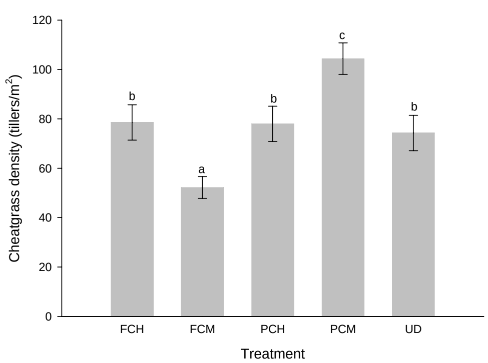

Figure 3. Treatment effect on density of cheatgrass. FCH = full control herbicide, FCM = full control mechanical, PCH = partial control herbicide, PCM = partial control mechanical, and UD = undisturbed control. Error bars represent ±1 SE.

Project Title: Revegetation Equipment Catalog Project

Project Location: College Station, Texas

Principal Investigators and Contact Information:

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Project Description: Prepare and publish an equipment catalog describing types and operations of equipment designed or adapted for rangeland vegetation manipulation, wildlife habitat improvement, and disturbed land rehabilitation. Categories include all types of implements used in brush and weed control, site preparation, seeding and planting, seed collection and processing, and related equipment such as tractors, all-terrain vehicles, global positioning systems, trailers, and miscellaneous items. Photographs, special features, and suppliers (including website addresses and other contact information) will be listed for each type of equipment. The final product will be a web-based publication allowing for updates and new advances in technology. It will likely be used throughout the United States and internationally.

Project Status: The Revegetation Equipment Catalog text was completed and placed on the World Wide Web. It was officially announced at the Rangeland Technology and Equipment Council (RTEC) meeting during the Society for Range Management Annual Meeting in Ft. Worth, Texas in February 2005. It has been well received nationally and internationally, and in 2006 it received a Blue Ribbon Educational Website Award from the American Society of Agricultural and Biological Engineers.

The catalog has been publicized by a poster and live laptop demonstrations in a tradeshow booth and laptop demonstrations at RTEC programs at the Society for Range Management annual meetings in Vancouver, Canada and Reno, NV. A poster presentation and demonstration was given at the Soil & Water Conservation Society annual meeting in Keystone, Colorado. The tradeshow displays have resulted in several companies wanting to list new equipment in the website.

Our publicity and inquires from search engines such a Google has resulted in significant use of the catalog. Tracking software logged 102,561 visitors in 2006. The United States accounts for 91% of the visitors while the remaining 9% are international. The top five states are Texas (7.4%), California (6.2%), Virginia (5.6%), Colorado (3.2%), and New York (2.6%).

The catalog is being used in restoration classes at Brigham Young and Oregon State universities and possibly others. Restoration classes taught at the BLM National Training Center in Phoenix have utilized the catalog. Information about equipment and its use has been included in handbooks by the Florida NRCS and Colorado Department of Fish and Wildlife. Rangeland West http://rangelandswest.org, the BLM Great Basin Restoration Initiative http://www.fire.blm.gov/gbri/links.html, the Great Basin Native Plant Selection and Increase

Project http://www.fs.fed.us/rm/boise/research/shrub/greatbasin.shtml, and Society for Range Management http://www.rangelands.org each have a link to the catalog's website. Additionally, several requests for special information have been received from ranchers and government field personnel.

There have been several new equipment additions and a few minor corrections. This demonstrates the advantages of the book being published on the web and the author's proximity to the Biological & Agricultural Engineering Department at Texas A&M University who are currently hosting the website.

Products

A. Publications: Wiedemann, H.T., Nancy Shaw, Mike Pellant. 2006. Revegetation Equipment Catalog. 2006 Conference Abstract Book, p 68. Soil and Water Conservation Society annual meeting, Keystone, Colorado, July 22-26, 2006.

B. Presentations: Wiedemann, H.T. 2006. Revegetation Equipment Catalog. Poster presentation and website demonstration. Society for Range Management, Tradeshow, Vancouver, Canada, February 12-17.

Project Title: The Association of Official Seed Certifying Agencies Cooperative Native Seed Increase Program

Project Location: Idaho, Nevada, Oregon, Utah, Washington

Principal Investigators and Contact Information:

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Project Description:
In May 2003, the Association of Official Seed Certifying Agencies (AOSCA) executive vice president invited the Great Basin Native Plant Selection and Increase Project to submit a proposal to work through their national organization towards the development of a multi-state approach for increasing native forb seed supplies for Great Basin restoration. The program involves distribution of wildland-collected seed to growers via the Foundation Seed Programs of states producing seed for the Great Basin (Idaho, Nevada, Oregon, Utah, Washington, and surrounding areas). Initial emphasis was on species not included on the principal research list, but research species were added to the list of offerings in 2005 to bolster efforts to "jump-start" their increased availability as well. To implement this program, RMRS and AOSCA drafted and signed an agreement in 2003. The agreement was revised and funding was appropriated in 2006 to continue the program's efforts for another 3 years.

Project Status:
Seed was cleaned, tested and source-identified prior to distribution to state Foundation Seed Program managers and growers (Table 1). Table 1 and the following narrative provide additional details as to the program's status and 2006 seed lot distributions.

- Seed lots distributed in 2006:
    - ***Chaenactis** douglasii* (Douglas false-yarrow) – Northern Basin and Range (Ecoregion 80 a); sole source from Owyhee County, Idaho (3700-4500 feet). Distributed to central Idaho grower.
    - *Crepis acuminata* (Tapertip hawksbeard) – Central Basin and Range (Ecoregion 13); sole source from Eureka County, Nevada (6,400 feet). Distributed to southern Idaho grower.
    - *Erigeron pumilus* (Shaggy fleabane) – Snake River Plain (Ecoregion 12 a); sole source from Owyhee County, Idaho (4400 feet). Distributed to central Idaho grower.

- ***Lomatium*** *dissectum* (Fernleaf biscuitroot) – Northern Basin and Range (Ecoregion 80 a, e, f) source; pooled from 6 sites between 3,147 and 4,452 feet, from 3 counties in Idaho and Oregon. Distributed to northern Utah grower.
- *Penstemon acuminatus* (Sand penstemon) –Snake River Plain (Ecoregion 12 a, h, j) source; pooled from 13 sites on sandy soil between 2,330 and 3,361 feet, from 6 counties in Idaho and Oregon. Distributed to eastern Washington grower.
- *Penstemon deustus* (Hotrock penstemon) – Snake River Plain (Ecoregion 12 f, h) source; pooled from 3 sites between 2,829 and 3,320 feet. Distributed to southern Idaho grower.
- *Penstemon speciosus* (Sagebrush penstemon) – Snake River Plain (Ecoregion 12 j/a); sole source from Payette County, Idaho (2,500 feet). Distributed to eastern Washington grower.
- *Penstemon speciosus* (Sagebrush penstemon) – Northern Basin and Range (Ecoregion 80 a, f) source; pooled from 4 sites between 3,400 and 4,292 feet. Distributed to southern Idaho grower.

In spring 2007, we will distribute several species to a grower in eastern Oregon for spring sowing. Species will include those that do not require a long prechill treatment.

<u>Meetings and Field Tours</u>

DeBolt: Attended the Annual Field Day at Oregon State University, Malheur Experiment Station, Ontario, OR (July 13, 2006). Gave short overview presentation on GBNPSIP and the Cooperative Native Seed Increase Program.

DeBolt: Attended a tour of Pacific Northwest Seed Growers. June 2006.

Table 1. Cooperative Native Seed Increase Program accessions distributed to growers (March 2004 through November 2006).

Program Manager Name and State	Species	Lot Number and Ecoregion	Seed Origin	Weight (g)	Distribution Date	Status
Kathy Stewart-Williams (ID)	Thurber needlegrass	AchThu2-BSE-03 (Snake River Plain)	NV	13.6	Aug-04	planted Oct-05; poor stand in '06; very dry spring; no seed yet
	Sulfur buckwheat	ERUM U9-03 (Central Basin & Range)	NV	99	Aug-04	planted Oct-05; good emergence and high uniformity; no seed yet, but seed expected in 2007
	Sagebrush penstemon	PenSpe9A-BSE-03 (N Basin & Range)	OR	212	Aug-04	planted Oct-05; excellent stand in '06; no seed yet, but seed expected in 2007
	Fernleaf biscuitroot	LomDis56-BSE-05 (Snake River Plain)	ID	350	Dec-05	not planted; seed lot returned to RMRS
	Sagebrush penstemon	Pooled PESP (N Basin & Range)	ID, OR	375	Oct-06	planted Nov-06
	Tapertip hawksbeard	CRAC U36-04 (Central Basin & Range)	NV	454	Oct-06	planted Nov-06
	Hotrock penstemon	Pooled PEDE (Snake River Plain)	ID	908	Oct-06	planted Nov-06
Gary Cross (NV)	Yellow beeplant	CLLU U1-01 (Central Basin & Range)	NV	300	Aug-04	not planted; will be returned to RMRS
	Oval-leaf buckwheat	EROV U9-02 (Central Basin & Range)	NV	10	Aug-04	not yet planted but will be sown in Mar-07
Stanford Young (UT)	Arrowleaf balsamroot	BASA U32-02 (Central Basin & Range)	NV	735	Mar-04	established; no seed crop yet
	Tapertip hawksbeard	CRAC U10-01 (Central Basin & Range)	NV	110	Mar-04	failed to establish
	Wyeth buckwheat	EriHer1-BSE-03 (Snake River Plain)	ID	43	Mar-04	poor establishment; no seed production
	Fernleaf biscuitroot	*LomDis18-BSE-03 (Idaho Batholith)	ID	488	Mar-04	poor establishment; no seed production; remaining seed redistributed to WA grower
	Fernleaf biscuitroot	LODI 11-B7-03 (N Basin & Range)	OR	91	Mar-04	poor establishment; no seed production
	Sagebrush penstemon	PenSpe1-BSE-03 (Snake River Plain)	ID	92	Mar-04	*3 lbs seed produced in 2006; other field planting failed
	Fernleaf biscuitroot	Pooled LODI (N Basin & Range)	ID, OR	908	Oct-06	planted Nov-06
Lee Schweitzer (OR)	Arrowleaf balsamroot	BalSag55-BSE-04 (Snake River Plain)	OR	390	Sep-04	not planted until fall 2005; no production in 2006
	Munro globemallow	SphMun3-BSE-04 (N Basin & Range)	OR	45.2	Sep-04	not planted until fall 2005; no production in 2006

Table 1. Cooperative Native Seed Increase Program accessions distributed to growers (March 2004 through November 2006).

Program Manager Name and State	**Species**	**Lot Number and Ecoregion**	**Seed Origin**	**Weight (g)**	**Distribution Date**	**Status**
Jerry Robinson (WA)	Royal penstemon	Pecy1-B6-02 (Snake River Plain)	ID	300	Oct-04	*3 lbs seed production in 2006
	Sagebrush penstemon	PenSpe43-BSE-06 (N Basin & Range)	ID	95	Jan-06	did not establish due to lack of appropriate prechill treatment
	Fernleaf biscuitroot	*LomDis18-BSE-03 (Idaho Batholith)	ID	454	December 2005 (redistributed from UT to WA)	not yet planted due to lack of proper site; may need to return to RMRS
	Douglas false-yarrow	ChaDou1-BSE-05	ID	248	Apr-06	Planted in spring; small amount of seed production in year 1 due to herbicide effect; plants do not appear to have overwintered
	Shaggy fleabane	EriPum4-BSE-05	ID	30	Apr-06	Grower never planted and will return to RMRS
	Sagebrush penstemon	PenSpe35-BSE-05 (Snake River Plain)	ID	375	Nov-06	planted Nov-06
	Sand penstemon	Pooled PEAC (Snake River Plain)	ID, OR	4.1 lbs	Nov-06	planted Nov-06

* 2006 seed production

Project Title: Establishment and Maintenance of the Buy-Back Program for Certified Seed

Project Location: Utah Crop Improvement Association, Utah State University

Principle Investigators and Contact Information:

Stanford Young, Research Professor/Seed Certification Specialist
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Project Description:
This project is funded through a Research Joint Venture Agreement between the USFS-RMRS in Boise, ID and the Utah Crop Improvement Association (UCIA), initiated in the fall of 2003 and renewed with additional funds in the fall of 2004. Seed was distributed using the Buy-back option, a mechanism for obtaining 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.

Project Status:
A synopsis of the Buy-back Program follows (dated January 10, 2007). Table 1 lists forb and grass seed acquisitions, distributions, inventory, field status, and seed harvested for species germplasms included in the UCIA Stock Seed Buy-back Program from 2002-2006. It is expected that in 2007 several additional forbs and grasses will be included in the program. Table 2 lists the standardized market price for contract negotiations.

Project Synopsis:
Great Basin Native Plant Selection and Increase Project (GBNPSIP) and Utah Crop Improvement Association (UCIA) Stock Seed Buy-back Program, January 10, 2007. 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 purpose of the UCIA Stock Seed Buy-back Program, funded through the GBNPSIP, is: 1) to facilitate development of a seed market for specific germplasm accessions and formal germplasm releases developed through GBNPSIP; these include all germplasms prior to 2003 and certain others assigned through 2006 (Table 1); 2) to reward initial seed growers financially for the risks they have assumed to participate in the program; 3) to document germplasm identity through the seed increase process by utilizing seed certification protocols; and 4) to increase stock seed available for potential secondary seed growers. This program is administered through the Utah Crop Improvement Association.

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

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

Notes:

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

Publications and Presentations:

Young, S.A. Updating seed assurance. Plants, Soils, and Biometeorology Seminar, USU, Feb. 13, 2006. PowerPoint Presentation and Discussion.

Young, S.A. Tracking the natives from wildlands to fields and back. 6th Annual Native Seed Quality Conference, Omaha, NB, Feb. 21-22, 2006. PowerPoint Presentation and Discussion.

Bouck, M. Seed stock of forbs grown for the GBRI and nursery and landscape industries. Intermountain Native Plant Summit IV, Boise, ID, March 28-30, 2006. PowerPoint Presentation and Discussion.

Young, S.A. Source Identified native plant species program. Association of American Seed Control Officials, 20th Annual Meeting, Billings, MT, July 24-26, 2006. PowerPoint Presentation and Discussion.

Young, S.A. and G.W. Andersen. Reasons for specifying certified and Source Identified seed. UDWR Great Basin Research Center Restoration Workshop and Training Session, Sept. 18-21, 2006, Ephraim, UT. Handouts and Discussion.

Table 1. 2006 Update: Utah Crop Improvement Association (UCIA) forb and grass seed acquisition, distribution, inventory, and field planting status for species germplasms included in the Great Basin Native Plant Selection and Increase Project, UCIA Stock Seed Buyback Program

Kind & Variety / Germplasm	Lot/ Source	Seed acquisition and production status	Generation	Added to Inventory	Date	Distributed from Inventory	Date	Inventory 12/31/2005	State distributed to	Field Status	Seed Harvested
FORBS & SHRUBS				**bulk**		**bulk**		**bulk**			
Achillea millefolium											
Western Yarrow											
Germplasm (Eagle Mountain)	NSW4-1-EMY1-1	*3	G2	6.5	9/23/04	6.5	9/14/05	0	WA WY	Established	yes
	NWS-1-YAR-FDN	*3	G2	13	9/20/05	0		13			
Balsamorhiza hookeri	BAHO B1-02	*1*2	G0	271g	Fall 2002	271g	Fall 2002	0.0	CO ID	Seedling	no
Hooker Balsamroot											
Crepis acuminata	CRAC U11-02	*2	G0	50g	Fall 2002	50g	Fall 2002	0.0	ID	Established, taken out	yes
Taperstip hawksbeard											
Lomatium dissectum	LODI B7-02	*2	G0	39g	Fall 2002	39g	Fall 2002	0.0	ID	Established, taken out	yes
Giant Lomatium	LODI B14-02	*2	G0	96g	Fall 2002	96g	Fall 2002	0.0	NV	unsuccessful	no
	LODI PS-04	*3	G1	60g	11/30/04	0		60g *4			
Lomatium triternatum	LOTRT B2-02	*2	G0	446g	Fall 2002	446g	Fall 2002	0.0	ID OR	Established, taken out	yes
Ternate lomatium											
Penstemon acuminatus	PEAC2 B4-02	*1*2	G0	102g	Fall 2002	102g	Fall 2002	0.0	ID	established	yes
Sharpleaf Penstemon	PEAC2 B1-01	*2	G0	37g	Fall 2002	37g	Fall 2002	0.0	NV	unsuccessful	no
Penstemon cyaneus	PECY2 B6-02	*2	G0	968g	Fall 2002	968g	Fall 2002	0.0	ID CO	Established	yes (shoshone office)
Blue Penstemon	PPI-04-1	*1*3	G1	3 lbs	1/6/05	3	9/16/05	0.0	ID	Seedling	no
	2004.0448	*1*3	G1	16	2/2/05	16	2/2/05	0.0	CO	Seedling	no
Penstemon deustus	PEDE B11-02	*1*2	G0	150g	Fall 2002	150g	Fall 2002	0.0	ID	Established	yes
Hotrock Penstemon	PEDE B10-02	*1*2	G0	123g	Fall 2002	123g	Fall 2002	0.0	OR	?	

Table 1 cont. 2006 Update: Utah Crop Improvement Association (UCIA) Forb and grass seed acquisition, distribution, inventory, and field planting status for species germplasms included in the Great Basin Native Plant Selection and Increase Project, UCIA Stock Seed Buyback Program.

Kind & Variety / Germplasm	Lot/ Source	Seed acquisition and production status	Generation	Added to Inventory	Date	Distributed from Inventory	Date	Inventory 12/31/2005	State distributed to	Field Status	Seed Harvested
				bulk		bulk		bulk			
Penstemon pachyphyllus	PEPA2 U6-99	*1*2	G0	1020g	Fall 2002	1020g	Fall 2002	0.0	ID OR NV	Various	yes
Thickleaf Penstemon	PEPA PS-04	*3	G1	345g	11/30/04	0		345g *4			
	A5-4-P1	*3	G1	50lbs	6/7/05	7	Fall 2005	43.0	UT ID	Seedling	no
Sphaeralcea parvifolia	SPGR U19-02	*2	G0	150g	Fall 2002	150g	Fall 2002	0.0	OR	Unsuccessful	no
Small Flower Globemallow	SPGR U13-01	*2	G0	150g	Fall 2002	150g	Fall 2002	0.0	OR	unsuccessful	no
	SPPA U14-02	*1*2	G0	150g	Fall 2002	150g	Fall 2002	0.0	CO	Established	yes
	S04-2-4	*3	G1	1.44lbs	8/19/04	0		1.44lbs			
	SPGR PS-04	*3	G1	130g	11/30/04	0		130g *4			
Tragopogon dubius	TRDU U2-02	*2	G0	5.44lbs	Fall 2002	5.44lbs	Fall 2002	0.0	ID CO	Established, taken out	yes
Yellow Salsify	TRDU DW-04	*3	G1	201g	9/15/04	0		201g			
			subtotal	105.2lbs		46.8lbs		59lbs			
GRASS											
Bluebunch Wheatgrass											
P7 Germplasm	BB-3207, UCIA 84	*2	G4	450.0	10/15/03	0.00		450.0			
Anatone Germplasm	JA-03, UCIA 44	*3	G2	300.0	3/4/04	300.0	3/17/04	0.0	WA	Various	yes
Indian Ricegrass											
Star lake Germplasm	GV LOW, ARS 14	*1*2	G2	5.0	3/15/04	5.0	4/14/04	0.0	WA	Established	no
	GV MED	*2	G2	4.0	10/19/04	0.0		4.0			
Sandberg Bluegrass											
Mountain Home Germplasm	557-215-31A	*3	G2	304.0	8/20/03	254.2	9/15/03	54.9	UT ID WA	various	yes
Mountain Home Germplasm	557-215-31A	*3	G2	0.0		54.9	9/15/05	0.0	ID WA WY	seedling	no
Squirreltail (Bottlebrush)											
Sand Hollow Germplasm	SH RI-98	*2	G2	25.4	11/15/02	0.0		25.4			

Table 1 cont. 2006 Update: Utah Crop Improvement Association (UCIA) Forb and grass seed acquisition, distribution, inventory, and field planting status for species germplasms included in the Great Basin Native Plant Selection and Increase Project, UCIA Stock Seed Buyback Program.

Kind & Variety / Germplasm	Lot/ Source	Seed acquisition and production status	Generation	Added to Inventory	Date	Distributed from Inventory	Date	Inventory 12/31/2005	State distributed to	Field Status	Seed Harvested
				bulk		**bulk**		**bulk**			
Toe Jam Creek Germplasm	LHS1B2J-336	*3	G4	127.5	9/19/05	127.5	9/19/05	0.0	WA	Seedling	no
	LHS1B2G-335	*3	G4	41.0	11/12/04	41.0	9/19/05	0.0	WA	Seedling	no
Fish Creek Germplasm	LHS1B2K-336	*3	G3	113.5	9/14/05	113.5	9/14/05	0.0	WA	Seedling	no
	LHS1B2H-335	*3	G3	47.0	10/28/04	47.0	9/19/05	0.0	WA WY	Seedling	no
			subtotal	1417.4		943.1		534.3			
			Total	1522.6		989.9		593.3			

*1 Currently under Stock Seed Increase contract with grower/cooperators

*2 Seed acquired at no charge from GBRI Cooperators

*3 Cost of seed reimbursed to UCIA through USFS joint venture buy-back program agreement.

*4 Seed not certified, can be used for demonstration plots

Table 2. 2007 Standardized Market Price for contract negotiation.

Scientific Name	Common Name	2007 Suggested Market Price
Balsamorhiza hookeri	Hooker's balsamroot	$ 60.00
Crepis acuminata	Tapertip hawksbeard	$ 140.00
Lomatium dissectum	Giant lomatium (Fernleaf biscuitroot)	$ 50.00
Lomatium triternatum	Ternate lomatium (Nineleaf biscuitroot)	$ 50.00
Penstemon acuminatus	Sharpleaf penstemon (Sand penstemon)	$ 50.00
Penstemon cyananthus	Wasatch penstemon	$ 50.00
Penstemon cyaneus	Blue penstemon	$ 50.00
Penstemon deustus	Hotrock penstemon	$ 50.00
Penstemon pachyphyllus	Thickleaf penstemon	$ 50.00
Penstemon palmeri	Palmer penstemon	$ 25.00
Sphaeralcea munroana	Munro globemallow	$ 60.00
Sphaeralcea grossulariifolia	Gooseberryleaf globemallow	$ 60.00
Sphaeralcea parvifolia	Small-flower globemallow	$ 60.00
Tragopogon dubius	Yellow salsify	$ 30.00
Achnatherum thurberianum	Thurber's needlegrass	$ 50.00
Balsamorhiza sagittata	Arrowleaf balsamroot	$ 45.00
Achillea millefolium	Western yarrow Eagle Site	$ 15.00
Poa secunda	Sandberg bluegrass Mountain Home Site	$ 12.00
Elymus elymoides	Fish Creek Germplasm bottlebrush squirreltail	$ 25.00
Elymus elymoides	Toe Jam Creek Germplasm bottlebrush squirreltail	$ 25.00
Pseudoroegneria spicata	P-7 Germplasm bluebunch wheatgrass	$ 6.50

Appendix 1. Great Basin Native Plant Selection and Increase Project: Status of Research Species.

Family Species	Common Name	Great Basin Project Research									Private Sector	
		Selection, seed increase, seed transfer guidelines[1]	Shrub transfer guidelines	Genetic variability	Pollinators and predators	Cultural practices	Seed germination, testing	AGCR diversification	Wildland shrub seed collection	Releases	Buy-back Program (UCIA)	AOSCA
Apiaceae												
Lomatium dissectum	Fernleaf biscuitroot	SSL-B, Aberdeen		SSL-P	BBSL, CSU	SSL-B, OSU	SSL-B, NSL				X	X
Lomatium graveolens var. *graveolens*	Stinking lomatium	UDWR				UDWR	UDWR, NSL					
L. grayi	Gray's biscuitroot	SSL-B, Aberdeen		SSL-P		SSL-B, OSU	SSL-B, NSL					
L. leptocarpum	Slender-fruit lomatium	SSL-B				SSL-B	SSL-B				X	
L. triternatum	Nineleaf biscuitroot	SSL-B, Aberdeen				SSL-B, OSU	SSL-B, NSL					
Perideridia bolanderi	Yampah	UDWR				UDWR	UDWR, NSL					
Asteraceae												
Achillea millefolium	Western yarrow									SSL-B	X	
Agoseris aurantiaca	Orange agoseris	SSL-P				SSL-P	SSL-P					
A. glauca	Pale agoseris	SSL-P				SSL-P, BYU	SSL-P					
A. grandiflora	Bigflower agoseris	SSL-P				SSL-P	SSL-P					
A. heterophylla	Annual agoseris	SSL-P				SSL-P	SSL-P					
A. tridentata wyomingensis	Wyoming big sagebrush		SSL-P						BYU, SSL-P			
Balsamorhiza hookeri	Hooker balsamroot	UDWR				UDWR	NSL				X	
B. sagittata	Arrowleaf balsamroot	UDWR		SSL-P	BBSL, CSU	UDWR	UDWR, NSL					X

Appendix 1. Great Basin Native Plant Selection and Increase Project: Status of Research Species.

		Great Basin Project Research									Private Sector	
Family **Species**	**Common Name**	**Selection, seed increase, seed transfer guidelines[1]**	**Shrub transfer guidelines**	**Genetic variability**	**Pollinators and predators**	**Cultural practices**	**Seed germination, testing**	**AGCR diversification**	**Wildland shrub seed collection**	**Releases**	**Buy-back Program (UCIA)**	**AOSCA**
Chaenactis douglasii	Douglas false-yarrow						NSL					
Chrysothamnus nauseosus	Gray rabbitbrush		SSL-P									
Crepis acuminata	Tapertip hawksbeard	UDWR		SSL-P	BBSL, CSU	UDWR, BYU	UDWR NSL				X	X
C. intermedia	Gray hawksbeard	UDWR				UDWR	UDWR					
C. occidentalis	Western hawksbeard			SSL-P			NSL					
Erigeron pumilus	Shaggy fleabane			SSL-P		UDWR	NSL					X
Machaeranthera canescens	Hoary aster						NSL					
Viguiera multiflora	Showy goldeneye			SSL-P								
Capparaceae												
Cleome lutea	Yellow beeplant	UDWR			BBSL	UDWR	UDWR					X
C. serrulata	Rocky Mountain beeplant				BBSL							
Chenopodiaceae												
Atriplex canescens	Four-wing saltbush	Aberdeen	SSL-P									
A. confertifolia	Shadscale		SSL-P									
A. torreyi	Torrey's saltbush		SSL-P									
Krascheninnikovia lanata	Winterfat	Aberdeen	SSL-P									
Fabaceae												
Astragalus eremeticus	Hermit milkvetch						NSL					

Appendix 1. Great Basin Native Plant Selection and Increase Project: Status of Research Species.

Family Species	Common Name	Great Basin Project Research: Selection, seed increase, seed transfer guidelines[1]	Shrub transfer guidelines	Genetic variability	Pollinators and predators	Cultural practices	Seed germination, testing	AGCR diversification	Wildland shrub seed collection	Releases	Private Sector: Buy-back Program (UCIA)	AOSCA
A. filipes (A. stenophyllus)	Threadstalk milkvetch	FRRL		FRRL	BBSL, CSU	FRRL	NSL					
A. utahensis	Utah milkvetch	SSL-P		SSL-P		SSL-P, BYU	SSL-P					
Dalea ornata	Prairie clover	FRRL		FRRL	BBSL, CSU							
Hedysarum boreale	Boreal sweetvetch	FRRL		FRRL, SSL-P	BBSL, CSU		UDWR					
H. occidentale	Western sweetvetch	FRRL		FRRL		UDWR	UDWR					
Lathyrus brachycalyx	Sweetpea			SSL-P								
Lupinus arbustus	Longspur lupine	SSL-P		SSL-P		SSL-P	SSL-P					
L. argenteus	Silvery lupine	SSL-P		SSL-P	BBSL, CSU	SSL-P	SSL-P					
L. caudatus	Tailcup lupine	SSL-P		SSL-P		SSL-P	SSL-P					
L. polyphyllus	Bigleaf lupine	SSL-P		SSL-P		SSL-P	SSL-P					
L. sericeus	Silky lupine	SSL-P		SSL-P		SSL-P, BYU	SSL-P					
Vicia americana	American vetch			SSL-P								
Liliaceae												
Allium acuminatum	Tapertip onion			Pullman		Pullman						
Calochortus macrocarpus	Green-banded star tulip											
C. nuttallii	Sego lily											
C. gunnisonii	Gunnison's mariposa lily											

Appendix 1. Great Basin Native Plant Selection and Increase Project: Status of Research Species.												
		Great Basin Project Research									**Private Sector**	
Family Species	**Common Name**	**Selection, seed increase, seed transfer guidelines**[1]	**Shrub transfer guidelines**	**Genetic variability**	**Pollinators and predators**	**Cultural practices**	**Seed germination, testing**	**AGCR diversification**	**Wildland shrub seed collection**	**Releases**	**Buy-back Program (UCIA)**	**AOSCA**
Linaceae												
Linum lewisii lewisii	Blue flax	Aberdeen		SSL-P						SSL-P		
L. perenne	Blue flax			SSL-P								
Malvaceae												
Sphaeralcea spp.	Globemallow											
S. coccinea	Scarlet globemallow	UDWR				UDWR, BYU	UDWR					
S. grossulariifolia	Gooseberryleaf globemallow	UDWR		SSL-P, FRRL		UDWR, BYU	UDWR				X	
S. munroana	Munro's globemallow	FRRL		FRRL								X
S. parvifolia	Small-flower globemallow	UDWR				UDWR	UDWR				X	
Poaceae												
Achnatherum hymenoides	Indian ricegrass	FRRL		SSL-P, FRRL							X	
A. thurberianum	Thurber's needlegrass	SSL-B		FRRL						SSL-B	X	X
Agropyron cristatum	Crested wheatgrass							BYU, EOARC, NRCS, BLM[1]				
Bromus carinatus	California brome			SSL-P								
B. marginatus	Mountain brome			SSL-P	CSU							
Elymus elymoides	Squirreltail grass	FRRL		FRRL						FRRL		
E. elymoides brevifolia	Bottlebrush	FRRL		FRRL							X	

Appendix 1. Great Basin Native Plant Selection and Increase Project: Status of Research Species.

Family Species	Common Name	Great Basin Project Research									Private Sector	
		Selection, seed increase, seed transfer guidelines[1]	Shrub transfer guidelines	Genetic variability	Pollinators and predators	Cultural practices	Seed germination, testing	AGCR diversification	Wildland shrub seed collection	Releases	Buy-back Program (UCIA)	AOSCA
	squirreltail											
E. multisetus	Big squirreltail	FRRL		FRRL								
E. wawawaiensis	Snake River wheatgrass	FRRL		FRRL								
Hesperostipa comata	Needle-and thread grass	UDWR, SSL-P, FRRL		SSL-P, FRRL		UDWR, SSL-P	UDWR, SSL-P					
Leymus cinereus	Basin wildrye	UDWR, FRRL		FRRL	CSU	UDWR						
L. triticoides	Beardless wildrye	FRRL		FRRL								
Nassella viridula	Green needlegrass										X	
Pascopyrum smithii	Western wheatgrass	FRRL		FRRL								
Poa fendleriana	Muttongrass	UDWR					UDWR					
P. secunda	Sandberg bluegrass	FRRL		FRRL						SSL-B	X	
Pseudoroegneria spicata	Bluebunch wheatgrass	UDWR, Aberdeen, FRRL		FRRL SSL-B						SSL-B	X	
Polemoniaceae												
P. longifolia	Longleaf phlox	SSL-P		SSL-P		SSL-P, BYU	SSL-P					
Polygonaceae												
Eriogonum heracleoides	Wyeth buckwheat											X
E. ovalifolium	Cushion buckwheat	UDWR				UDWR, BYU	UDWR, NSL					X

Appendix 1. Great Basin Native Plant Selection and Increase Project: Status of Research Species.

Family Species	Common Name	Great Basin Project Research: Selection, seed increase, seed transfer guidelines[1]	Shrub transfer guidelines	Genetic variability	Pollinators and predators	Cultural practices	Seed germination, testing	AGCR diversification	Wildland shrub seed collection	Releases	Private Sector: Buy-back Program (UCIA)	AOSCA
E. umbellatum	Sulfur-flower buckwheat	SSL-B, Aberdeen		SSL-P	BBSL, CSU	SSL-B	SSL-B, NSL					X
Rosaceae												
Purshia tridentata	Bitterbrush	SSL-P	SSL-P						BYU, SSL-P			
Scrophulariaceae												
Penstemon acuminatus	Sharpleaf penstemon	SSL-B, Aberdeen		SSL-P	CSU	SSL-B, OSU	SSL-B, NSL, OSU				X	X
P. cyaneus	Royal penstemon										X	X
P. deustus	Scabland penstemon	SSL-B, Aberdeen		SSL-P		SSL-B, OSU	SSL-B, NSL, OSU				X	X
P. pachyphyllus	Thickleaf penstemon										X	
P. palmeri	Palmer penstemon			SSL-P								
P. speciosus	Sagebrush penstemon	SSL-B, Aberdeen		SSL-P	BBSL, CSU	SSL-B, OSU	SSL-B, NSL, OSU					X

Aberdeen = Natural Resources Conservation Service Plant Materials Center, Aberdeen, ID (St. John, Ogle)
AOSCA = Association of Official Seed Certifying Agencies Cooperative Native Seed Increase Program
BBSL = USDA-ARS Bee Biology and Systematics Laboratory (Cane)
BYU = Brigham Young University (Anderson, Roundy, Johnson, Jessop)
CSU = Colorado State University, Cooperative Extension, Tri-River Area (Hammon)
EOARC = USDA-ARS Eastern Oregon Agricultural Research Center (Mangold)

FRRL = USDA-ARS Forage and Range Research Laboratory (Johnson, Jones, Larson, Monaco, Peel)
NSL = National Seed Laboratory (Karrfalt, Vankus)
OSU = Oregon State University, Malheur Experiment Station (Shock, Feibert, Johnson)
Pullman = ARS, Western Regional Plant Introduction Station, Pullman, WA (Johnson, Hellier)
SSL-B = USDA-FS-RMRS Shrub Sciences Laboratory - Boise (Shaw, DeBolt, Cox)
SSL-P = USDA-FS-RMRS Shrub Sciences Laboratory - Provo (McArthur, Jensen, Sanderson)
UCIA = Utah Crop Improvement Association (Young, Bouck)

Notes:

1. Crested wheatgrass diversification: studies.