Great Basin Native Plant Selection and Increase Project FY07 Progress Report

USDI Bureau of Land Management, Great Basin Restoration Initiative
USDA Forest Service, Rocky Mountain Research Station, Grassland, Shrubland and Desert Ecosystem Research Program, Provo, UT and Boise, ID
USDA Agricultural Research Service, Bee Biology and Systematics Laboratory, Logan, UT
USDA Agricultural Research Service, Eastern Oregon Agricultural Research Center, Burns, OR
USDA Agricultural Research Service, Forage and Range Research Laboratory, Logan, UT
USDA Agricultural Research Service, Western Regional Plant Introduction Station, Pullman, WA
USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center, Aberdeen, ID
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Montana State University, Bozeman, MT
University of Nevada, Reno, NV
Utah State University, Logan, UT
Private seed industry

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March 2008

COOPERATORS

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

Research priorities include: 1) improvement in the availability of native plant materials adapted to major bio-geographic areas of the Great Basin with an emphasis on native forbs; 2) development of seed technology and cultural practices required for agricultural seed increase of native forbs and grasses; 3) management or re-establishment of wildland shrub stands to improve seed availability and conserve native populations; 4) evaluation of the potential for increasing native plant diversity in established crested wheatgrass stands in the Great Basin while minimizing weed invasion; 5) investigation of the biology of native forbs, emphasizing seed germination and seedling establishment; 6) examination of interactions among restoration species and between restoration species and invasive exotics; 7) evaluation of rangeland drills and strategies for establishing diverse native communities; and 8) technology transfer.

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 Kelsey Sherich, Matthew Fisk, Nicholas Williams, Jan Gurr and Robert Cox for their tenacity and cheerfulness while completing this report and the 2001-2007 report to the Washington Office.

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

Great Basin Restoration Initiative Website:
http://www.blm.gov/nifc/st/en/prog/fire/more/gbri.html

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

Summary of 2007 Progress

Highlights from the 2007 report are provided below. Current status of plant materials and restoration studies are summarized in the Appendix.

Plant materials development:

Common gardens studies to examine adaptive variation/seed zone development:

- Seed collections: 109.

- *Hesperostipa comata* (needle-and-thread grass) (four common gardens), *Lupinus prunophilus* (hairy bigleaf lupine) and *L. arbustus* (longspur lupine) (two common gardens) and other forb and grass species (See Appendix I) are being evaluated at multiple locations.

- Strong differences in plant traits measured on 115 *Achnatherum hymenoides* (Indian ricegrass) accessions in two common gardens showed that genetic variation was associated with seed collection location. Since plant traits frequently correlated with environmental factors such as elevation, attitude, and minimum temperature at seed collection sites, adaptation in *A. hymenoides* appeared to be driven by the seed source environment. A second year of study is needed but this shows that an understanding of seed transfer zones will be required for revegetation efforts.

- In the first year of a study on *Pseudoroegneria spicata* (bluebunch wheatgrass) strong genetic variation was observed among the 120 seed collection locations. Interactions with garden site and collection location were also strong. Thus, growth and development of *P. spicata* depended both on where the germplasm originated and on where it was evaluated. These results show a need for assessing seed adaptation zones for bluebunch wheatgrass revegetation in the Great Basin.

- *Allium acuminatum* (taper-tip onion) populations collected across the Great Basin and grown in common gardens showed strong genetic differences. Correlation of plant traits with factors such as elevation, temperature, and precipitation also showed that much of the genetic variation was associated with seed source environment. The data suggest that adaptive difference in *A. acuminatum* exist among Great Basin germplasm with the potential need for seed transfer zones. This will be determined with final data analysis in 2008.

- *Astragalus utahensis* (Utah milkvetch) and *Agoseris aurantiaca* (orange agoseris), *A. heterophylla* (annual agoseris) and *A. glauca* (pale agoseris) are going through seed increases. Release may be possible in 2008, but efficient and economical seed harvesting is the main obstacle to commercial production at present.

- *Crepis acuminata* (tapertip hawksbeard) and *C. intermedia* (gray hawksbeard): One new irrigated trial of each was established. Established gardens began flowering in the third year. More flowering and better survival were noted for *C. intermedia*. Aphids and seed predators reduced seed production.

- *Eriogonum ovalifolium* (cushion buckwheat): Some seed was produced during the first year from a transplanted garden. Increase of separate materials for four Level 3 ecoregions will begin in 2008.

- The USDA NRCS Aberdeen Plant Materials Center provided a report on third-year performance of 82 accessions of 27 commonly seeded grasses, forbs and shrubs (native and introduced) in a demonstration planting at the Orchard Research Site near Boise, ID.

Plant releases:

- *Astragalus filipes* (basalt milkvetch) NBR-1 Selected germplasm (12 pooled NV, OR, ID, UT, and CA accessions, manipulated track). This germplasm is recommended for use in stabilizing degraded rangelands, revegetation of disturbed areas, and beautifying roadsides in the Northern Basin and Range. Seed fields will be established in Oregon and Utah in 2008.

Molecular genetics studies to better understand diversity in a species:

- Genetic variation in 180 populations of 35 grass, forb and shrub species has been examined to explore between and within population variation. This information will improve manager's ability to select plant materials for maintaining the natural variation and genetic integrity of seeded areas.

- Comparison of the genetic architecture of seeded populations with that of adjacent native populations indicates that many of the seeded populations lie within the natural range of variation of native populations.

- Artificial hybridization experiments indicate that the nonnative *Linum perenne* 'Appar' (blue flax) is not likely to hybridize with the native *Linum lewisii* (Lewis flax).

- Molecular genetic analysis of 81 accessions of *Astragalus filipes* suggests two distinct groupings (central Nevada and British Columbia) and one 'catchall' population that includes 69 accessions.

Seed increase:

- New initial increase plots/fields: *Heliomeris multiflora* (showy goldeneye), *Agoseris grandiflora* (bigflower agoseris), *A. heterophylla, Townsendia florifer* (showy Townsend daisy), *Chaenactis douglasii* (Douglas' dustymaiden), *Eriogonum sphaerocephalum* (rock buckwheat).

- Distribution of new materials to seed growers: *Astragalus filipes* (pooled sources, Northern Basin and Range), *Ephedra viridis* (green ephedra), *Heliomeris multiflora, Penstemon deustus* (scabland penstemon) (pooled sources – northern Basin and Range), *P. speciosus* (royal penstemon) (pooled sources, Northern Basin and Range), *Leymus cinereus* (basin wildrye)(pooled sources, northern Great Basin), *Balsamorhiza sagittata* (arrowleaf balsamroot) (plugs).

- Seed increase fields of *Balsamorhiza sagittata* and *Perideridia bolanderi* (Bolander's yampah) are planned for 2008. Seven increase plots are being maintained at the Aberdeen Plant Materials Center.

- 573 lbs of stock seed were distributed to growers by the Aberdeen Plant Materials Center, the Utah Crop Improvement Association and the Utah Division of Wildlife Resources, Great Basin Research Center.

- The Utah Crop Improvement Association Buy-back program continues to facilitate establishment of initial seed fields for GBNPSIP plant materials.

Cultural practices for agricultural seed production:

Pollinators:

- *Lomatium dissectum* (fernleaf biscuitroot) was shown to be fully self-fertile but requires pollinators. Across a 5-state region, these consist solely of small ground-nesting floral specialists and sometimes floral generalists, only the latter likely to be available on-farm.

- Generalist foragers (hummingbirds, honey bees and bumblebees) will forage somewhat indiscriminately between similar-looking flowers of a given genus. Observations now indicate that hybridization of a genus of closely-related interfertile species, the *Balsamorhiza* (balsamroots), is as likely to result during the foraging trips of specialist as generalist bees. Consequently, using specialist pollinators will not avoid the problem of hybridization in seed fields.

- Nesting habitats of the most frequent and promising group of pollinators found visiting flowers of GBNPSIP Great Basin forbs, bees of the genus *Osmia*, were compiled and reviewed, highlighting species whose cavity-nesting habits make them amenable to on-farm management.

- Species of four *Osmia* bee species and one *Hoplitis* bee that effectively pollinate *Hedysarum boreale* (northern sweetvetch) and *Astragalus filipes* have been acquired from the wild and are being propagated at the USDA ARS Logan labs for evaluation and later distribution to seed growers, possibly in 2008.

Seed/plant predators:

- The Native Plant Seed Production web site is now on-line at http://wci.colostate.edu. This site has current information on life history and control of insect pests affecting seed production of plants grown for the GBNPSIP.

- The *Sphaeralcea* weevil *Anthonomus sphaeralciae* Fall was found attacking globemallows at two sites. Losses exceeded 33% at one of the sites. Management studies were initiated and current information is posted on the Native Plant Seed Production web site.

- A study on seed losses to invertebrate seed predators found that three forbs of the Asteraceae (*Wyethia amplexicaulis* [mule-ears], *Crepis acuminata*, and *Agoseris glauca*) have a consistent and high degree of seed pest damage in wildland settings. These results forewarn future seed producers of the need to implement Integrated Pest Management Plans (IPMP).

Planting practices:

- Planting trials indicate 12-inch spacing is preferable to 18-inch spacing for seed production of *Sphaeralcea grossulariifolia* (gooseberryleaf globemallow) and *S. parvifolia* (smallflower globemallow).

- Seeds of native forbs (*Balsamorhiza sagittata, Crepis intermedia* and *Perideridia bolanderi*) were planted at several depths to determine optimal planting depths for each in sandy or clay soils. Most emerged best from shallow depths (generally <0.25 inches). The high cost of native seeds suggests that proper placement of seed is essential to maximize establishment and economic benefits of seedings.

- Woven weed barrier was superior to plastic weed barrier or no weed barrier in terms of *Crepis intermedia* survival and reduction of hand weeding.

- *Hedysarum boreale* and *Sphaeralcea grossulariifolia* did not require cold moist stratification for germination in a seed recovery trial while fall seeding and over winter stratification were essential for *Eriogonum ovalifolium*, *Balsamorhiza sagittata*, *Perideridia bolanderi* and C*repis acuminata*.

- *Rhizobia* strain I-49 was determined to be most appropriate for inoculation of *Astragalus filipes* seed and will be made commercially available.

- Laboratory and greenhouse tests indicated that hard seeded *Astragalus utahensis* germinates more readily when inoculated with *Aspergillus* or *Alternaria* fungi. Field data suggests that when fall seeded, seeds treated with *Aspergillus* germinated better than untreated seeds, seeds treated with *Alternaria*, or scarified seeds.

- Five potential *Rhizobia* isolates from untreated *Lupinus* seeds will be inoculated on established *Lupinus* seedlings to assess their effects on plant growth and health. Current studies are focusing on developing protocols for improving *Lupinus* germination and seedling establishment.

- Preliminary work indicates that inoculation with *Alternaria* may increase *Hesperostipa comata* seed germination.

Irrigation:

- Growers need to have economic return on their seed plantings, but forbs may not produce seed every year. Due to the arid environment, supplemental irrigation may be required for successful flowering and seed set many years because soil water reserves may be exhausted before seed formation.

- Subsurface drip irrigation (SDI) systems are being tested for native seed production because SDI has two potential strategic advantages; a). low water use, and b). the buried drip tape provides water to the plants at depth, out of reach of stimulating weed seed germination on the soil surface and away from the plant tissues that are not adapted to a wet environment.

- The total irrigation water requirements for these arid land species are expected to be low, but will probably vary by species. Irrigation requirements need to be defined for each species.

Weed control in seed increase fields (Research is conducted to identify products that could eventually be registered for use for native forb seed production):

- In field trials, Prowl (H20 3.8 C) and Outlook (6.0 EC) applied as postemergence herbicides were tolerated by *Lomatium grayi* (Gray's biscuitroot), *L. dissectum*, *L. triternatum* (nineleaf biscuitroot), *Eriogonum umbellatum* (sulfur-flower buckwheat), *Penstemon speciosus, P. deustus* and *P. acuminatus* (sharpleaf penstemon). *P. deustus, P. acuminatus,* and the *Lomatium* species were tolerant of Select as a postemergence herbicide. Further research is needed to identify safe application ranges and any negative interactions.

- Greenhouse studies indicate *Crepis acuminata* and *Dalea ornata* emerge well when treated with Olympus (0.0267 lb ai acre^{-1}) or Plateau (0.0625 lb ai acre^{-1}) as preemergent herbicides.

Seed biology and technology:

- A 20-minute treatment in concentrated sulfuric acid improved germination or *Sphaeralcea coccinea* (scarlet globemallow) more than 10- or 30-minute treatments. Removal of carpels also improved germination. Data indicates seeds from immature schizocarps (fruits) are more germinable than those from mature schizocarps.

- Viability, germination and moisture content of Wyoming big sagebrush seeds are being tracked through long-term storage at 3 temperatures to examine the feasibility of using the seed in the year(s) following harvest.

- Seed cleaning protocols for 12 species and germination testing protocols for 3 species are complete; nine are in progress.

- *Lomatium dissectum* seed biology and ecology studies are elucidating mechanisms regulating embryo growth which precedes germination and variation in stratification requirements across an elevation gradient. Seed dormancy was not relieved by treatment with a number of common plant growth regulators.

Species interactions/Seeding to resist exotic invasives:

- Plant invasion in semi-arid systems is linked, in part, to the ability of the native vegetation to sequester nitrogen. Species-diverse plant communities are expected to sequester more nitrogen because they are more likely to contain groups of species differing in the seasonal pattern or soil depth in which they capture nitrogen. Total plant biomass in a community may be more important for invasion resistance than the numbers or types of plant species present. Most nitrogen sequestered was captured by the most dominant species. Less abundant species, although differing in patterns of nitrogen capture, were not large enough to be significant sinks for nitrogen in the plant community. In weed infested areas, these findings suggest that establishing one or two dominant species that grow quickly may be the best strategy to inhibit the spread of invaders. Additional time and money spent on establishing diverse communities may not have a benefit in terms of reducing the spread of weeds.

- Understanding how disturbance facilitates invasion and which species best resist establishment of weedy species is necessary for successfully restoring and managing Great Basin rangelands. Seeds of the annual *Bromus tectorum* (cheatgrass) and the broadleaf forb *Isatis tinctoria* (Dyer's woad) were added to disturbances in plots supporting a grass (*Pseudoroegneria spicata*), forb (*Achillea millefolium* [western yarrow]), or shrub (*Artemisia tridentata* var. *wyomingensis* [Wyoming big sagebrush]) monoculture. Disturbance increased weed density for all three growth forms in both years with the exception of *P. spicata* which was similar to the control in the second year. Results suggest that the capability of *P. spicata* to resist invasion may be related to its biomass productivity and resource utilization.

- Examination of the impact of *Bromus tectorum* density on native forb establishment indicated that *L. grayi* and *A. millefolium* growth was not negatively impacted at *B. tectorum* densities less than 50 plants m^{-2}, while growth of *Eriogonum umbellatum* and *Penstemon speciosus* was reduced at all *B. tectorum* densities. Changes in soil water content over time indicated that the early germinating forbs, *L. grayi* and *A. millefolium* may have had 6-8 weeks of growth before soil water content began declining on cheatgrass plots. *E. umbellatum* and *P. speciosus* germinated later and experienced greater competition for water.

Crested wheatgrass diversification:

- Studies of methods such as mechanical disturbance and herbicide application for controlling crested wheatgrass and reestablishing native species highlight the difficulty of simultaneously controlling crested wheatgrass, minimizing invasion of exotic species, and establishing desirable native species. Treatments in Utah and Oregon included controlling crested wheatgrass through partial and full mechanical (1-pass or 2-pass disking), partial (10 oz/ac) and full (44 oz/ac) glyphosate application, and seeding of native species. It appears that by addressing site availability (bare ground) and species availability, initial native plant establishment can be achieved by directly seeding native species into crested wheatgrass stands. High mortality of germinated seedlings demonstrates that selecting species for areas that fulfill their germination and emergence requirements does not guarantee their establishment and that more than one wet year is needed for species establishment. Hydrothermal models of native seed germination will allow managers to better select native species that will establish on a revegetation site.

Restoration strategies and equipment:

Equipment and strategies for reestablishing diverse native Wyoming big sagebrush communities post-fire:

- Capabilities of the Kemmerer rangeland drill and the Truax Rough Rider minimum till drill to seed seeds of diverse sizes and shapes at appropriate depths to reestablish grasses, forbs, and shrubs on two former Wyoming big sagebrush sites are being compared at two northern Nevada sites. First-year (2007) emergence data (species richness, seedling density, plant cover, basal gap) suggests that broadcast species experienced greater emergence in plots seeded with the Truax Rough Rider, as compared to the Kemmerer rangeland drill. Only small differences were observed between the two drills in terms of densities of drilled species.

- Drill comparisons and seeding strategies to enhance post-fire establishment and persistence of diverse Wyoming big sagebrush communities are being further investigated (with partial funding from the Joint Fire Sciences Program). Determining techniques for enhancing Wyoming big sagebrush and seeding rates for native grass, forb and shrub establishment, analysis of long-term grazing effects on sagebrush seedings, and application of new ESR monitoring protocols are major objectives. Treatments include seeding at 3 rates with the two drills, plus a fall and winter broadcast seeding. Fenced and non-fenced blocks will provide an opportunity for long-term monitoring of grazing effects on seeded plots. Sites near Mt. Home, ID and Burns, OR were seeded in fall 2007. Two additional sites will be treated in 2008. GPS units will be added to each drill to track seeded area, drill speed and seeding rates.

- The Revegetation Equipment Catalog (http://reveg-catalog.tamu.edu/) provides descriptions, applications, photographs, and sources for more than 200 equipment items used for rangeland vegetation manipulation, wildlife habitat improvement and disturbed land rehabilitation.

Deliverables, Products, Technology Transfer

Plant materials: 109 seed collections, 1 plant release, 573 lbs stock seed distributed, seed of 7 new materials placed with growers, 92 seed collections and more than 400 site records provided to the Seeds of Success Program, 42 seed collections provided to the National Seed Laboratory.

Publications: 6 journal and 3 proceedings papers, 2 special reports, 2 plant guides, 1 tech note.

Graduate programs: 8 M.S. and 1 Ph.D. completed, 9 programs in progress.

Presentations: 3 international (2 invited), 42 national (32 invited), 22 regional/local (13 invited).

Meetings: 3 symposia (2 national, 1 regional), 2 workshops and 4 field days conducted.

Interaction with Tribes: 3 training sessions (seed collection), 1 workshop (seed cleaning), 1 tour.

Displays: 4 (Revegetation Equipment Catalog and GBNPSIP).

Popular articles, brochures, awards: 1 popular article, 3 additional in progress, GBNPSIP brochure updated, 2 national awards (Service First and National Grassland Research and Technology).

Websites: 1 new (Seed predator identification and management), Revegetation Equipment Catalog and GBNPSIP websites updated.

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APPENDIX

Project Title: Forb and Shrub Genetics Research

Project Location: USDA Forest Service, Shrub Sciences Laboratory, Provo, UT

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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
Thirty-five species (6 shrubs, 3 grasses, and 27 forbs) and more than 180 populations have been examined in a series of studies. These include *Artemisia tridentata, Astragalus utahensis, Atriplex canescens, Balsamorhiza sagitatta, Bromus carinatus, Castilleja miniata, Chrysothamnus nauseosus (Ericameria nauseosa), Crepis acuminata, Epilobium angustifolium* (*Chamerion angustifolium*), *Erigeron pumilus, Eriogonum umbellatum, Gerenium richardsoni, Linum lewisii, Linum perenne, Lomatium dissectum, Lomatium grayi, Lupinus argenteus/sericeus, Penstemon deustus, Penstemon palmeri, Penstemon speciosus, Phlox*

longifolia, Sphaeralcea ambigua, Sphaeralcea grossulariifolia, Hesperostipa 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 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 of restoration seeding, e.g., will the seeding be appropriate in maintaining the natural variation and genetic integrity of the site under consideration.

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McArthur, E. D. 2007. Genetic considerations for wildland forb and shrub restoration plantings. p. 7, Abstracts of papers, Native wildflower seed production research symposium. University of Florida-Gainsville, Orlando, FL.

Project Title: Plant Materials Development, Cultural Practices for *Agoseris* and *Lupinus*

Project Location: USDA Forest Service, Shrub Sciences Laboratory, Provo, UT

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Species Status:

Astragalus utahensis

Data on initial establishment, plant size, flowering phenology, seed yield, longevity and seed characteristics are being compiled. We anticipate a final seed harvest in 2008 will complete the dataset and recommendations on a release can be made. Economical harvest techniques presently preclude *Astragalus utahensis* from being a viable commercial product.

***Agoseris* spp**

Inventory of *Agoseris* seed for all species is low. In 2007 we converted a portion of our greenhouse for *Agoseris* increase and producing seed of two species, *Agoseris aurantiaca* and *A. heterophylla*. Both performed well without vernalization. We modified our production design again and continue to increase seed in preparation for field trials. *Agoseris glauca* and *A. aurantiaca* performed poorly in a greenhouse setting. Both species bolted few stems and require insect pollination. Lack of vernalization may have been responsible for poor performance. We are cold treating both species and will grow them outside in 2008 to take advantage of native pollinators.

We perceive the crux of success with *Agoseris spp.* has less to do with selecting the best biotype and more to do with developing cultural techniques for economical production. As more seed becomes available our efforts will focus there.

Hesperostipa comata

Common gardens of needle and thread grass at Fountain Green, Orovada and Ephraim are yielding good establishment and phenology data. In 2008 we will emphasize seed yield and seed cleaning qualities. We anticipate establishing an additional garden at the Desert Experimental Range this winter.

***Lupinus* spp.**
Considerable effort was made in 2007 to collect several pounds of seed from *Lupinus argenteus* (Nevada source), *L. prunophilus* (Utah source), and *L. arbustus* (Nevada source) to establish a replicated cultural practice study at two sites. *Lupinus sericeus* (Utah source) was purchased from a local collector. The study is designed to assess stand establishment and subsequent seed yield from drill seeded, broadcast and plugged plots. Cost comparisons will be computed.

Common gardens at Nephi and Fountain Green have established adequately and are providing data on seed characteristics, longevity, and phenology.

New species
Several new species were collected in 2007.We will attempt to establish preliminary observation/data plots from plugged plants in 2008 and expand collection and work with those that show potential.

Presentations:

Jensen, S.L. 2007. Wildland seed collecting in the Great Basin. Native wildflower seed production research symposium. Native Wildflower Seed Production Symposium, Orlando FL.

Jones, C.D., Jensen, S.L. 2007. Working with natives: lessons learned. Uncompahgre Plateau Project, Plant Community Restoration Workshop. Grand Junction, CO.

Jensen, S.L. 2007. New container propagation protocols for *Lupines* and *Agoseris* and projecting production costs. Are some species cost prohibitive? Developing native plant materials for the Great Basin. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th annual meeting, Reno, NV. Abstract. Invited presentation.

Jensen, S.L. 2008. Fire and weed ecology in the Great Basin: The need for revegetation. Community awareness presentation, Orem, Utah.

Products:

Equipment Development and Modification
We built 5 and 50 gallon seed driers following Robert Karrfalt's design. These will be used to dry both wildland collections and increase plot harvests.

Our mulch layer was modified to handle 6' wide materials. The wider material is more conducive to our harvesting equipment.

We installed an automated watering system in one of our greenhouses feeding both drip tape and overhead misters.

Stock Seed Production
An Idaho source of *Agoseris grandiflora* and a Nevada source of *Agoseris heterophylla* were increased in our greenhouse. Seed from this effort is again being increased in 2008 using the same method.

A Nevada source of *Heliomeris multiflora* was increased at Fountain Green. This seed will be used to establish a larger increase plot.

Seed Distribution to Growers
Heliomeris multiflora and *Ephedra viridis* were distributed to a Sanpete County, Utah grower.

Lupinus prunophilus and *Lupinus argenteus* were provided to research and increase efforts at Oregon State University's Malheur Experiment Station.

Field Tours and Workshops
S. Jensen instructed a one day seed collection workshop to members of the Shoshoni and Bannock Tribes at Fort Hall Reservation.

S. Jensen spoke at a Squarrose knapweed summer tour, Tintic Valley, UT.

Equipment Loan
A tractor and precision seeder was lent to a Sanpete County, Utah grower to plant *Sphaeralcea grossulariifolia*, *Heliomeris multiflora* and *Krascheninnikovia lanata.* Our Flail-Vac was loaned to assess its utility to collect mountain big sagebrush.

Cooperator Assistance
Several thousand feet of weed barrier were installed at Fountain Green for Division of Wildlife Resource plantings.

S. Jensen delivered a tractor and spent a week helping install a large field study in Oregon and Idaho that will evaluate various seed mixes when planted with the rangeland drill or the Truax Rough Rider drill.

We seeded field trials of *Astragalus utahensis* for BYU at study plots in Nephi, Spanish Fork and Fountain Green.

We made several collections of *Elymus elymoides* for the PNW Lab in Corvallis, OR.

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

Project Location: Utah Division of Wildlife, Great Basin Research Center, Ephraim, UT

Principal Investigators and Contact Information:

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Project Description:
We are working with six species of Great Basin native forbs to develop them for use in rehabilitation of disturbed sites. To accomplish this, we collect wildland accessions, test germination requirements, explore and develop cultural techniques, screen accessions for suitability in various locations and applications, and work with growers to implement cultural methods and build the seed production industry.

Project Status:
Wildland Seed Collection
We made 28 new forb wildland collections in 2007. The collections were from eight different plant families (Table 1).

We also made 20 wildland collections of grasses, and put most of the accessions into greenhouse plug production for transplanting to Fountain Green in 2008 for observation. The collected species were muttongrass (*Poa fendleriana*), Sandberg bluegrass *(Poa secunda*), Indian ricegrass (*Achnatherum hymenoides*), purple three-awn (*Aristida purpurea*), and Galleta grass (*Pleuraphis jamesii*). Genetic collections of Indian ricegrass were given to researchers at USDA-ARS, Pullman, for genetic work.

The wildland forb seed collections have been dried and cleaned, and several have been entered into studies.

The database now registers over 1000 wildland seed collections and several stock seed increased lots.

Table 1. Collections made in 2007.

Plant Family	Species Acronym	Genus Species	Common Name	Number of Collections 2007
Apiaceae	CYMOP	*Cymopterus* sp.	Spring-parsley	0
Apiaceae	LOGR	Lomatium grayi	Milfoil Lomatium	2
Apiaceae	LOGRGR	*Lomatium graveolens* var. *graveolens*	Stinking lomatium	0
Apiaceae	LODI	Lomatium dissectum	Giant Lomatium	1
Apiaceae	PEBO2	Perideridia bolanderi	Yampah	3
Asteraceae	BAHO	Balsamorhiza hookeri	Hooker balsamroot	0
Asteraceae	BASA	Balsamorhiza sagittata	Arrowleaf balsamroot	2
Asteraceae	CRAC	*Crepis acuminata*	Tapertip hawksbeard	1
Asteraceae	CRIN	*Crepis intermedia*	Gray Hawksbeard	1
Capparaceae	CLLU	*Cleome lutea*	Yellow bee-plant	0
Fabaceae	ASUT	*Astragalus utahensis*	Utah milkvetch	2
Fabaceae	HEBO	*Hedysarum boreale*	Northern sweetvetch	4
Fabaceae	LABR	*Lathyrus brachycalyx*	Rydberg sweetpea	1
Fabaceae	LUAR	*Lupinus argenteus*	Silver lupine	2
Linaceae	LILE	*Linum lewisii*	Blue flax	1
Malvaceae	SPGR, SPCO2	*Sphaeralcea grossularifolia*, *S. coccinea*	Gooseberryleaf and Scarlet globemallows	4
Polemoniaceae	PHLO	*Phlox longifolia*	Longleaf phlox	2
Polygonaceae	EROV	*Eriogonum ovalifolium*	Cushion buckwheat	1

Common Gardens

We maintained older common garden field trials of all the forb species in Ephraim and Fountain Green during 2007. We continued to observe growth, seed set and plant survival in the trials. Based on the trial data, we have been able to narrow down the number of accessions we intend to focus on for all of our species. Decisions were based on seed origin to provide plant material appropriate for the several different ecological sites throughout the Great Basin, and also on plant vigor and seed production capability. These decisions guided the new common garden planting lists and selection of stock seed sent to growers.

We planted new seedling plug trials of cushion buckwheat in April 2007, and gooseberry leaf, scarlet, and littleleaf globemallows in May 2007 at our Fountain Green farm. In November of 2007 we direct-seeded a trial of all the *Crepis acuminata* and some of the *C. intermedia* accessions into a nearby field trial. All trials were planted into weed barrier-covered beds with Netafim® drip irrigation installed on top of the weed barrier. Rainstorms in June and July caused flooding across the trials, and brought in deep mud and seed of weeds from the grazed hills above the trials. Some trial plants were lost to mud inundation. We dug the trial out of the mud, and removed the weeds. In November of 2007 we consulted with NRCS personnel regarding the flooding and erosion of our fields, and based on their recommendations, installed a runoff capture channel through the field, and planted it and the surrounding ground with grass.

Hawksbeards

We continued to maintain and observe the *Crepis acuminata* and *C. intermedia* trial in Ephraim and found the plants increasing in size and flowering in the third season. *C. intermedia* was again the predominant success story, but some of the *C. acuminata* accessions did appear to survive, grow, and flower. Aphids and other flower head predators reduced the seed production, no seed was collected.

The *C. acuminata* and *C. intermedia* trial seeded in 2007 at Fountain Green consisted of 31 accessions. This trial would experience natural winter stratification in the field and will be evaluated for germination and growth in spring 2008. The trial was not randomly replicated, but was planted as four rows of an accession per bed in 26-foot blocks, to allow combine harvest.

Cushion Buckwheat

The buckwheat trial planted in spring 2007 consisted of 23 accessions, principally of cushion buckwheat (*Eriogonum ovalifolium*), with one to three replicates, depending on seed and plant plug production success. The lines chosen for the trial were those that had performed the best in the Ephraim trial over three years, plus new accessions acquired since the Ephraim trial was planted. We made field observations on morphological traits, phenology, and plant vigor throughout the summer and into the fall on the new buckwheat trial. The trial bloomed and produced some seed in the first season. Seed was not collected because it would be cross-pollinated, and there was not enough to obtain useful seed-production information.

Based on the first year's observations, combined with observations over three years in the Ephraim trial, we determined that eight of the accessions from five geographic areas are superior (Table 2). Mapping the selections onto Omernik ecoregion maps showed the ecological distribution (Fig. 1.) The accessions came from Nevada and Utah, between elevations 4400 and 6400 feet elevation. Only two of the accessions, Drum Mt. and Newcastle, were in the same Level 4 ecoregion. Grouping just to Level 3 ecoregions, the sites represented four ecoregions. A focus in 2008 will be to collect more wildland seed of these accessions, and to produce seed in increase gardens with adequate isolation distance from other *E. ovalifolium*. Two accessions of this species from areas north of Elko, NV, were sent out to growers in years past, and one of these accessions showed promise in our trials, but neither was among the best accessions. Attempts to track down the outcome of the grower increases have been unsuccessful due to personnel changes.

Table 2. *Eriogonum ovalifolium* best accessions.

Sitename	**County state**	**elevation**	**LEVEL4_NAM**
North Battle Mountain EROV	Lander Co., NV	5445	13z Upper Lahontan Basin
Pequop Foothills EROV	Elko Co., NV	5900	13p Carbonate Sagebrush Valleys
Toano EROV	Elko Co., NV	6365	13q Carbonate Woodland Zone
Crittenden Reservoir EROV	Elko Co., NV	5250	80a Dissected High Lava Plateau
Drum Mountains EROV	Millard Co., UT	5955	13c Sagebrush Basins and Slopes
FR031 to St. George EROV	Washington Co., UT	4368	19f Semiarid Foothills
Horse Canyon EROV	Emery Co., UT	5450	20b Shale Deserts
Newcastle EROV	Iron Co., UT	5393	13c Sagebrush Basins and Slopes

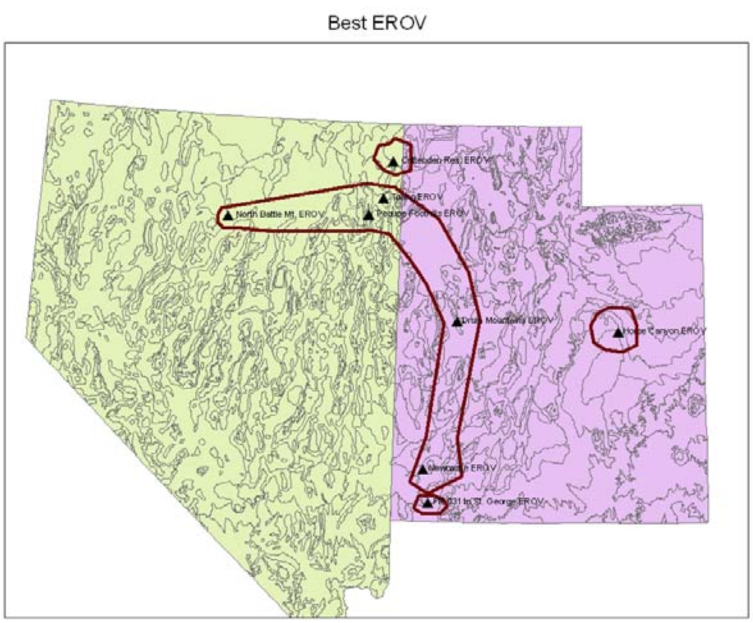


Figure 1. Geographic distribution of superior *Eriogonum ovalifolium* accessions through Nevada and Utah. Polygons group sites to Omernik Ecoregion Level 3. See Table 2 for Level 4.

Globemallow common gardens

We made field observations and plant measurements throughout the summer and into the fall on the new globemallow trial in Fountain Green (Fig. 2.)

Figure 2. Globemallow trial on weed barrier cloth and drip system; Fountain Green, UT.

We collected seed for seed production studies. The seed was dried, cleaned, and weighed. We compared seed production at three harvest points in the season, seed production between the accessions, seed production between species, and compared seed production from different plant spacings. These analyses indicate that there are significant differences in quantity of seed produced between the species in the trial, with the larger-statured species (*Sphaeralcea grossularifolia*, *S. parvifolia*) producing greater quantities of seed (Fig.3). There are also differences in amount of seed produced between accessions within species (data not shown) and this information will be incorporated, as well as Ecoregion information, into decisions about suitability for release to growers.

The 12" plant spacing averaged 4.9 grams seed per plant (averaging all the globemallow species together), while the 18" plant spacing averaged 5.88 grams seed per plant, but this difference was not significant statistically. Disregarding this lack of significance, when calculated on a per acre basis, the 12" plant spacing would generate more seed for a better financial reward than 18" spacing (Fig. 4).

Perideridia Common Gardens

The small common garden of *Perideridia bolanderi* in Ephraim continued to grow in 2007, and we collected a small amount of seed from the trial. One accession from Nevada continued to outshine the other collections in plant vigor and seed production. We began planning a larger trial or seed increase at the Fallon PMC, but due to delays in infrastructure there, did not install the field in 2007. We started 12 *P. bolanderi* accessions in stratification in December 2007 and will grow plugs in the greenhouse for a trial in Fountain Green. A larger seed increase field will be planned, but because of concern that herbivores enjoy the seed of this species, which could be detrimental to seed collection, we intend to place the increase plot inside a fenced exclosure (perhaps Fountain Green.)

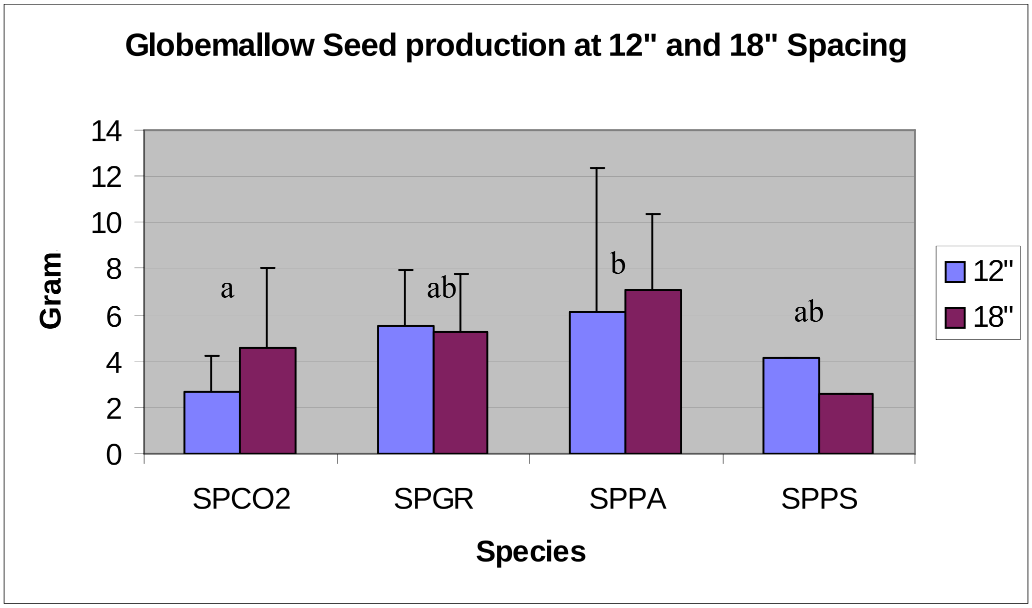


Figure 3. 2007 Fountain Green globemallow plug trial: average grams of seed produced per plant, by species, at 12" and 18" plant spacing. (Letters above bars indicate levels of significance for species at P=0.05 if combining all spacings; difference between spacings was not significant when all species were combined.)

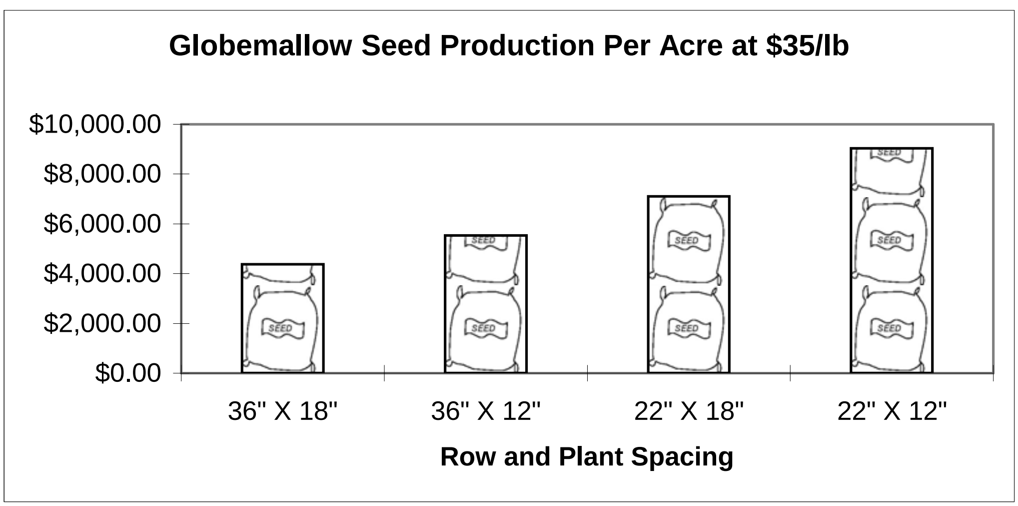


Figure 4. Expected financial returns for growing globemallow agrnomically for seed production at two row and plant spacings.

Balsamroot Common Gardens
Balsamroot (*Balsamorhiza sagittata* and *B. hookeri*) has been difficult to establish and maintain in common gardens. A small planting of *B. sagittata* in Fountain Green as part of a cultural trial (discussed later in this report), and possibly two trials in Nevada (also discussed later) are the only plantings of these species that we currently maintain. In December 2007 we put into stratification 95 grams of *B. sagittata* seed from Box Elder Co., UT; we will grow plant plugs in the greenhouse to distribute to growers and will install a production field in Fountain Green. This accession was selected based on its relatively central geographic location at 5500' elevation and on seed availability.

Sweetvetch Common Gardens
The trial of *Hedysarum boreale* and *H. occidentale* in Fountain Green since 2005 was tilled out at the end of the 2007 field season to make way for new trials. We did collect seed from the trial after installing short strips of woven weed barrier around blocks of plants in the spring. Weed barrier allowed vacuum collection of seed that shattered off the plants (Fig. 5.) Three Timp accessions outperformed most of the other accessions, but one accession, U6-04, from San Juan Co. UT, outperformed Timp. This accession will be studied further, but since it is from outside the Great Basin, it technically holds less interest for this project. We do not have any good accessions of *H. boreale* from within the Great Basin except several from road cuts or other areas that were potentially seeded with Timp prior to the collections, and these collections look like Timp in trial. We will seed a new trial of *H. boreale* and *H. occidentale* in Fountain Green in spring 2008, with some new accessions as well as the old accessions that showed some promise for drought tolerance and seed production.

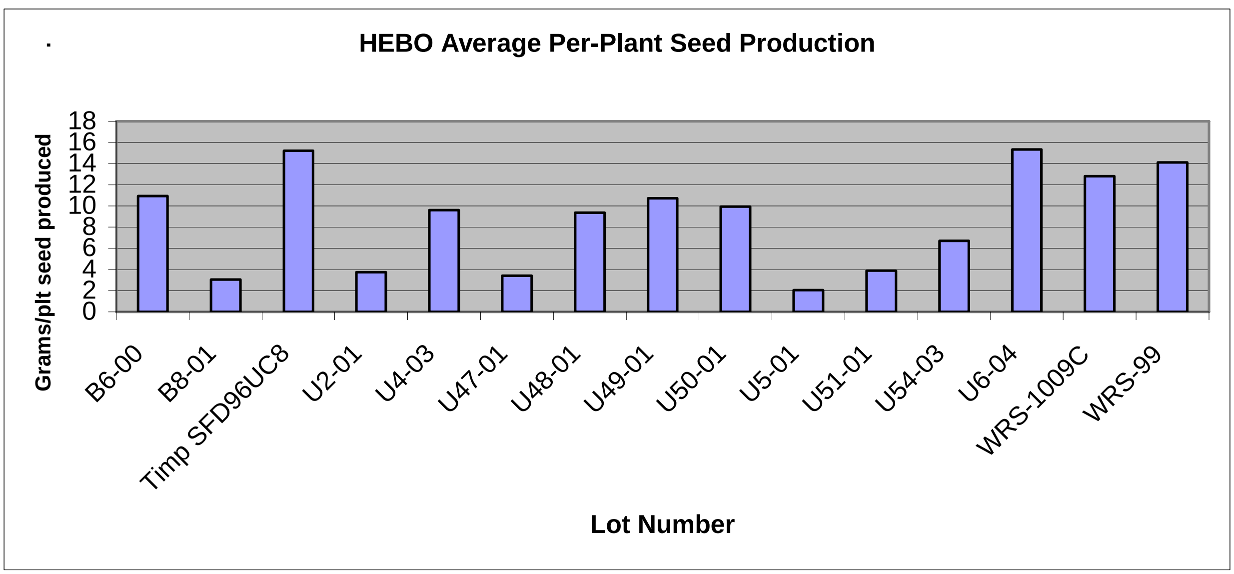


Figure 5. Seed produced on a per-plant basis on Sweetvetch, Fountain Green, 2007.

Nevada Common Gardens

Plantings made in Nevada at the two sites, Orovada and Wells, were not as successful as the Utah plantings. The Orovada *Balsamorhiza sagittata* and *Crepis acuminata* trials were planted into young but established Canby bluegrass that had been seeded the previous year. The *B. sagittata* and *C. acuminata* plugs may have been unable to compete with the grass, and by the following spring in May 2007, only a few *B. sagittata* and *C. acuminata* plants were surviving. Although the Canby bluegrass was successful in keeping weeds at bay, it also may have prevented establishment of the desired trial forbs.

The Wells trials, without Canby bluegrass, did much better. The *Crepis acuminata*/*C. intermedia* trial, in particular, showed fair survival. *C. intermedia* was much more durable than *C. acuminata*. *C. intermedia* averaged 38% survival (7.6 plants/20 planted per block) versus 13% survival of *C. acuminata* (2.6 plants/20 planted per block) (Fig. 6).

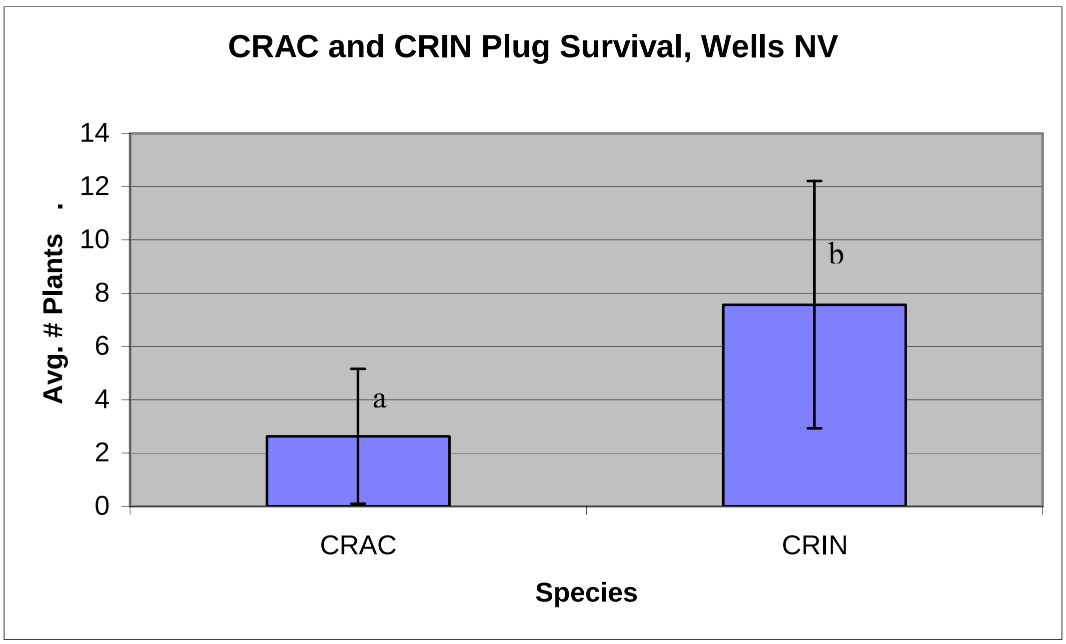


Figure 6. *Crepis* plant survival after one year. Trial was planted with seedling plugs in a Wells, Nevada exclosure.

The Wells *Crepis acuminata*/*C. intermedia* trial also demonstrated survival differences between accessions within the two species. Although the plug planting survival information is useful, it alone is not sufficient to make judgments regarding suitability of particular accessions for restoration projects. We will wait until more information is garnered from the other common garden trials on seeding success, vigor of accessions, and seed production capability.

The Wells *B. sagittata* trial had poor plug survival into the second year, although it was better than the Orovada *B. sagittata* trial. There were not enough surviving plugs to continue the trial. Based on my experience with several attempts at transplanting *B. sagittata*, I feel that once *B. sagittata* seedlings begin to develop a corky root epidermis they do not transplant successfully.

Seed Production Technology Studies:

Spacing and Weed Barrier Study
We installed a weed barrier and spacing study at Fountain Green in May 2006 for two of our forb species: *Balsamorhiza sagittata* and *Crepis intermedia*. The plants were grown in the greenhouse over the winter 2005-2006 and plug-planted into holes cut through the weed barrier. The trial was under drip irrigation with each species on a separate system. The weed barriers were installed by hand by digging trenches, tucking the edge of the barrier material into the trench, burying the edge with soil, and also using long staples through the material into the soil. This installation method for weed barrier material 3' wide proved to be inadequate; wind blew the material off sections of the trial. The problem was exacerbated by the east-west direction of the rows since the prevailing winds were in a north-south direction. Additionally, a flood event in 2007 washed through this trial and tore off some of the weed barriers. We re-installed the blown-out sections several times.

In spite of the difficulties with the installation and maintenance of the trial, the plants produced leaves the first season, went dormant over the summer, and re-leafed in the fall. In the spring of 2007, some of the plants leafed out, and in March, we made plant counts. *C. intermedia* survived better than *B. sagittata*. Fig. 7 shows the survival percentages of *C. intermedia* plants (all spacings grouped together) on the three weed barrier treatments.

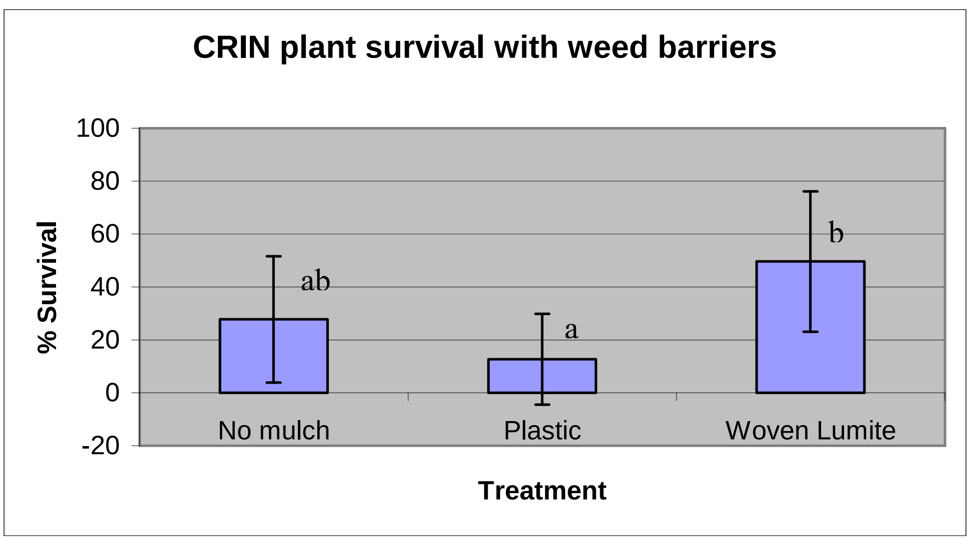


Figure 7. Hawksbeard (*Crepis intermedia*) survival on two weed barrier mulches and no weed barrier.

Woven weed barrier material resulted in the highest percentage survival of hawksbeard plants, at about 50% survival. Non-woven, plastic weed barrier mulch resulted in the lowest survival, at 13%. Using no weed barrier mulch resulted in 28% survival. Use of the weed barrier mulches reduced the amount of hand weeding necessary in the trial, whereas the "No mulch" rows required extensive hand weeding.

There were not enough plants left at the designated spacing distances to conduct comparisons on that treatment.

We continue to maintain the trial to study field persistence of *C. intermedia* and *B. sagittata*.

Rhizobial Inoculant

To explore whether inoculation of *Hedysarum* seed with rhizobial cultures will increase germination, growth, biomass, and survival, we designed greenhouse experiments. We collected root nodules from wildland plants of Northern sweetvetch and contracted to have rhizobia cultured from them. The cultures will be compared to cultures from other legumes as well as the "no inoculant" control in a greenhouse study to test and compare efficacy of the cultures in improving Northern sweetvetch growth and vigor. The study was installed and we began seedling counts and observations as the year ended (Fig. 8.)

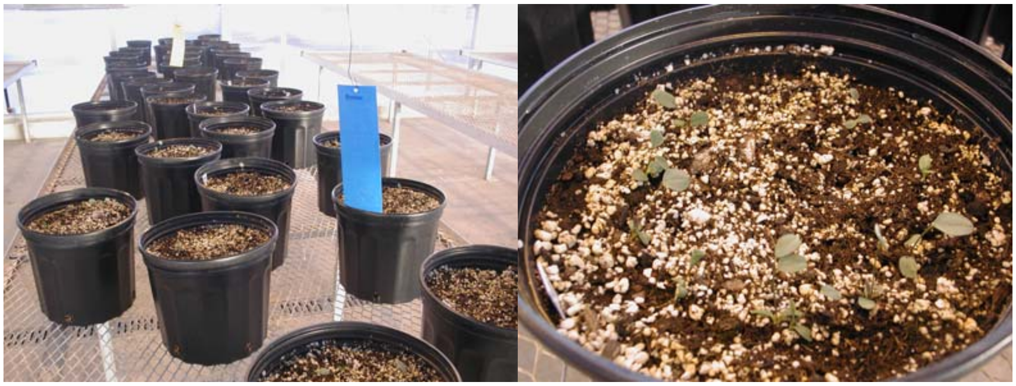


Figure 8. *Hedysarum* rhizobial inoculant greenhouse study.

Sulfuric Acid Scarification of Scarlet Globemallow Seed

Continuing our work to increase germination rates of globemallow seed, we studied the effect of a time series of concentrated sulfuric acid scarifications. Four accessions of scarlet globemallow, with and without carpels (indehiscent and dehiscent, respectively), were exposed to either 10, 20 or 30 minute soak in concentrated sulfuric acid followed by a water rinse, with a water rinse as the control treatment. The seeds were then tested for germination (Fig. 9.)

Twenty minutes of sulfuric acid scarification resulted in the highest germination rate and significantly increased the rate from that of the water rinse alone from 6% to 25%. Thirty minutes of acid scarification significantly increased the rate of germination over water alone, but may have caused some loss of viability due to seed damage. Ten minutes of sulfuric acid scarification also increased germination from 6% to approximately 17%, but this increase was not statistically significant.

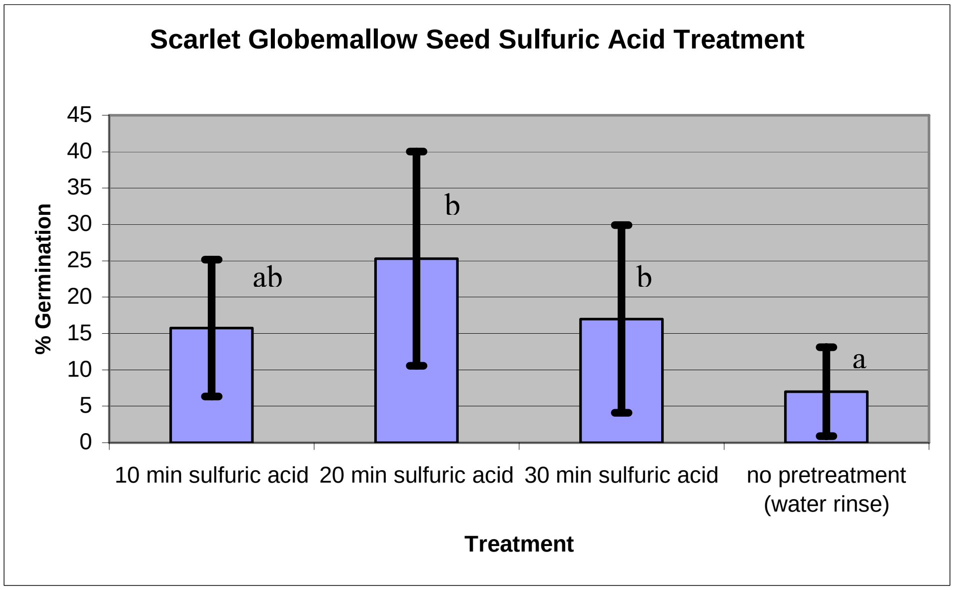


Figure 9. Germination of scarlet globemallow seeds following seed pretreatments.

Presence of carpels on the seeds resulted in a significant decrease in seed germination (Fig. 10.) Carpel retention may be caused by genetic factors affecting splitting of carpels at ripening or it may be an artifact of schizocarp maturity, with less-mature schizocarps failing to split open. Many *Sphaeralcea coccinea* accessions tend to have indehiscent carpels, regardless of maturity, suggesting that there may be a genetic component. It is not clear if indehiscent carpels always convey lower germination on globemallow seed, but this data suggest that is the case in this species.

There was a significant difference in germination between the accessions of globemallow, combining all seed pretreatments and carpel status (Fig. 11.) B12-03 was the only accession that had no carpels in any of the seed pretreatments, since it evidently is completely dehiscent, but it is not clear if this characteristic conveyed an increase in germination over the other species.

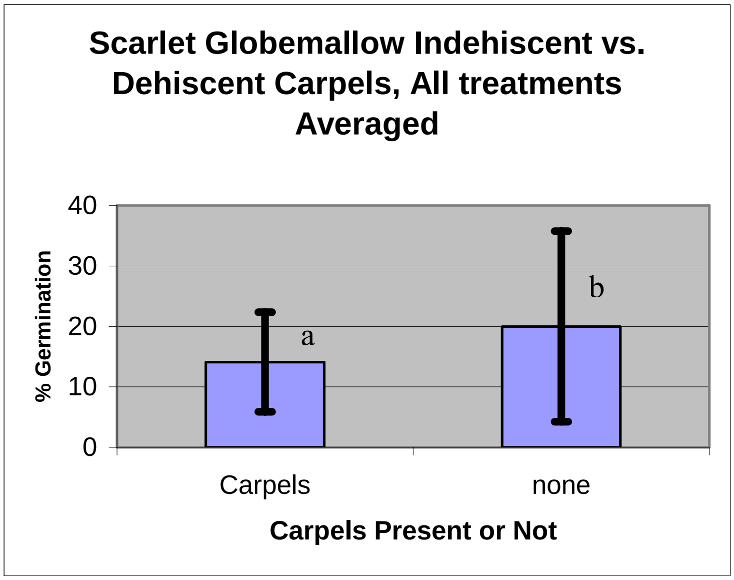


Figure 10. Germination of scarlet globemallow seed with and without carpels, combining all seed pretreatments.

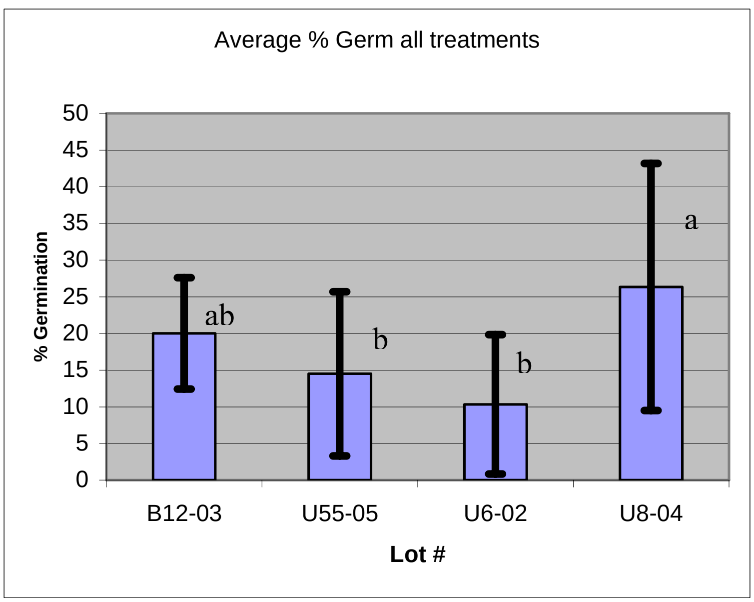
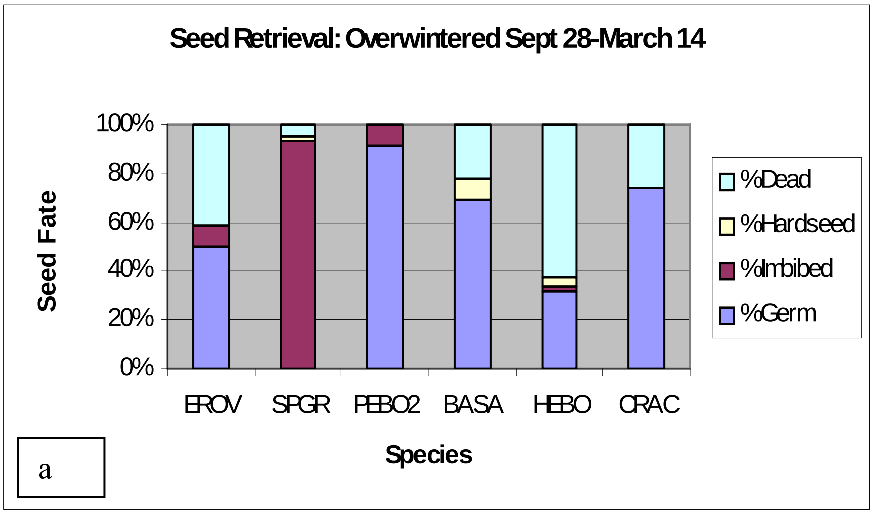


Figure 11. Germination of four accessions of scarlet globemallow seed combining all seed pretreatments and carpel status.

Seed Fate Studies

We completed a seed retrieval study on 2007 that compared direct seeding in the fall vs. in the spring on the six principal forbs in our project. The study solidified previous knowledge about seed dormancy among our study forbs.

The study showed that sweetvetch (*Hedysarum boreale*) and gooseberry leaf globemallow (*Sphaeralcea grossulariifolia*) did not require cold, moist stratification to germinate seed, but the other forbs, cushion buckwheat (*Eriogonum ovalifolium*), arrowleaf balsamroot (*Balsamorhiza sagittata*), olasi (*Perideridia bolanderi*), and tapertip hawksbeard (*Crepis acuminata*) did require stratification to break seed dormancy (Fig. 12 (a) and (b).) Other work by our group has shown that *S. grossularifolia* and other globemallows benefit from warmer temperatures to germinate seed, and the early spring temperatures of this study were too low to effectively stimulate *S. grossularifolia* to germinate.



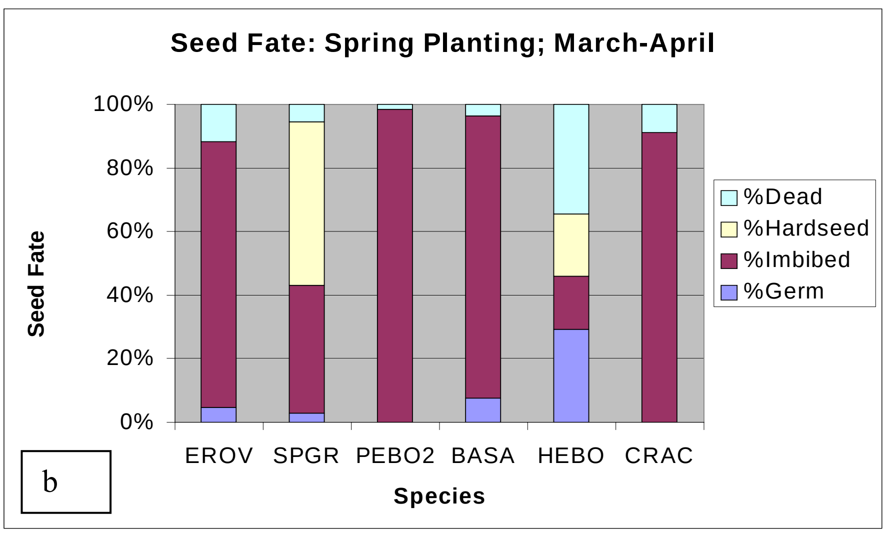


Figure 12. Seed fate studied through seed retrievals. (a) Overwintering benefited *Eriogonum ovalifolium*, *Perideridia bolanderi*, *Balsamorhiza sagittata*, and *Crepis acuminata* seed, but *Sphaeralcea grossularifolia* and *Hedysarum boreale* suffered higher mortality or absence of germination. (b)Spring planted seed showed dormancy breaking in *H. boreale* but not in the other species.

Seed Field Production Technology
In spring of 2007 we planted an experimental production field of Scarlet globemallow in Ephraim at Snow Field, using woven weed barrier and sub-surface T-tape drip irrigation. The plants were grown as plugs in the greenhouse and planted out in the field in the spring. The plants flowered but produced insufficient seed in 2007, so we did not harvest. The trial will be maintained and, hopefully, harvested in 2008.

Globemallow Seed Harvest Phenology
To understand how to maximize seed harvest on the typically indeterminant-flowering globemallows, we studied phenology of flowering and fruit maturation, and viability of seed harvested at various stages of ripeness.

We cut entire branches off littleleaf globemallow (*Sphaeralcea parvifolia*) on 8/15/07 and 8/28/07, dried the stems, then separated the fruits (schizocarps) by visual examination into three categories: immature, medium mature and mature. We calculated the percentage by weight of apparently mature seed (entire, brown or black) from each maturity category, and did germination tests of the resultant partitions (Fig. 13.)

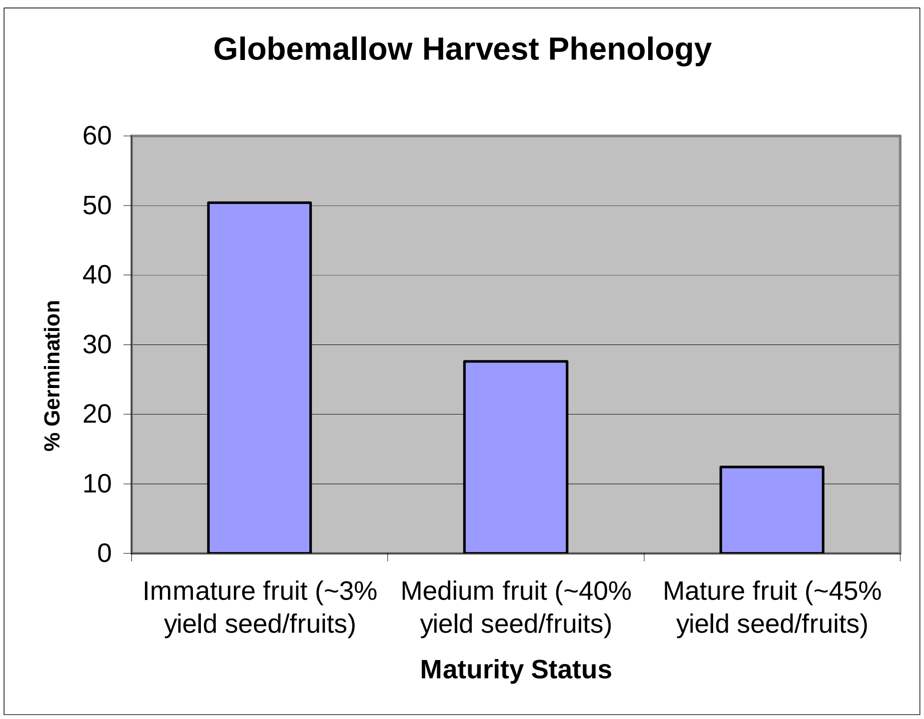


Figure 13. Seed yields and germination rates of globemallow seeds harvested at different stages of maturity.

Although the immature schizocarp partition yielded the smallest percentage (3%) of mature seed, this partition germinated at the highest percentage (50%). The medium ripe schizocarps generated 40% mature seed by weight, but had a lower germination percentage (28%), and the mature schizocarps yielded the highest percentage mature seed by weight (45%) but had the lowest germination at 12%. We speculate that the seeds from the least mature schizocarps have thinner seed coats or some other less-well developed seed dormancy feature. We also speculate that the riper seeds could eventually be released from dormancy, although in our germination study, they were not.

Comparing percent of schizocarps in each maturity stage at the two harvest times showed that the earlier harvest had a higher percentage of immature schizocarps, but even the later harvest had some immature schizocarps, as expected with an indeterminant-flowering species (Fig. 14.)

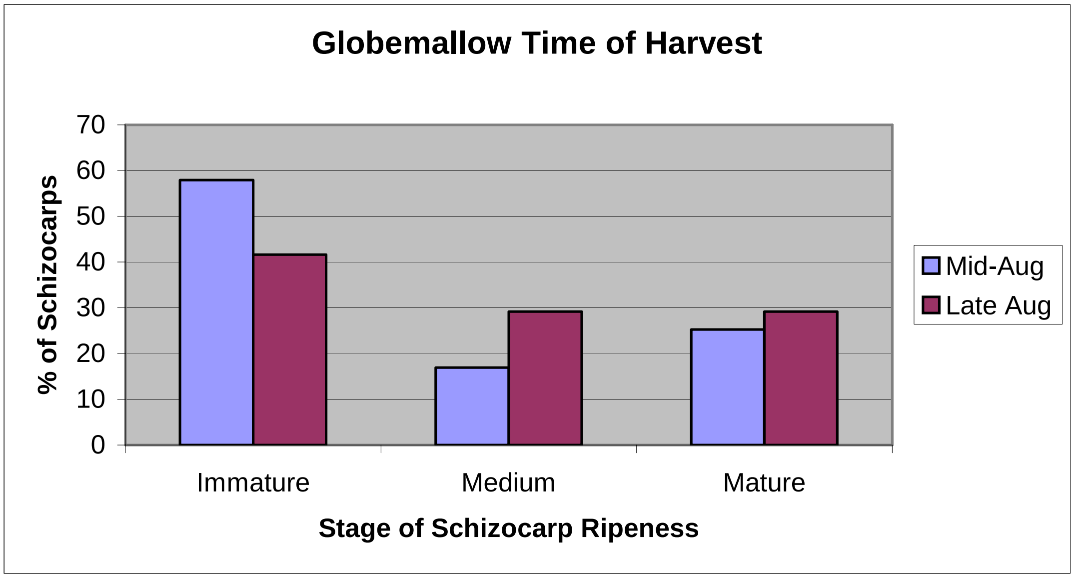


Figure 14. Percent of globemallow schizocarps (fruits) in three stages of maturity harvested either in mid- or late August.

Evaluating germination averaged across all seeds of various maturities on branches harvested two weeks apart resulted in the seed from the earlier harvest having higher germination (32%) than seed from branches harvested two weeks later (18%) (Fig. 15.) We again speculate that earlier harvest arrests the dormancy-instilling process in the schizocarps. These findings are somewhat in contradiction of our findings in the acid scarification study, with respect to presence or absence of carpels and that trait's relationship to schizocarp maturity. Further work will need to be done to clarify these questions, species-by-species in the globemallow group.

Commercial Seed Production:
We successfully grew globemallow with three new growers, one in Brigham City, UT, one in Price, UT, and one in Fountain Green, UT. All were able to harvest seed from their fields this summer. Our Forb project purchased 5.1 lbs. of seed from one of the growers, and one-quarter lb. seed from another grower. The Brigham City and Price growers planted using seedling plugs that we had produced and the Fountain Green grower direct-seeded during the summer using our precision seeder. All had excellent growth of the plants. The Brigham City and Price growers also have plantings of tapertip hawksbeard that should begin flowering in 2008.

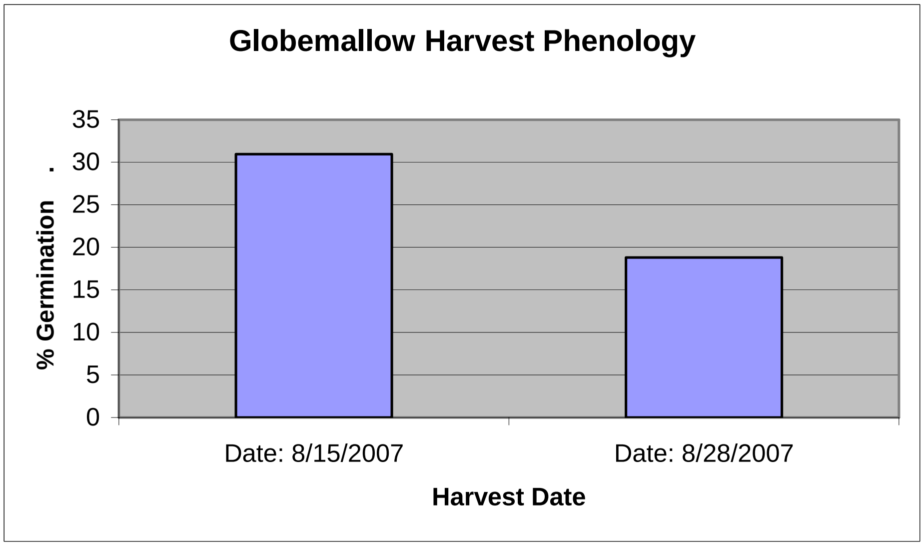


Figure 15. Globemallow seed germination (averaged across all seeds of various maturities on a branch) harvested 2 weeks apart.

We contracted with a grower in Connell, WA, to continue maintaining a large field of tapertip hawksbeard for at least another season in anticipation of obtaining seed from the field.

We are also contracting with a grower in Vale, OR, to plant our stock seed of gooseberry leaf globemallow and gray hawksbeard to produce a seed increase.

We continue to work with three additional growers in Pleasant Grove, UT, Joseph, UT, and Panguitch, UT, who have planted our stock seed or plugs in previous seasons.

Gooseberry-leaf globemallow stock seed (G1) 5.1 pounds, scarlet globemallow stock seed (G1) 4.1 oz. available to send out to larger production fields. One lb. of the Gooseberry-leaf globemallow stock seed was sent to Vale, OR for further seed increase.

Four new native seed growers are working with the Great Basin Research Center.

Results of the seed retrieval study will help growers and vegetation restoration workers determine the optimum time of year to seed the forbs we are developing.

Results of the northern sweetvetch rhizobia study may increase seed production of this species in growers' fields.

Narrowing the field of potential seed accessions through common garden work, greenhouse studies, geographic distribution analysis, and laboratory studies has enabled us to choose certain seed lines to advance into grower increases.

Presentations:

Native seed production handouts distributed at meetings, workshops, and as PDF files emailed to potential growers.

Meyer, Therese, and Jason Vernon. 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.

Meyer, Therese. 2007. Meyer gave presentation for Ibapah Band Goshute Tribe about agronomic farming of native plants for seed. Conservation and Development Committee meeting.

Meyer, Therese. 2007. Meyer gave a short presentation about Utah Division of Wildlife Resources and the Great Basin Native Plant Selection and Increase Project. Cannon Envirothon, Salt Lake City, UT.

Meyer, Therese. 2007. Native plant development for wildland restoration: Research at Great Basin Research Center. Native vegetation community restoration workshop, Grand Junction, CO.

Vernon, Jason. 2007. Site preparation and seedbed requirements for planting multiple species. Native vegetation community restoration workshop, Grand Junction, CO.

Meyer, Therese. 2007. Co-leader of native seed workshop. Society for Ecological Restoration and Pacific Northwest Society of Wetland Scientists joint conference, Yakima, WA.

Meyer, Therese. 2007. Native plant development for wildland restoration: Research at Great Basin Research Center. Society for Ecological Restoration and Pacific Northwest Society of Wetland Scientists joint conference, Yakima, WA.

Meyer, Therese. 2007. Seeds in restoration. Society for Ecological Restoration Pacific Northwest Chapter and Society of Wetland Scientists Pacific Northwest Chapter joint conference, Yakima, WA.

Meyer, Therese. 2007. Therese Meyer attended “Ecological Site Descriptions as a Management Tool” training workshop in Park City, UT.

Posters:

Therese Meyer. 2007. Native plant development for wildland restoration: Research at Great Basin Research Center. Native wildflower seed production research symposium, Orlando, FL.

Project Title: Phylogeographic Characterization of Genetic Diversity in Basalt Milkvetch

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

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Project Description:
This project is being conducted to ensure that the best selection and release strategies will be used to most effectively represent existing genetic variation within the widespread North American legume, *Astragalus filipes* (basalt milkvetch). Inherent molecular marker-based diversity and population structure was obtained from 81 previously collected accessions of basalt milkvetch. Seeds from these accessions were germinated in a greenhouse in Logan, UT. DNA was extracted from 10 plants of each accession, and the AFLP procedure was used for molecular marker development.

Exploratory analysis of the molecular data from these 81 accessions was conducted using Analysis of MOlecular VAriance (AMOVA), which indicated significant population structure ($P < 0.001$). Two groups of populations were prominent in their distinction, one group from Canada and another group from central Nevada (Fig. 1). No other groups of accessions were apparent. In support of this, Bayesian analysis conducted with the program STRUCTURE v2.1 was also used to explore population structure in the accessions. Between two and 16 population structures were tested. A general increase in fit was found as the numbers of structures increased (Fig. 2), and significant admixture among some populations was detected. Thus the exploratory data analysis suggests two distinct populations (central Nevada and British Columbia), and one 'catchall' population that encompasses the vast majority of accessions. However, further in-depth analyses are required to confirm the groups of accessions.

Kishor Bhattarai (a M.S. student at Utah State University supported from funds on this project) conducted a series of greenhouse and field experiments with basalt milkvetch. Two greenhouse studies evaluated combinations of six rhizobial strains with several basalt milkvetch accessions for their N-fixation characteristics. Plants inoculated with rhizobial strain I-49 had the greatest nodule weight, number of nodules, and shoot N compared to plants inoculated with other rhizobial strains. Results showed that I-49 was the best strain across all basalt milkvetch accessions tested. Consequently, I-49 will be made commercially available (EMD Crop BioScience, 13100 West Lisbon Ave., Brookfield, WI 53005, phone: 262-957-2000). Data were also obtained from common garden experiments at two sites in northern Utah (Evans Farm and Millville). Collected accessions were evaluated for forage yield and quality, regrowth after defoliation, seed yield, and seed weight. Kishor used these data for his thesis, which he successfully defended in Spring 2007. Manuscripts summarizing the study results are being finalized and submitted to journals for publication.

In consultation with those administering the Great Basin Native Seed Increase Project, it was determined that a pooling of basalt milkvetch accessions from across the Northern Basin and Range Ecoregion (Number 80) would be most useful for restoration, reclamation, and rehabilitation efforts in the northern Great Basin. Basalt milkvetch accessions from the Northern Basin and Range Ecoregion with the highest seed yields were identified. In addition, two accessions from these collections were excluded from NBR-1 Germplasm because they had detectable levels of selenium, nitrotoxin, or swainsonine. The remaining 12 selected accessions were not statistically different from each other for seed yield and were used to constitute NBR-1 Germplasm. The 12 constituent accessions of NBR-1 come from sites in Oregon, Idaho, Nevada, Utah, and California that ranged in elevation from about 1,315 to 1,874 m (4,300 to 6,200 feet). The NBR-1 germplasm did not contain seed from accessions in central Nevada that were distinct in exploratory molecular analysis. Seed collected from the respective wildland collection sites for these 12 selected accessions was bulked in equal amounts to form the G0 generation of NBR-1 Germplasm.

NBR-1 Germplasm was placed in the manipulated track for release because not all original collections from the Northern Basin and Range Ecoregion were included as constituent accessions of NBR-1 Germplasm. No further selection or manipulation was conducted for any traits besides the above-mentioned selection for seed yield, and selection against selenium, nitrotoxin, and swainsonine content. NBR-1 Germplasm was approved for release by the Utah Crop Improvement Association and USDA-ARS. Seed of NBR-1 Germplasm will be increased in Oregon and Utah.

Publications:

Bhattarai, K. 2007. Potential of basalt milkvetch (*Astragalus filipes* Torr. Ex A. Gray) populations and rhizobial strains for revegetation and restoration of Intermountain West rangelands. Utah State University, Logan, Utah. M.S. thesis. 116 p.

Bhattarai, K., D. A. Johnson, T. A. Jones, and D. R. Gardner. Physiological and morphological characteristics among ecotypes of basalt milkvetch (*Astragalus filipes*). Rangeland Ecology and Management. (submitted)

Presentations:

Bhattarai, K., D. A. Johnson, and T. A. Jones. 2007. Basalt milkvetch: candidate species for rangeland restoration in the western U.S. Abstracts of the Ecological Society of America annual meetings, San Diego, Calif.

Johnson, D.A., K. Bhattarai, T. Jones, and S. Bushman. 2007. North American legumes for rangeland restoration, conservation, and forage production in the western United States. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th annual meeting, Reno, NV. Abstract. Invited presentation.

Management Applications:

The molecular information generated from this project is being used to genetically characterize collections of basalt milkvetch across six states of the western U.S. and British Columbia, Canada. These molecular data will allow identification of optimal germplasm releases to most effectively represent existing genetic variation in basalt milkvetch. These data are critical in determining if collections of basalt milkvetch can be treated as one unstructured population, or if significant differences in genetic diversity and population structure exist so that populations need to be grouped into several distinct populations for release.

Products:

Plant release

NBR-1 Germplasm of basalt milkvetch was released for use in the northern Great Basin. When used in seed mixtures with adapted grasses and shrubs, basalt milkvetch will be of value in stabilizing degraded rangelands, revegetation of disturbed areas, and beautifying roadsides. This native legume will be of use where introduced species are not desired. The attractive foliage and flowers of basalt milkvetch make it an excellent choice for use in wildflower seed mixtures.

Grants leveraged through GBNPSIP

A $5,400 grant through the Center for Integrated Biology at Utah State University was leveraged through GBNPSIP to support the dissertation research of Kishor Bhattarai. This funding will be used to partially defray costs of chemicals, enzymes, DNA extraction kits, consumables, and DNA analyses on the project. The funding will also provide partial support for Kishor Bhattarai to present project results at the 2009 Annual Meeting of the Society for Range Management in Albuquerque, New Mexico.

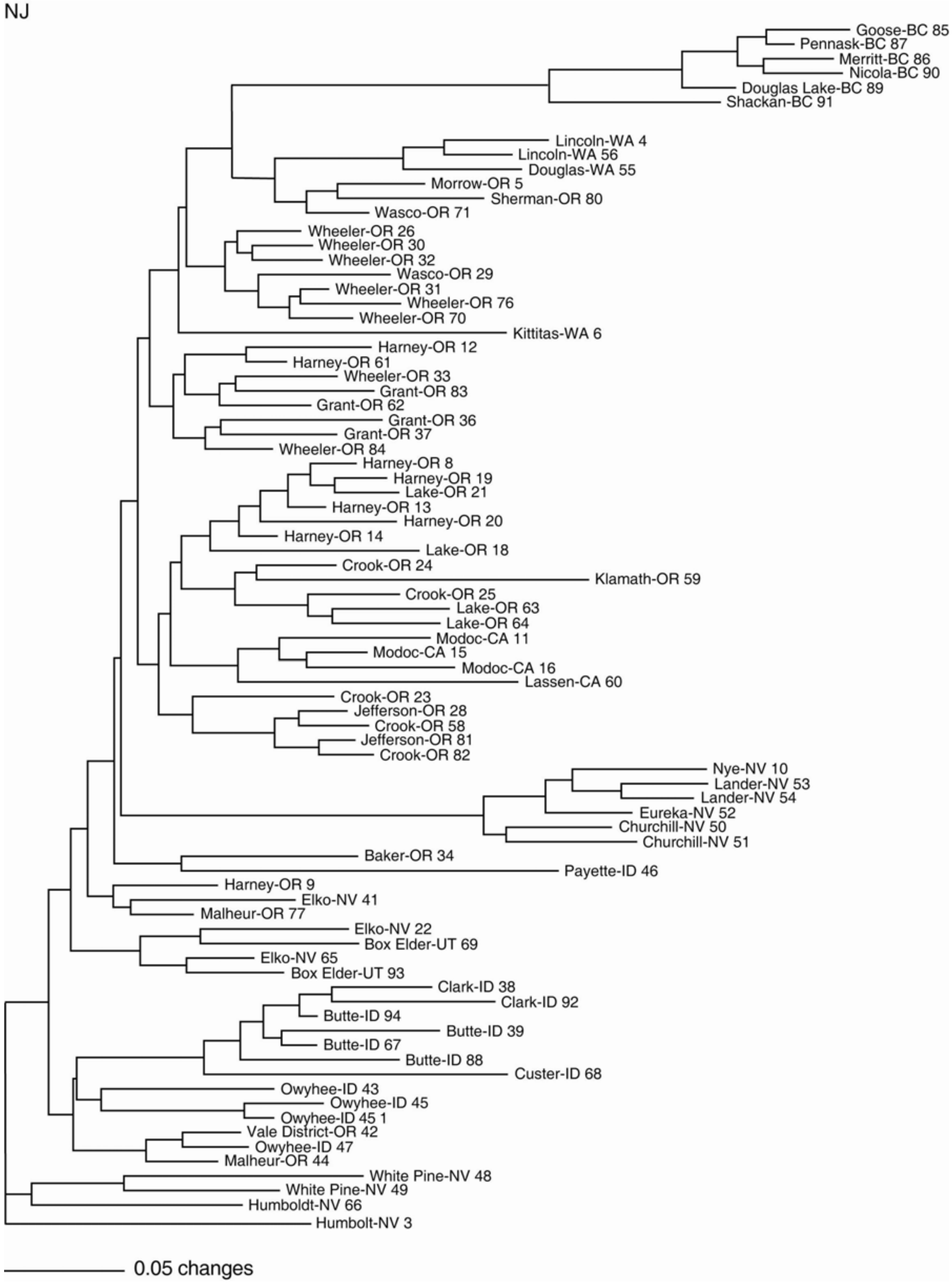

Figure 1. Neighbor-joining dendrogram of 81 basalt milkvetch accessions using analysis of molecular variance estimates of differences.

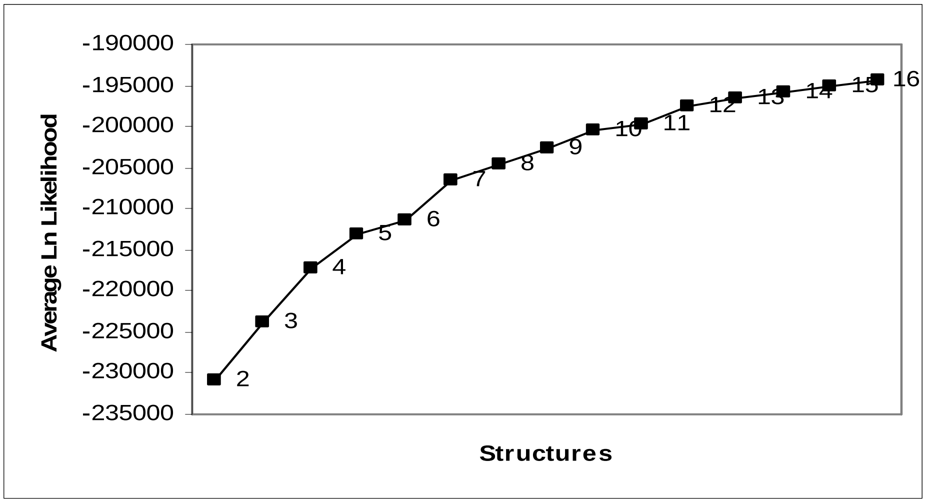

Figure 2. Log likelihood estimates of testing 2 to 16 population structures using Bayesian clustering in the program STRUCTURE 2.1. Increases in Log likelihood values suggest a better fit of data to the structure size tested.

Project Title: Adapted Indian Ricegrass, Genetic Diversity Patterns of *Allium acuminatum*, and Genetic Diversity and Genecology of Bluebunch Wheatgrass

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

Principal Investigators and Contact Information:

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1. Adapted Indian Ricegrass for the Great Basin

Additional Principal Investigator and Contact Information:

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Project Description:

Indian ricegrass (*Achnatherum hymenoides* [Roem. & Schult.] Barkworth) has a major role in wildlife habitat and grazing in the Great Basin. Current releases of Indian ricegrass are useful but we know of no germplasm derived specifically from the Great Basin. Information on how Indian ricegrass germplasm varies across the landscape and which populations may be best adapted is lacking. Considering the importance of Indian ricegrass in the Great Basin plant community, germplasm specifically adapted to Great Basin climatic and environmental factors is critically needed.

The available USDA-ARS collections of Indian ricegrass collections are primarily from the eastern and southern regions of the Great Basin, extending into Colorado, Arizona, and New Mexico. This material was established in common gardens in 2007 to relate genetic variation to environmental factors and develop adaptive seed zones.

Collections of new germplasm in the northern and central Great Basin are ongoing and should be completed in 2008. This germplasm will form the basis of additional genecology studies and will include families within collection locations to assess genetic variation across the landscape. So far, about 45 Indian ricegrass accessions have been collected.

Objectives

1. Collect Indian Ricegrass from diverse sites and ecological areas in the Great Basin in areas previously uncollected, especially in the northern Great Basin.
2. Based on the current collections representing the southern Great Basin, establish common garden studies in contrasting environments and measure numerous phenotypic factors associated with growth and development. Continue this research on new material collected from the northern Great Basin.
3. Compare the patterns in phenotypic variation with molecular variation among and within Indian Ricegrass populations collected in the Great Basin.
4. Identify seed transfer zones along with complementary *in situ* conservation sites.
5. Make source-identified plant material available for utilization through the Western Regional Plant Introduction Station seed repository and the National Plant Germplasm System.

Table 1. ANOVA summary for 2007 Indian ricegrass common gardens at Central Ferry WA, 2007.

Variable	Mean	CV	P-values‡		
		%	Irrigation Env.	Location	Environ*Loc
Heading date†	191.10	6.9	< 0.01	< 0.01	0.66
Bloom date†	179.49	6.7	< 0.01	< 0.01	0.06
Maturity date†	205.11	6.2	< 0.01	< 0.01	0.59
Leaf width (mm)	1.88	36.9	< 0.01	< 0.01	0.43
Leaf length (mm)	14.86	29.6	0.93	< 0.01	0.93
Lf length/Lf width	8.92	45.2	< 0.01	< 0.01	0.64
Lf length*Lf width	29.64	56.2	0.12	< 0.01	0.73
Inflorescence quantity	13.45	73.9	< 0.01	< 0.01	0.36
Seed Quant/Inflor	9.31	121.0	< 0.01	< 0.01	< 0.01
Culm length (cm)	25.46	21.5	0.35	< 0.01	0.51
Inflores. length (cm)	15.16	26.6	0.13	< 0.01	0.67
Culm lth/Inflor lth	1.78	28.7	0.96	< 0.01	0.26
Habit (1-9)	5.49	21.3	0.32	< 0.01	0.47
Height/Habit	8.18	52.5	0.14	< 0.01	0.72
Leaf texture (1-9)	5.16	24.6	< 0.01	< 0.01	0.18
Leaf abundance (1-9)	4.82	23.2	0.15	< 0.01	0.22
Lf Text/Lf width	3.47	49.9	< 0.01	< 0.01	0.35
Leaf roll (1-9)	4.46	37.1	0.03	< 0.01	0.36
Dry wt. (g)	51.40	36.1	< 0.01	< 0.01	0.33

†Day of year
‡Differences declared significant at P<0.05

In spring 2007, a diverse set of 120 Indian Ricegrass accessions from the USDA germplasm collection was planted in a two common gardens at Central Ferry, WA, one under dryland and the other under light irrigation conditions, forming two growing environments. Evaluation of key growth and developmental traits was completed in 2007. The data showed that collection location effects were all highly significant (Table1). Thus, there was considerable genetic variation in collections across the southern Basin and extending into Colorado. Although the environments (irrigated and non-irrigated) differed for the majority of traits, the environment by location interaction was generally not significant (Table 1). Thus, irrigation caused differences in plant growth and development but the relative ranking of germplasm remained similar.

Mean values of numerous traits correlated with location climatic/environmental data (Table 2). Elevation, latitude, and maximum and minimum temperatures were the factors that correlated most often with the plant traits. The correlation between seeds per inflorescence and latitude had the highest individual coefficient at r=0.40. Blooming date had five significant correlations with climatic factors, the most of any plant trait (Table 2). These results show a linkage between collection location climate/environment and plant traits, indicating a good potential for developing adaptive seed zones in Indian ricegrass.

This research at Central Ferry will continue in 2008. We also expect to have to have sufficient new locations collected in 2008 for comprehensive genecology studies of new Great Basin collections starting in 2009.

Table 2. Linear correlation between traits and environmental factors for Indian ricegrass (Central Ferry WA, 2007)

Trait (n=112)	Elev.	Slope	Aspect	Lat.	Long.	Max. Temp.	Min. Temp.	Precip.
Heading date	ns	ns	ns	ns	ns	ns	ns	ns
Bloom date	0.24*	0.20*	ns	ns	ns	-0.34**	-0.35**	0.19*
Maturity date	ns	ns	ns	0.23*	ns	ns	ns	ns
Leaf width	-0.30**	ns	ns	ns	ns	ns	0.19*	ns
Leaf length	-0.22*	ns	ns	ns	ns	ns	0.21*	ns
Lf length/Lf width	ns	-0.19*	ns	ns	0.28**	ns	ns	ns
Lf length*Lf width	-0.34**	ns	ns	0.21*	ns	ns	0.23*	ns
Inflores./plant	ns	ns	ns	-0.22*	ns	0.33**	0.32**	-0.20*
Seeds/Inflor	-0.25**	ns	ns	0.40**	ns	ns	ns	ns
Culm length	ns	ns	-0.20*	0.19*	0.21*	ns	ns	0.28**
Inflores. length	ns	ns	ns	0.20*	ns	ns	ns	ns
Culm lth./Inflor lth	ns	ns	ns	ns	0.22*	ns	ns	0.22*
Habit	ns	ns	ns	-0.38**	ns	0.26**	ns	ns
Height/Habit	ns	ns	ns	0.36**	ns	-0.29**	ns	0.28**
Leaf texture	0.31**	ns	ns	ns	ns	ns	-0.24*	ns
Leaf abundance	ns	ns	ns	0.23*	ns	ns	ns	ns
Lf Text/Lf width	0.24*	ns	ns	ns	ns	ns	-0.22*	ns
Leaf roll	0.28**	ns	ns	ns	0.26**	ns	-0.24*	ns
Dry wt.	-0.30**	ns	ns	ns	ns	0.19*	0.29**	ns

*,**,ns, Significant at P<0.05, P<0.01, and not significant, respectively.

Presentations:

Johnson, R.C. 2007. Uncovering adapted native germplasm for successful restoration. Society for Ecological Restoration Northwest/Society for Wetland Scientists joint meeting, Yakima, WA.

Management Applications:

Results from this study will be used to develop guidelines and appropriate source material for revegetation and restoration in the Great Basin and adjacent areas.

Products:

Adapted germplasm for the Great Basin conservation of germplasm within the National Plant Germplasm System.

2. Genetic Diversity Patterns of *Allium acuminatum* in the Great Basin

Additional Principal Investigator and Contact Information:

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Project Description:

Genetic information to identify locally adapted seed sources for restoration and reclamation is generally lacking. An understanding of the geographic and ecological distance that plant material should be transferred from original source populations is critically needed. *Allium acuminatum* Hook. (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 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, USDA NRCS Plant Material Centers, and commercial collectors/producers to improve genetic quality and production efficiency of this species.

<u>Objectives</u>

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:

Collections

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 USDA Forest Service and USDI 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 114º to 119º longitude. *Allium acuminatum* was collected in 20 of the Level IV Omernick Ecoregions across the Great Basin.

Figure 1. Collection locations for *Allium acuminatum* in 2005 representing 20 Level IV Omernick Ecoregions.

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, 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.

Common Gardens
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. There were also significant garden site by collection location interactions for bolting and seed maturity dates, and for flower color. Thus, for these traits, 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 than local material and as such may be ecologically unsuitable.

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
Bolting date†	248	113	4.0	<0.001	<0.001	0.003
Leaves/plant	467	2.17	19.5	ns‡	<0.001	ns
Flowering date†	229	146	2.2	<0.001	<0.001	ns
Flower color (1-9)	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
Scape dia. (mm)	231	1.71	28.4	ns	ns	ns
Scape length (mm)	230	99.8	28.8	ns	<0.001	ns
Seed Maturity date†	183	174.8	6.7	<0.001	0.024	<0.001
Seeds/plant	170	15.7	70.9	0.001	ns	ns

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

The number of plots evaluated at the two sites in 2006 (Table 1) varied widely as many plants senesced soon after transplanting to the field. Prior to field planting, many plants showed active growth in the 4°C vernalization chamber and these often became dormant soon after transplanting.

For 2007, plants from most plots developed and the data collected was more complete (Table 2). Strong location effects were observed in 2007 for all factors measured. As in 2006, the location by site interaction was significant for bolting and seed maturity date. For both years there were strong differences in plant development and morphology associated with collection location.

Correlation between plant traits and climatic/environmental factors in 2007 was significant for numerous factors (Table 3). Bolting date showed relatively strong correlation between with elevation, maximum and minimum temperature, and precipitation. Elevation and maximum temperature each had four significant correlations with plant traits, and latitude, minimum temperature, and precipitation had three (Table 3). These data linking plant traits with climatic/environmental factors at their collection locations indicate that developing seed adaptive zones for Taper-tip onion should be possible.

Table 2. *Allium acuminatum* ANOVA summary from common gardens at Pullman and Central Ferry, WA sites and 55 collection locations (Loc) (2007).

Factor	n	Mean	CV	‡Prob. Site	‡Prob. Loc	‡Prob. Site X Loc
Bolting date†	500	107	2.6	ns‡	<0.001	0.010
Leaf color (1-9)	497	3.02	13.1	<0.001	0.005	ns‡
Leaf habit (1-9)	497	7.26	8.3	0.001	<0.001	ns
Leaf width (mm)	497	2.65	17.8	ns	<0.001	ns
Leaf length (mm)	487	127	14.3	0.244	<0.001	ns
Leaves/plant	500	2.55	20.9	<0.001	<0.001	ns
Flowering date†	487	147	1.46	<0.001	<0.001	ns
Flower color (1-9)	487	7.11	17.0	0.024	<0.001	ns
Flowers/umbel	487	28.6	31.1	0.006	0.018	ns
Umbel dia.(mm)	487	52.4	17.1	ns	0.005	0.027
Scape dia. (mm)	487	2.58	18.4	0.004	<0.001	ns
Scape length (mm)	487	150	16.0	ns	<0.001	ns
Seed Maturity date†	487	175	1.7	<0.001	<0.001	0.059
Seeds/plant	487	65.4	37.6	<0.001	<0.001	ns

†Day of year; ‡ns, not significant; ‡ leaf habit from 1 decumbent, to 9 erect; flower color from 1, white to 9, purple; leaf color from 1 light green to 9 dark green.
‡ Differences declared significant at P<0.05

Table 3. Linear correlations between traits measured at Central Ferry and Pullman, WA in 2007 and environmental factors at collection location, 2007 (n=55).									
Traits	Lat.	Long.	Elev.	Slope	Aspect	Max. temp.	Min. temp.	Precip.	Eco3
Bolting	ns	ns	0.46**	ns	ns	-0.50**	-0.56**	0.31*	ns
Leaf color	ns	ns	ns	0.27*	ns	ns	ns	ns	ns
Leaf habit	ns	ns	ns	-0.37**	-0.30*	ns	ns	ns	ns
Leaf length	ns	ns	ns	ns	ns	ns	ns	ns	ns
Leaf width	-0.31*	ns	0.26*	ns	ns	ns	ns	ns	ns
Leaf number	0.28*	ns	ns	ns	ns	-0.35**	ns	0.54**	ns
Flowering	ns	ns	ns	ns	ns	-0.28*	-0.34**	ns	ns
Flower color	-0.36**	ns	0.32*	ns	ns	ns	ns	ns	ns
Flowers/umbel	ns	ns	ns	ns	ns	ns	ns	ns	ns
Umbel dia.	ns	ns	ns	ns	ns	ns	ns	ns	ns
Scape dia.	ns	ns	0.29*	ns	ns	ns	ns	ns	ns
Scape length	ns	ns	ns	ns	ns	ns	ns	ns	ns
Seed maturity	ns	ns	ns	ns	ns	ns	ns	ns	ns
Seeds/plant	ns	ns	ns	ns	ns	-0.28*	-0.30*	0.42**	ns
*,**,ns, Significant at P<0.05, P<0.01, and not significant, respectively.									

Future Plans

In 2008, data analysis will continue to determine adaptive seed zones and to guide conservation and revegetation decisions for *A. acuminatum* in the Great Basin. A manuscript for peer reviewed publication is expected in 2008 that will summarize results and recommendations.

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.

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Publications:

Johnson, R.C., B.C. Hellier, and T.J. Kisha. Collection, conservation, and seed zones for Tapertip onion (*Allium acuminatum* Hook.). *in* Jeff Norcini (ed.). Proceedings, native wildflower seed production research symposium, Orlando, Florida (http://nfrec.ifas.ufl.edu/Norcini/WFSympWeb/2007Sympindex.htm)

Presentations:

Johnson, R.C., B.C. Hellier, and T.J. Kisha. 2007. Collection, conservation, and seed zones for Tapertip onion (*Allium acuminatum* Hook.). Native wildflower seed production research symposium, Orlando, FL.

Johnson, R.C. 2007. Uncovering adapted native germplasm for successful restoration. Society for Ecological Restoration Northwest/Society for Wetland Scientists joint meeting, Yakima, WA.

Johnson, R.C.; B. Hellier, R. Adair, M. Cashman, B. St. Clair, N. Shaw, and V. Erickson. Uncovering adapted germplasm for the Great Basin: Tapertip onion, bluebunch wheatgrass and others. Developing native plant materials for the Great Basin. Great Basin Native Plant Selection and Increase Project 2007 Symposium, Society for Range Management 60th annual meeting, Reno, NV.

Management Applications:

This work is providing the research needed to develop adapted germplasm for restoration in the Great Basin. In addition, long-term conservation and management of germplasm is being conducted within the National Plant Germplasm System. This provides security back-up for native populations that may be lost as a result of climate change and disturbances such as fire and invasive weeds.

Products:

Adapted germplasm for the Great Basin and conservation within the National Plant germplasm System.

3. Genetic Diversity and Genecology of Bluebunch Wheatgrass

Project Location: Plant Germplasm Introduction and Research, USDA-ARS, Western Regional Plant Introduction Station (WRPIS), Pullman, WA.; USDA Forest Service Rocky Mountain Research Station 322 E. Front Street, Suite 401, Boise, Idaho 83702; USDA Forest Service, Pacific Northwest Research Station, Corvallis, Oregon.

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Project Description:

Bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] Á. Löve) is a cool-season, long-lived, self-incompatible perennial bunchgrass of semi-arid regions of western North America. 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 climatic factors across the Great Basin or the greater range of bluebunch wheatgrass in a large set of diverse populations. Questions concerning the suitability of cultivars will continue until this work is completed. Determining if and to what extent adaptive genetic variation is linked to climatic variation is needed to ensure that the proper germplasm is chosen for revegetation.

Objectives

1. Determine genetic variation among bluebunch wheatgrass from a wide range of source environments in the inland West and Great Basin
2. Relate genetic variation to environmental variation at collection locations
3. Compare common cultivars of bluebunch wheatgrass to native sources
4. Develop seed transfer guidelines.

In 2005, seed was collected from 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 near Boise, ID. In-depth evaluation of plants at each site was completed in 2007.

In 2007, data were collected on each of 16 plant traits at three study sites (Pullman and Central Ferry WA, and Lucky Peak ID) resulting in approximately 4,600 data points for each trait

(~73,560 total data points). Analyses of variance were completed to determine the effects of garden site, collection location, and the site by location interaction on the measured traits (Table 1).

Table 1. ANOVA summary for selected traits of bluebunch wheatgrass measured at Pullman and Central Ferry WA, and Lucky Peak ID, 2007					
Trait			P-value†		
	CV	Mean	Site	Loc	Site x Loc
Pt. habit, 1-9‡	16.9	6.25	0.0100†	<0.0001	<0.0001
Leaf pubes.,1-9‡	29.0	4.74	0.0747	<0.0001	<0.0001
Leaf width, mm	92.7	0.55	0.4683	<0.0001	0.9893
Leaf length, mm	23.9	14.7	<0.0001	<0.0001	0.0184
Leaf color, 1-9‡	69.0	3.28	0.5314	<0.0001	0.1194
Heading date	5.08	133	<0.0001	<0.0001	0.0009
Plant ht, cm	23.9	36.6	<0.0001	<0.0001	<0.0001
Culm length, cm	21.8	40.9	<0.0001	<0.0001	<0.0001
Anthesis date	14.1	148	<0.0001	0.0002	0.1535
Inflor. Num	65.1	29.2	<0.0001	<0.0001	<0.0001
Spikelets/spike	29.7	10.0	<0.0001	<0.0001	0.0327
Awn length, 1-9‡	34.1	4.48	0.9343	<0.0001	0.0163
Maturity date	4.7	189	<0.0001	<0.0001	<0.0001
Dry wt., g	56.1	42.0	<0.0001	<0.0001	<0.0001
Crown width, cm	30.8	5.53	0.0003	<0.0001	0.0183
Regrowth wt.	99.4	8.70	<0.0001	<0.0001	<0.0001
†P-values declared significant at <0.05. ‡Trait was rated from 1-9 with 1 indicating decumbent habit, no leaf pubescence, light green color, and short awn length					

The data showed strong collection location effects for all factors measured indicating genetic differences were present among the populations collected at different locations. Given these results the prospects for genecology analysis appears good.

The majority of traits had significant site effects as might be expected given the different environments at Pullman, Central Ferry, and Lucky Peak. However, 13 of the 16 traits had significant garden site by collection location interactions. This shows that growth and development of bluebunch wheatgrass germplasm cannot be predicted based on evaluation at any one site, and differences in adaptation among collection locations are likely. Continued data collection is planned for 2008.

Presentations:

Johnson, R.C. 2007. Uncovering adapted native germplasm for successful restoration. Society for Ecological Restoration Northwest/Society for Wetland Scientists joint meeting, Yakima, WA.

Management Applications:
Results from this study will be used to develop guidelines and appropriate source material for revegetation and restoration in the Great Basin and adjacent areas.

Products:
Adapted germplasm for the Great Basin conservation of germplasm within the National Plant Germplasm System.

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

Location: NRCS Aberdeen, ID Plant Materials Center

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Project Description:
Production of Certified Generation 1 (G1) seed of Anatone Germplasm bluebunch wheatgrass, Maple Grove Germplasm Lewis flax, 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. Assist in development of technology to improve the diversity of introduced grass stands by evaluating methods to introduce native species into established plant communities. Equipment and Strategies to enhance the post-wildfire establishment and persistence of Great Basin native plants.

Project Status:

1. Seed Production

Anatone Germplasm Bluebunch Wheatgrass
Currently 5.2 acres are in production. Estimated seed yield from 2007 seed crop is 1,384 pounds. Shipped 400 pounds of Certified seed to commercial growers in 2007.

Maple Grove Germplasm Lewis Flax
Seed fields established in 2005 (3.2 acres) and 2006 (3.2 acres) were contaminated with ‘Appar’ blue flax so harvested seed could not be certified. Attempts to rouge out Appar were unsuccessful. The field established in 2006 was used to conduct a herbicide tolerance trial in cooperation with the University of Idaho. No seed was shipped to commercial growers in 2006.

The PMC will establish a new field in 2008 with stock seed to be provided by the FS Rocky Mountain Research Station.

Snake River Plains Germplasm Fourwing Saltbush
Estimated seed yield from 2007 crop is 24 pounds. No seed was requested by commercial growers in 2007.

Northern Cold Desert Germplasm Winterfat
Estimated seed yield from 2007 crop is 8 pounds. Shipped 4 pounds of Certified seed to commercial growers in 2007.

2. Propagation of Native Forbs

The original project plan in 2005 was to propagate 8,000 plants total of *Lomatium dissectum* (LODI) fernleaf biscuitroot, *Lomatium grayii* (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 speciousus* (PESP) sagebrush penstemon in the greenhouse. Approximately 1000 plants each of ERUM and LOTR were to be transplanted at the PMC and remaining plants were to be made available to cooperators for transplanting at field 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 were completed at the PMC in November 2005. Weed barrier fabric was installed to control weeds.

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

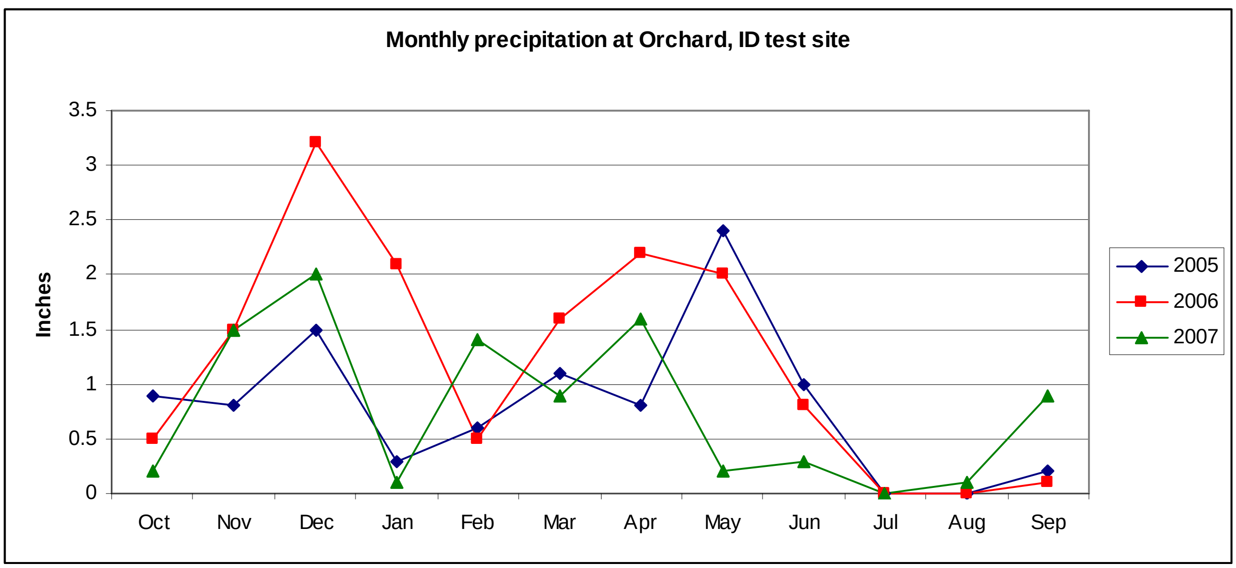
Species	Survival (percent)	Clean seed (pounds)
ERUM	40	4.0
LODI	25	NA
LOGR	70	NA
LOTR	71	NA
PEAC	68	8.0 (estimated)
PEDE	58	19.0 (estimated)
PESP	60	0.7

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

3. 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 includes 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, 2006 was 14.4 inches and total accumulated precipitation for 2007 was 8.5 inches (USDA 2007).



Materials and Methods

The Bureau of Land Management (BLM) burned the site in the fall of 2002. The PMC staff sprayed the site in May 2003 and May 2004 with a Roundup/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. 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 the buttercup plants had already flowered. At the time of the second evaluation, there was a heavy infestation of tumble mustard (*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.

The first evaluation of the plots for initial establishment 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, totaling 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 occurred on May 25, 2005. The 2006 evaluation was conducted on May 31, and the 2007 evaluation took place on May 16. The methods followed in 2006 and 2007 were the same as described above; however, 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 then divided by 10.8 to calculate approximate plants/ft^2. It is important to note that because cells with plants were counted and not 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 receiving 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 steadily in density from 2005 to 2007.

In 2005 the best performing Indian ricegrass accession was White River, having a plant density of 0.56 plants/ft^2 during the first evaluation and 0.17 plants/ft^2 during the second evaluation. In 2006 and continuing to 2007 there were no plants of any Indian ricegrass accessions observed in the evaluation grids and very few seen within their respective plots.

In 2005 the squirreltail plots had as high as 0.54 plants/ft^2 with Fish Creek. In 2006 all squirreltail accessions had decreased. Fish Creek maintained the best plant density with 0.26 plants/ft^2. Densities remained essentially the same in 2007.

Bannock thickspike wheatgrass had a density of 1.04 plants/ft^2 and stayed essentially the same at the second evaluation of 2005. In 2006 Bannock had dropped to nearly half of the original density to 0.58 plants/ft^2. The 2007 evaluations showed small declines from established plots.

Revenue and San Luis slender wheatgrass both showed zero plants/ft^2 in 2006. Pryor slender wheatgrass similarly dropped in density but had 0.02 plants/ft^2. In 2007 no slender wheatgrass plants could be found in any of the evaluated grids.

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. In 2007 all accessions had zero plants surviving.

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 shared low densities. In 2007 densities were generally slightly lower, but still higher than all other species as a whole. The highest density recorded in 2007 was Jim Creek at 1.07 plants/ft^2.

Snake River wheatgrass accessions had good densities the establishment year with three accessions having densities greater than 1.00 plants/ft^2. Numbers declined slightly yet steadily over the next 2 years. In 2007 the best density was from SERDP with 0.70 plants/ft^2.

The plant densities of the basin wildrye accessions also decreased from 2005 to 2006; U108-02 and Trailhead retained the highest densities at 0.24 and 0.26 plants/ft^2 respectively. By 2007 the best density was achieved by Trailhead with 0.17 plants/ft^2. U108-02 and U100-01 had similar densities with 0.11 and 0.13 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. In 2007 Covar still had 0.07 plants/ft^2, and Initial Point sheep fescue had decreased to 0.00 plants/ft^2.

Thurber's needlegrass had no plants in the evaluated grids for any year.

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/ft^2. In 2007 all stands had been reduced to 0.0 plants/ft$^{2.}$

Species	Name or accession	4/27/05	5/25/05	5/30/06	5/16/07
		Plants/ft²			
Indian ricegrass	Rimrock	0.37	0.20	0.00	0.00
	White River	0.56	0.17	0.00	0.00
	Nezpar	0.42	0.17	0.00	0.00
	Ribstone	0.14	0.09	0.00	0.00
	Paloma	0.05	0.00	0.00	0.00
Squirreltail	Fish Creek	0.97	0.54	0.26	0.22
	Sand Hollow	0.37	0.20	0.19	0.20
	Shaniko Plateau	0.81	0.52	0.06	0.09
	Toe Jam Creek	0.58	0.17	0.00	0.00
	9019219	0.02	0.02	0.00	0.00
Thickspike wheatgrass	Bannock	1.04	1.07	0.58	0.43
	Schwendimar	0.69	0.52	0.39	0.24
	Critana	0.90	0.56	0.24	0.17
	Sodar	0.37	0.30	0.15	0.07
Slender wheatgrass	Revenue	1.00	0.93	0.00	0.00
	San Luis	0.60	0.69	0.00	0.00
	Pryor	0.30	0.30	0.02	0.00
Western wheatgrass	Rodan	0.28	0.35	0.13	0.00
	Rosana	0.05	0.20	0.04	0.00
	Arriba	0.16	0.15	0.06	0.00
Bluebunch wheatgrass	Jim Creek	0.83	1.02	1.02	1.07
	Wahluke	0.97	1.26	1.02	0.98
	P-12	1.34	1.59	1.04	0.89
	Columbia	1.30	1.23	0.84	0.83
	Anatone	0.81	1.15	0.80	0.69
	P-7	0.93	1.15	0.67	0.57
	P-15	0.60	0.93	0.54	0.50
	Goldar	0.51	0.37	0.33	0.19
	P-5	0.42	0.61	0.22	0.13
Snake River wheatgrass	SERDP	1.02	0.94	0.67	0.70
	Secar	1.00	1.11	0.76	0.56
	Expedition	1.27	1.44	0.54	0.41
	E-26	0.21	0.23	0.22	0.13
Basin wildrye	Trailhead	0.60	0.52	0.26	0.17
	U100-01	0.53	0.41	0.11	0.13
	U108-02	0.56	0.57	0.24	0.11
	Washoe	0.21	0.09	0.09	0.06
	Magnar	0.28	0.22	0.04	0.04
	U70-01	0.30	0.22	0.02	0.02
Sheep fescue	Covar	0.16	0.00	0.07	0.07
	Initial Point	0.21	0.04	0.02	0.00
Thurber's needlegrass	Thurber's	0.00	0.00	0.00	0.00
Sandberg bluegrass	High Plains	0.25	0.00	0.54	0.00
	Sherman	0.00	0.00	0.02	0.00
	Mountain Home	0.00	0.00	0.35	0.00
	Toole County, MT	0.00	0.00	0.04	0.00
	Hanford Source	0.00	0.00	0.19	0.00

Introduced Grasses
Although many of the introduced grass accessions had fair emergence, an outbreak of black grass bugs at the time of the first evaluation in 2005 was noted. The infestation appeared limited to the introduced grass section of the nursery. Plants were covered with yellow spots making the plants 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 of crested wheatgrass were very small when compared to the other wheatgrass accessions in the nursery and still appear to be recovering from black grass bug pressure. The 2007 evaluation showed all established plots with reduced densities, many accessions dropping out completely.

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 black grass bug infestation during the spring of 2005. In 2007 the best density was obtained from Nordan with 0.67 plants/ft^2. Ephraim had dropped from 1.23 to 0.02 plants/ft^2.

Both Siberian wheatgrass accessions similarly increased from 2005 to 2006, but decreased in 2007. In 2007 Vavilov was down to 0.26 plants/ft^2 and P-27 had 0.00 plants/ft^2.

The three pubescent wheatgrass accessions decreased from 2005 to 2006 with the highest density in 2006 coming from Manska at 0.28 plants/ft^2. Manska continued to have the best density in 2007 with 0.13 plants/ft^2.

Rush intermediate wheatgrass, had 0.00 plants/ft^2 in 2006 and 2007.

Prairieland and Eejay Altai wildrye had zero plants in 2006. Pearl Altai wildrye had 0.02 plants/ft^2. In 2007 Prairieland and Eejay again had 0.00 plants/ft^2 and Pearl increased slightly to 0.04 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. Bozoisky select had the best stand in 2007 with 0.35 plants/ft^2. Bozoisky II had the next best rating with 0.26 plants/ft^2.

Species	Name or accession	4/27/05	5/25/05	5/30/06	5/16/07
		Plants/ft²			
Crested wheatgrass	Nordan	1.30	1.19	1.10	0.67
	Roadcrest	1.30	0.07	0.52	0.19
	Hycrest	0.39	0.24	0.15	0.07
	Ephraim	0.65	0.28	1.23	0.02
	CD-II	0.56	0.24	0.20	0.00
	Douglas	0.28	0.04	0.09	0.00
Siberian wheatgrass	Vavilov	0.65	0.20	0.61	0.26
	P-27	0.09	0.02	0.33	0.00
Pubescent wheatgrass	Manska	0.69	0.65	0.28	0.13
	Greenleaf	0.60	0.59	0.15	0.09
	Luna	0.79	0.54	0.13	0.00
Intermediate wheatgrass	Rush	0.60	0.56	0.00	0.00
	Pearl	0.35	0.15	0.02	0.04
Altai wildrye	Prairieland	0.56	0.39	0.00	0.00
	Eejay	0.16	0.28	0.00	0.00
Russian wildrye	Bozoisky Select	0.72	0.54	0.58	0.35
	Syn-A (Bozoisky II)	0.21	0.13	0.24	0.26
	Mankota	0.46	0.28	0.32	0.19
	Tetracan	0.42	0.20	0.17	0.07

<u>Forbs and Shrubs</u>

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. In 2007 more plants of Eagle had either germinated from the original seeding, or seed had spread from established plants. Plant density for Eagle in 2007 equaled 0.24 plants/ft^2. Snake River Plains fourwing saltbush also had a single plant found in the plots, increasing its density from 0.00 to 0.02 plants/ft^2.

Species	Name or accession	4/27/05	5/25/05	5/30/06	5/16/07
		Plants/ft²			
Western yarrow	Eagle	0.51	0.50	0.07	0.24
	Great Northern	0.19	0.09	0.00	0.00
Utah sweetvetch	Timp	0.14	0.02	0.00	0.00
Firecracker penstemon	Richfield Selection	0.02	0.02	0.00	0.00
Scarlet globemallow		0.00	0.00	0.00	0.00
Lewis flax	Maple Grove	0.42	0.15	0.00	0.00
Blue flax	Appar	0.90	0.26	0.00	0.00
Wyoming big sagebrush		0.02	0.02	0.00	0.00
Fourwing saltbush	Snake River Plains	0.00	0.00	0.00	0.02
	Wytana	0.00	0.00	0.00	0.00
	Rincon	0.00	0.00	0.00	0.00
Gardner's saltbush	9016134	0.00	0.00	0.00	0.00
Winterfat	Hatch	0.28	0.17	0.00	0.00
	Northern Cold Desert	0.00	0.00	0.00	0.00
	Open Range	0.00	0.00	0.00	0.00
Forage kochia	Immigrant	0.00	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 0.57plants/ft^2 at the second evaluation. In 2006 the cover crop density was 0.13 plants/ft^2. Cover crop densities increased in 2007 up to 0.20 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 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 and again into 2007. The low precipitation at the site, especially the lack of moisture in July and August every year 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. In 2007 many more plants had died out leaving poor or no stands in many plots. Snake River and bluebunch wheatgrass had consistently good stands from essentially all accessions. Introduced species like crested wheatgrass and Russian wildrye also had good performers such as Nordan and Bozoisky select.

Future evaluations will provide more information on plant establishment, persistence and longevity. The PMC staff will continue to evaluate plant performance at the site.

Literature Cited

Hammon, R.W. and F.B. Peairs. 2001. Black grass bugs. Colorado State University Cooperative Extension. No. 5.575.

[USDA NRCS] USDA Natural Resources Conservation Service. 2007. National Water and Climate Center. http://www.wcc.nrcs.usda.gov/snotel/. Accessed 20 October 2006.

Tilley, D.J., D.G. Ogle, and L. St. John. 2005. NRCS Aberdeen Plant Materials Center Display Nursery, Orchard, Idaho. Aberdeen, ID Plant Materials Center, Aberdeen, ID. 10 January 2005. 10 p.

Vogel, K.P. and R.A. Masters. 2001. Frequency grid-a simple tool for measuring grassland establishment. Journal of Range Management 54(6): 653-655.

4. 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 sites in Utah and Oregon. In 2006, modified seed drop boots by the manufacturer were installed on the Truax drill and the second year of seeding was completed. In addition to these seedings, the PMC also seeded drill comparison trials near Elko, NV on recently burned rangeland to compare the Truax drill to the Kemmerer drill, a standard range drill used by BLM. 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.

In 2007, seeding trials were scheduled to be planted near Elko, NV. However, seedbed preparation was unable to be completed. Trials have been rescheduled to the fall of 2008.

5. Equipment and Strategies to Enhance the Post-wildfire Establishment and Persistence of Great Basin Native Plants

The objectives of this project are to: examine seeding techniques for Wyoming big sagebrush; test seeding technology for native species, particularly native forbs; compare the ability of a modified rangeland drill and an experimental minimum-till drill to plant native seeds of diverse size and to reduce surface disturbance; apply and examine the use of USGS proposed monitoring protocols for gauging seeding success for both the short and long term; and provide plantings for long-term examination of livestock on diversity in native seedings.

The minimum-till drill (Truax Rough Rider range drill), which has been modified by PMC personnel, was provided by the FS Rocky Mountain Research Station. The PMC provided a trailer and tractor and the Utah Division of Wildlife provided an additional tractor. The modified rangeland drill (Kemmerer range drill) was provided by the BLM.

The PMC mixed the seed and rice hull mixtures and calibrated the drills prior to seeding. The PMC also made a modification to the Kemmerer drill by replacing the existing drop tubes with used aluminum 3-inch diameter irrigation pipe to facilitate seed flow to the drill openers. The aluminum pipe provided a more slippery surface for the seed to flow. The drills were set up to both broadcast and drill seed in the same pass so species that require broadcasting or very shallow planting were broadcast and the deeper seeded species were drill seeded in alternating rows.

Wildfire sites near Mountain Home, ID and Burns, OR were seeded during the week of October 28, 2007. A total of approximately 184.3 acres were seeded in plots to the following mixes:

Cover Crop Mix
24.3 acres

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Rimrock Indian ricegrass	4.5	5.25
Anatone bluebunch wheatgrass	4.0	4.64
Rice hulls		6.16

Drill Mix
80.0 acres

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Rimrock Indian ricegrass	1.0	1.17
Munro globemallow	0.50	0.94
Anatone bluebunch wheatgrass	2.0	2.32
Toe Jam Creek squirreltail	1.0	1.09
Sulphurflower buckwheat	0.24	0.39
Rice hulls		1.79

Mountain Home 10X Broadcast Mix
5 acres

Species	Pounds PLS/ac	Pounds bulk seed/ac
Wyoming big sagebrush	1.30	6.22
Rubber rabbitbrush	0.50	1.85
Hotrock penstemon	0.09	0.16
Mtn. Home Sandberg bluegrass	0.40	0.48
Rice hulls		5.05

Mountain Home 5X Broadcast Mix
30 acres

Species	Pounds PLS/ac	Pounds bulk seed/ac
Wyoming big sagebrush	0.65	3.11
Rubber rabbitbrush	0.50	1.85
Hotrock penstemon	0.09	0.16
Mtn. Home Sandberg bluegrass	0.40	0.48
Rice hulls		5.05

Mountain Home Standard Broadcast Mix
5 acres

Species	Pounds PLS/ac	Pounds bulk seed/ac
Wyoming big sagebrush	0.13	0.62
Rubber rabbitbrush	0.50	1.85
Hotrock penstemon	0.09	0.16
Mtn. Home Sandberg bluegrass	0.40	0.48
Rice hulls		3.54

Burns 10X Broadcast Mix
5 acres

Species	Pounds PLS/ac	Pounds bulk seed/ac
Wyoming big sagebrush	0.95	3.25
Rubber rabbitbrush	0.50	1.85
Hotrock penstemon	0.09	0.16
Mtn. Home Sandberg bluegrass	0.40	0.48
Rice hulls		8.03

Burns 5X Broadcast Mix
30 acres

Species	Pounds PLS/ac	Pounds bulk seed/ac
Wyoming big sagebrush	0.45	1.54
Rubber rabbitbrush	0.50	1.85
Hotrock penstemon	0.09	0.16
Mtn. Home Sandberg bluegrass	0.40	0.48
Rice hulls		6.62

Burns Standard Broadcast Mix
5 acres

Species	Pounds PLS/ac	Pounds bulk seed/ac
Wyoming big sagebrush	0.10	0.34
Rubber rabbitbrush	0.50	1.85
Hotrock penstemon	0.09	0.16
Mtn. Home Sandberg bluegrass	0.40	0.48
Rice Hulls		3.81

It is planned to repeat these trials in the fall of 2008. Location of the trials to be determined based on areas that burn during the 2008 fire season.

Publications:
(Available online at http://plant-materials.nrcs.usda.gov/idpmc/publications.html)

St. John, L., B. Cornforth, B. Simonson, D. Ogle, and D. Tilley. 2007. Technical Note 20: Calibrating the Truax Rough Rider drill for restoration plantings. Aberdeen Plant Materials Center, Aberdeen, ID. December 10, 2007. 14 p.

Tilley, D.J., L. St. John, and D. G. Ogle. 2007. Great Basin Native Plant Selection and Increase activities at the Aberdeen, Idaho Plant Materials Center. Aberdeen Plant Materials Center, Aberdeen, ID. January 18, 2007. 1 p.

Tilley, D.J., D. G. Ogle, and L. St. John. 2007. Parsnipflower buckwheat Plant Guide. Aberdeen Plant Materials Center, Aberdeen, ID. March 30, 2007. 3 p.

Tilley, D.J. and L. St. John 2006. Orchard Display Nursery evaluation summary (2005-2006). Aberdeen Plant Materials Center, Aberdeen, ID. October 24, 2006. 6 p.

Tilley, D. J. 2007. Reintroducing native plants to the American West. Aberdeen Plant Materials Center, Aberdeen, ID. February 20, 2007. 2 p.

St. John, L., D. J. Tilley, and D.G. Ogle. 2006. Plants for solving resource problems - Anatone germplasm bluebunch wheatgrass. Aberdeen Plant Materials Center, Aberdeen, ID. October 12, 2006. 2 p. Release brochure.

St. John, L., D. J. Tilley, and D.G. Ogle. 2006. Plants for solving resource problems - Maple Grove Flax. Aberdeen Plant Materials Center, Aberdeen, ID. November 13, 2006. 2 p. Release brochure.

St. John, L., D. J. Tilley, and D.G. Ogle. 2006. Plants for solving resource problems - Northern Cold Desert Winterfat. Aberdeen Plant Materials Center, Aberdeen, Idaho. November 15, 2006. 2p. Release brochure.

St. John, L., D. J. Tilley, and D.G. Ogle. 2006. Plants for solving resource problems - Snake River Plains germplasm fourwing saltbush. Aberdeen Plant Materials Center, Aberdeen, ID. November 7, 2006. 2 p. Release brochure.

St. John, L. 2006. Great Basin Native Plant Selection and Increase Project - 2006 Annual Report. Aberdeen Plant Materials Center, Aberdeen, Idaho.December 19, 2006. 11 p.

Presentations:

Tilley, D. Aberdeen PMC report of activities 2006: Great Basin Native Plant Selection and Increase Project. Society for Range Management annual meeting, Reno, NV.

Management Applications:
1. Certified seed stock of Anatone bluebunch wheatgrass, Snake River Plains fourwing saltbush, and Northern Cold Desert winterfat produced by the PMC is available though the University of Idaho Foundation Seed Program and Utah Crop Improvement Association.

2. Based on propagation studies at the PMC, sulphur-flower buckwheat, hotrock, sagebrush and sharpleaf penstemon appear to be able to be commercially grown, at least with the use of weed barrier fabric. Lomatium species are taking a long time to mature to reproductive stage and may not be conducive to commercial production because of the long period to reach reproductive capability.

3. The Orchard Display Nursery has been established for 3 years. The best performing native accessions identified in 2007 are: Fish Creek germplasm bottlebrush squirreltail, 'Bannock' thickspike wheatgrass, Jim Creek germplasm bluebunch wheatgrass, SERDP Snake River wheatgrass, 'Trailhead' basin wildrye, Eagle germplasm western yarrow and Snake River Plains germplasm fourwing saltbush.

Products:
1. Certified seed stock of Anatone bluebunch wheatgrass, Snake River Plains fourwing saltbush, and Northern Cold Desert winterfat produced by the PMC is available though the University of Idaho Foundation Seed Program and Utah Crop Improvement Association

2. Seed of sulphur-flower buckwheat and hotrock penstemon that were produced from the propagation studies were planted in the seed mixtures for the post-wildfire establishment study.

3. Technical Note 20: Calibrating the Truax Rough Rider drill for restoration plantings was developed and should be a useful guide to calibrating the drill.

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 Tree Seed Laboratory, Dry Branch, GA

Principal Investigators: **Robert Karrfalt**, Director
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Project Description:
The National Tree Seed Laboratory is developing seed cleaning, testing, and storage protocols for the species selected for the Great Basin Native Plant Selection and Increase Project. The NSL has a complete range of seed cleaning equipment so that manipulations of raw seed of almost any species can be performed in order to produce clean seed of high viability. Germination is tested over a range of temperatures and the data analyzed by response surface analysis to find the optimum combination of light and temperatures for optimum germination. Seed storage work was initiated this year also using a new technology to assess seed moisture conditions in preparing seed for storage. This new technology uses electronic hygrometers to measure the equilibrium relative humidity for the seed. Training and information on seed cleaning is also offered in workshops and conference presentations.

Project Status and Products:

- **Equipment development/modification**
  Seed Moisture: The relative humidity that a seed equilibrates with can be measured and used to determine if the seed's moisture condition is adequate for preserving seed viability in storage. Traditionally this was done by oven drying methods and, when possible, electronic meters that were calibrated by species with oven moisture content measurements on clean seed. Both methods presented a number of challenges and could be expensive. The relative humidity method can be done on any seed in any state of preparation from raw seed just off the plant to highly cleaned seed. A relatively inexpensive electronic hygrometer was adapted to do this moisture test. This method has been presented in the presentations made this past year. A handbook on seed drying and storage will be prepared in 2008. Seed workers will be able to easily and accurately assess seed moisture in any stage of handling the seed in order to preserve its viability.

- **Workshops**
  Cooperated with Nancy Shaw, RMRS, in organizing the seed cleaning workshop at Lucky Peak Nursery in August 2007.

- **Protocol development**
  Seed cleaning protocols were determined for the following 12 species: *Agoserus glauca, Astragulus filipes, Balsamorhiza sagitta, Crepis acuminata, Eriogonum heracleoides, E. umbellatum, Lomatium dissectum, L. grayii, L. triternatum, Penstemon acuminatus, P. deustus,* and *Sphaeralcea munroana.* The procedures were presented at the National Wildflower Seed Production Research Symposium in Orlando, FL in July, 2007 and a summary was published in the internet proceedings.

- **Seed testing**
  Moisture evaluations with an electronic hygrometer that can be universally applied to any seed lot. The procedure is being used in a sagebrush seed storage study.
  Germination conditions were identified for *Lomatium dissectum, L. grayii, and L. triternatum.* A paper on these 3 species will be published in 2008. Work is progressing on germination protocols for 9 other species.

- **Grants leveraged through GBNPSIP research**
  The GBNPSIP grant was combined with internal Forest Service funds to make a much needed purchase of germination cabinets. These cabinets provide the needed conditions to determine the germination protocols for the *Lomatium* mentioned above and are presently in use to determine germination protocols for the other species in the GBNPSIP.

- **Activities resulting from GBNPSIP participation**
  Participation in the Native Wildflower Seed Production Research Symposium was a direct result of participation in the GBNPSIP because it provided the project that was presented.

Publications:

The 1000 seed weight of several species were determined earlier and posted to the internet at http://www.nsl.fs.fed.us/great_basin_native_plants.html

Karrfalt, R.P. Seed Cleaning Research on Great Basin Forbs. In: Native wildflower seed production research symposium. 2007. Norcini, J.G. (editor). Program booklet. http://nfrec.ifas.ufl.edu/norcini/WFSympWeb/2007SymposiumProgram.pdf (accessed 2 Aug. 2007).

Presentations:

Karrfalt, R. P., V. G. Vankus, and J. R. Barbour. 2007. Germination, seed weight, purity and seed cleaning protocols for Great Basin native plants. The development of native plant materials for the Great Basin: Symposium. Society for Range Management annual meeting, Reno, NV.

Karrfalt, R. P. Seed cleaning research on Great Basin Forbs. 2007. Native wildflower seed production research symposium. Norcini, J. G., ed. Extended abstract. Online: http://nfrec.ifas.ufl.edu/norcini/WFSympWeb/2007SymposiumProgram.pdf.

Karrfalt, R. P. 2007. Seed Cleaning Workshop presented at Lucky Peak Nursery, Boise ID for 15 persons involved in native plant restoration.

Project Title: Pollinator and Seed Predator Studies

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

Principal Investigator and Contact Information:

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

At the same time, 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 laboratory's 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 are acquired, increased and distributed to growers with guidance for the bees' management.

Project Status:
A few systematic censuses of bees (as individuals per 100 flowering plants) were sampled at *Balsamorhiza sagittata, Hedysarum boreale,* and two globemallows (*Sphaeralcea*); the regional drought precluded further sampling. We planted raised, irrigated seed beds with experimental plantings of *Sphaeralcea* and *Lomatium*, transplanting greenhouse seedlings of *Lomatium triternatum* and *L. grayii*. An 8' perimeter fence successfully excluded deer. We trap-nested

widely in our mountains, but failed to obtain nests of the beardtongue pollinator *Osmia penstemonis*, even from locations where it had been taken in earlier decades.

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 2007, we focused our studies of breeding biologies on established plants of *Lomatium dissectum* and *Sphaeralcea* growing in our 20' x 20' common garden plots.

In general, bees continue to be revealed as the essential pollinators for the selected wildflower species. For *L. dissectum*, no seed results on racemes bagged to exclude pollinators. Manually self-pollinated plants yielded as much seed as manually outcrossed plants. Neither group was as productive as wild populations accessible to the small-bodied specialist bees of the genus *Andrena* that we have found associated with this species across five states. However, we did notice small sweat bees avidly visiting flowers of *Lomatium dissectum* for pollen in a different cage setting, so we are hopeful that these ubiquitous, often common floral generalists may serve to pollinate these flowers on some farms.

For the globemallows, the seed that we were sent by a federal seed repository proved to be hybrid, not pure. From our manual pollinations of a limited number of caged plants, we nonetheless obtained considerable seed, indicative of the hybrid's fertility. Could it be that our Great Basin "species" are in fact all one interfertile species? We are cooperating with Dr. Heidi Krantz at USU, who is studying the genetics of the three parent species, as well as our individual crossed plants. We have obtained what promises to be pure genotypes for our more extensive 2008 breeding trials.

On the topic of hybridization, I also experimented with bee foraging behavior and hybridization in *Balsamorhiza*. A number of experimental studies with foraging arrays have shown that generalist foragers (chiefly hummingbirds, honey bees and bumblebees) will forage more or less indiscriminately between similar-looking flowers of a given floral genus. We have now extended this observation to bees that are floral specialists, using two species of *Osmia* that are specialized for just *Balsamorhiza* and *Wyethia*. Hence, species-level specialization does not translate to enhanced floral constancy of individual foragers; specialists move among similar-looking flowers of related host species, too.

Graduate student Katharine Swoboda completed her Master's thesis on the pollination needs of *Hedysarum boreale.* She showed that two wild *Osmia* species, *O. bruneri* and *O. sanrafaelae*, effectively pollinate *H. boreale*, nest well with this floral resource, and are amenable to our artificial nesting substrates. We continue to increase populations of the two promising *Osmia* for commercial pollination of *H. boreale*. In 2007, we recovered 2000 progeny of *O. sanrafaelae* from 577 overwintered bees released with commercial nesting substrates placed at Rick Dunne's Wind River Farm in Worland, Wyoming, our third year of successfully increasing this bee. We are also able to increase populations of the native bees *O. lignaria* and *Hoplitis albifrons*, even when restricted to foraging at flowers of target forb species such as *H. boreale*.

Management Applications:
Growers of native forbs for seed who do not plan for pollination will have little seed production for most of the species chosen for the Intermountain West. A subset of species (e.g. *Dalea ornata*) can be handily pollinated with any one of several currently managed pollinators (honey bees, alfalfa leafcutting bees). More than half can be pollinated with cavity-nesting native *Osmia* bee species whose numbers are being increased at this lab for distribution to growers in the near future. We are also finding that some ground-nesting bee species as well as bumblebees that effectively pollinate these forbs are increasing on some native seed farms, and may eventually be responsible for much of the pollination of a given forb field.

Products:
A study was published that surveys and compiles the nesting substrates of most of North America's 140 species of native *Osmia* bees. It will be critical for choosing the manageable cavity nesters from among the various *Osmia* species that commonly pollinate various Great Basin wildflowers. Many of these *Osmia* species are ground-nesters, and though effective pollinators, have little potential for active management (although a grower or two is successfully favoring them on-farm by neither flooding them with rill irrigation nor churning up their nests by disking/plowing for weed control during bloom).

Species of four *Osmia* bee species and one *Hoplitis* that effectively pollinate *Hedysarum* and *Astragalus* are being increased at the Logan labs for distribution to seed growers, hopefully beginning as soon as 2008. With our guidance, one of these, *O. sanrafaelae*, continues to be successfully increased at Wind River Farm for pollination of sweetvetch (now 2,000 overwintering individuals). With one more successful field season, we expect to have enough bees, rearing experience, etc. to offer this bee to several growers of *Hedysarum* in Utah and western Colorado where this bee is native.

Publications:

Cane, J.H., T.G. Griswold and F.D. Parker. 2007. Substrates and materials used for nesting by North American *Osmia* bees. Annals of the Entomological Society of America 100:350-358.

Swoboda, K.A. 2007. The pollination ecology of *Hedysarum boreale* and evaluation of its pollinating bees for restoration seed production. Utah State University, Logan, UT. Thesis.

Cane, J.H. In press for 2008. Pollinating bees crucial to farming wildflower seed for U.S. habitat restoration. *In:* R.R. James and T. Pitts-Singer, eds. Bees in agricultural ecosystems. Oxford University Press, U.K.

Cane, J.H. In review. Breeding biologies, pollinating bees and seed production of *Cleome lutea* and *C. serrulata* (Cleomaceae).

Presentations:

Cane, J.H. 2007. Pollinating Great Basin forbs for seed to rehabilitate western rangelands. Symposium: Developing native plant materials for the Great Basin. Society for Range Management 60th annual meeting, Reno, NV. Abstract. Invited presentation.

Cane, J.H. 2007. Bee pollination of farmed wildflowers for habitat restoration seed. 9th International pollination symposium, Iowa State University, Ames. Abstract. Invited plenary presentation.

Cane, J.H. 2007. Bee pollination of farmed wildflowers for habitat restoration seed. Entomological Society of America, Pacific Branch, Portland, OR. Invited symposium presentation.

Cane, J.H. 2007. Bee pollination of farmed wildflowers for habitat restoration seed. Society for Ecological Restoration, Northwest Chapter, Yakima, WA. Invited presentation.

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

Project Location: Colorado State University Extension, Grand Junction CO

Principal Investigators and Contact Information:

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Project Description:

The goal of this project is to document insects affecting collections and field production of native plant seed. Insect collections from seed increase fields in the Great Basin states plus Oregon and Washington are forwarded to the lab in Grand Junction, CO for identification. In addition, seed production fields near Hotchkiss, CO that are associated with the Uncompahgre Plateau Project are being monitored for insect pests.

Project Status:

A weevil species complex composed primarily of *Anthonomus sphaeralciae* was found damaging a field of *Sphaeralcea coccinea* near Hotchkiss, CO. We estimated the seed loss from this pest to be in excess of 25%. The weevils were also found in a seed increase of *Sphaeralcea* sp. near Cortez, CO. Information on the identification and management of this native insect is online at http://wsprod.colostate.edu/cwis487/wci/Assets/html/Spco.html.

A moth larva that attacks *Lupinus sericeus* was discovered at the Hotchkiss, CO site in 2006. It was misidentified as an undescribed pyralid moth in the genus *Pima.* Specimens were reared in 2007, and that material forwarded to a taxonomist who identified the moth as the lima bean pod borer, *Etiella zinckenella***.** Information on this pest can be viewed at http://wsprod.colostate.edu/cwis487/wci/Assets/html/LUSE.html.

The western wheat aphid, *Diuraphis tritici* was found damaging a seed increase field of *Bromus marginata* at Hotchkiss, CO. This aphid had been found previously damaging a seed increase of *B. marginata* at the Upper Colorado Environmental Plant Center (UCEPC) at Meeker, CO. A second *Diuraphis* spp, *D. nodulus* has been a perennial production issue at UCEPC for the past decade. A key to North American *Diuraphis* is being developed in cooperation with USDA/ARS in Stillwater, OK.

Products

Publications:

A web site has been developed at http://wsprod.colostate.edu/cwis487/wci/seed_production.html for access to information regarding insects impacting native plant seed production associated with the Great Basin Native Plant Selection and Increase Project.

Presentations:

Hammon, Robert. 2007. Insects affecting collected versus field grown seed. Society for Range Management 60th annual meeting, Sparks/Reno, NV. Abstract.

Hammon, Robert. 2007. Identifying management strategies for pests affecting native forb seed production. Native wildflower seed production symposium, Orlando FL.

Field Tour:

Hammon, Robert. 2007. Insects affecting native plant seed production field tour at Western Colorado Research Center, Rogers Mesa. Plant community restoration workshop, Uncompahgre Project, Grand Junction, CO.

Management Applications:

Seed producers can access the web site to identify potential production pests and gather information regarding their management. Producers are invited to share information to add to the site.

Technology Transfer:

Western Colorado Entomology, Native Plant Seed Production
http://wsprod.colostate.edu/cwis487/wci/seed_production.html

Project Title: Native Forb Seed Production in Response to Irrigation in 2007

Project Location: Oregon State University Malheur Experiment Station, 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 flowering, seed set, and seed development. Excessive water stress during flowering, seed set, and seed 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 could promote seed production, but risk encouraging weeds. Furthermore, sprinkler and furrow irrigation can lead to the loss of plant stand and seed production due to fungal pathogens. By burying drip tapes at 12-inch depth, and avoiding wetting of the soil surface, we 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

<u>Plant establishment</u>

Seed of the seven intermountain west forb species (Table 1) was received in late November in 2004 from the Rocky Mountain Research Station (Boise, ID). The plan was to plant the seed in the fall of 2004, but due to excessive rainfall in October, the ground preparation was not completed and planting was postponed to early 2005. To 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°F. Every few days the seed was mixed and, if necessary, distilled water added to maintain moist seed. In late February, seed of *Lomatium grayi* and *Lomatium triternatum* had started sprouting.

Table 1. Forb species planted at the Malheur Experiment Station.

Species	Common name
Eriogonum umbellatum	Sulfur-flower buckwheat
Penstemon acuminatus	Sand penstemon
Penstemon deustus	Hotrock penstemon
Penstemon speciosus	Royal or Sagebrush penstemon
Lomatium dissectum	Fernleaf biscuitroot
Lomatium triternatum	Nineleaf desert parsley
Lomatium grayi	Gray's lomatium
Sphaeralcea parvifolia	Smallflower globemallow
Sphaeralcea grossularifolia	Gooseberryleaf globemallow
Sphaeralcea coccinea	Scarlet globemallow
Dalea searlsiae	Searls' prairie clover
Dalea ornata	Western prairie clover
Astragalus filipes	Basalt milkvetch

In late February, 2005, drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth between two rows (30-inch rows) of a Nyssa silt loam with a pH of 8.3 and 1.1% organic matter. 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.

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 *Eriogonum umbellatum* and the *Penstemon* spp. were planted at 0.25-inch depth and the *Lomatium* spp. at 0.5 inch depth. The trial was irrigated with a minisprinkler system (R10 Turbo Rotator, Nelson Irrigation Corp., Walla Walla, WA) for even stand establishment from March 4 to April 29. Risers were spaced 25 ft apart along the flexible polyethylene hose laterals that were spaced 30 ft apart and the water application rate was 0.10 inch/hour. A total of 1.72 inches of water was applied with the minisprinkler system. *Eriogonum umbellatum*, *Lomatium triternatum*, and *Lomatium grayi* started emerging on March 29. All other species, except *Lomatium 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 *Eriogonum umbellatum*, *Penstemon* spp., *Lomatium triternatum*, and *Lomatium grayi* were uneven. *Lomatium dissectum* did not emerge. None of the species flowered in 2005.

In early October, 2005, more seed was received from the Rocky Mountain Research Station for replanting. The *Eriogonum umbellatum* and *Penstemon* spp. plots had the blank 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 *Penstemon deustus*.

<u>Flowering, harvesting, and seed cleaning in 2006</u>
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 *Eriogonum 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 *Penstemon 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 structures in the combine. *Eriogonum umbellatum* unthreshed 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 pods were too hard to be opened in the combine. *Penstemon deustus* unthreshed seed was precleaned in a small clipper seed cleaner and then seed pods were broken manually by rubbing the pods on a ribbed rubber mat. The seed was then cleaned again in the small clipper seed cleaner.

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

<u>Expansion and fertilization of the trials</u>
On April 11, 2006, seed of three globemallow species (*Sphaeralcea parvifolia, S. grossularifolia, S. coccinea),* two prairie clover species *(Dalea searlsiae, D. ornata)*, and basalt milkvetch (*Astragalus filipes*) was planted at 30 seeds per foot of row. The field was sprinkler irrigated until emergence. Emergence was poor. In late August of 2006 seed of the three globemallow species was harvested by hand. On November 9, 2006 the six forbs were flailed. On November 10, 2006 the six forbs were replanted.

On October 27, 2006, 50 lb P/acre and 2 lb Zn/acre were injected through the drip tape to all plots of *Eriogonum umbellatum*, *Penstemon* spp., and *Lomatium* spp. On November 11, 100 lb N/acre as urea was broadcast to all *Lomatium* spp. plots. On November 11, the *Penstemon deustus* plots were replanted at 30 seeds/foot of row. On November 17, all plots of *Eriogonum* *umbellatum*, *Penstemon* spp. (except *P. deustus*), and *Lomatium* spp., had Prowl at 1 lb ai/acre broadcast on the soil surface.

Irrigation for seed production in 2006

In April, 2006, the field was divided into plots 30 feet long. Each plot contained 4 rows of each of *Eriogonum umbellatum, P. acuminatus, P. speciosus, P. deustus, L. dissectum, L. triternatum, and L. grayi*. 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 3). At the first irrigation on May 19, *Penstemon acuminatus* had ended flowering, *Penstemon deustus* and *Penstemon speciosus* were flowering, and *Eriogonum umbellatum* was just starting 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.

Irrigation for seed production in 2007

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

Soil volumetric water content was measured in 2007 as in 2006.

On April 5, irrigations for the three *Lomatium* species were started. On April 19, irrigations for *Penstemon deustus* and *Penstemon speciosus* were started. On May 2, irrigations for *Penstemon acuminatus* and *Eriogonum umbellatum* were started. Irrigation treatments were the same as in 2006. The three globemallow species, two prairie clover species, and basalt milkvetch were irrigated together according to the treatments starting on May 16. Inadvertently, irrigation treatments were not stopped after 4 irrigations were applied, as in 2006. Irrigation treatments for all species were continued until the last irrigation on June 24.

Cultural practices, harvest, and seed cleaning in 2007

Penstemon acuminatus and *Penstemon speciosus* were sprayed with Aza-Direct at 0.0062 lb ai/acre on May 14 and May 29 for lygus bug control.

Lomatium grayi seed was hand harvested on May 30 and June 29. *Lomatium triternatum* was hand harvested on June 29 and July 16. The seed was separated from the stalks by hand and cleaned with a small clipper seed cleaner. Since the seed harvest and cleaning varied by species, the details are reported in Table 2.

The three *Sphaeralcea* species were hand harvested on June 20, July 10, and August 13. The harvested seed pods were threshed in the small plot combine with an alfalfa seed concave. The two prairie clover species were hand harvested on June 20 and July 10.

Penstemon acuminatus was harvested on July 9 with the small plot combine with an alfalfa seed concave. The seed was further cleaned with a small clipper seed cleaner. *Penstemon speciosus* was hand harvested on July 23. Hand harvest for *Penstemon speciosus* was necessary due to poor seed set. *Penstemon speciosus* seed was separated by hand and cleaned with a small clipper seed cleaner.

Eriogonum umbellatum was harvested on July 31 using the small plot combine with a dry bean concave. The seed was threshed by hand and cleaned with a small clipper seed cleaner.

Table 2. Seed harvest and cleaning by species in 2007.

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

[a]Dry bean concave
[b]Alfalfa seed concave
[c]Cipper seed cleaner
[d]Specialized seed threshing machine at U.S.D.A. Lucky Peak Nursery. In 2007, due to travel constraints, an adjustable hand driven corn grinder was used to thresh seed.
[e]Hard seed pods were broken by rubbing against a ribbed rubber mat.
[f]Harvested by hand in 2007 due to poor seed set.

Results and Discussion

Precipitation in the fall of 2005 and spring of 2006 was higher than normal at the Malheur Experiment Station (Fig. 1). Precipitation from October 2005 through June 2006 was 15.9 inches. The 64-year average precipitation from October through June is 9.1 inches. Precipitation from March through June was 6.4 inches in 2006. The 64-year average precipitation from March through June is 3.6 inches. The wet weather could have attenuated the effects of the irrigation treatments in 2006 (Shock et al., 2007). Of the 7 species tested, only *Eriogonum umbellatum* and *Penstemon speciosus* showed seed yield responses to irrigation rate in 2006 (Table 4).

Precipitation from October 2006 through June 2007 was 6.2 inches, lower than the 64-year average. Precipitation from March through June was 2.0 inches in 2007. The total amount of water applied to the forbs was higher than planned in 2007 (Table 3). The biweekly irrigations were continued until June 24, instead of being terminated after four irrigations. The soil volumetric water content responded to the irrigation treatments (Figs. 2 to 6).

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

Flowering and seed set in 2007

Lomatium grayi started flowering in late March and ended in mid May. *Lomatium triternatum* started flowering in mid April and ended in early June. *Lomatium dissectum* did not flower. *Penstemon acuminatus* and *P. deustus* started flowering in early May and ended in late June. *P. speciosus* started flowering in early May and ended in late June. *Eriogonum umbellatum* started flowering in early May and ended in late July. The three *Sphaeralcea* species (globemallow) started flowering in early May and continued flowering through September. The two *Dalea* species (prairie clover) started flowering in early May and ended in late June.

The three *Sphaeralcea* species (globemallow) showed a long flowering period (early May through September). Multiple harvests were necessary because the seed falls out of the pods once the pods are mature.

Penstemon acuminatus and *Penstemon speciosus* had poor seed set partly due to a heavy lygus bug infestation that was not adequately controlled by the applied insecticides. Poor seed set for *P. acuminatus* and *P. speciosus* was also related to poor vegetative growth in 2007 compared to 2006.

Seed yields

In 2006, seed yield of *Eriogonum umbellatum* was highest with the 2-inch irrigation rate (Table 4). In 2007, seed yield of *E. umbellatum* with the 1-inch irrigation rate was significantly higher than with the non-irrigated check. Seed yield with the 2-inch rate was not significantly higher than with the 1-inch rate.

Seed yields of *Penstemon acuminatus* and *P. speciosus* in 2007 were substantially lower than in 2006, possibly due to poor vegetative growth and lygus bug damage to flowering structures (Table 4). There was no significant difference in seed yield between irrigation treatments for *P. acuminatus* in 2006. In 2007, seed yield of *P. acuminatus* was highest with the 1-inch irrigation rate. Seed yields with either the 2-inch irrigation rate or the non-irrigated check were similar and substantially lower.

For *P. speciosus* in 2006 and 2007, seed yields were increased with the 1-inch irrigation rate compared to the non-irrigated check. Seed yields with the 2-inch irrigation rate were lower, but not significantly different than for the 1-inch rate.

There was no significant difference in seed yield between irrigation treatments for *P. deustus* in 2006 and 2007. For *P. deustus*, the replanting of the low stand areas in October of 2005 and the replanting of the whole area in October 2006 resulted in very poor emergence and in plots with very low and uneven stand.

Of the three *Lomatium* species, *L. grayi* had the most vigorous vegetative growth in 2007. *L. dissectum* had the poorest vegetative growth in 2006 and 2007 and did not flower in either year. *Lomatium grayi* and *Lomatium triternatum* showed a trend for increasing seed yield with increasing irrigation rate in 2007. The highest irrigation rate resulted in significantly higher seed yield than the non-irrigated check. The much greater *Lomatium* growth in 2007 shows promise for higher seed yields in future years.

There was no significant difference in seed yield between irrigation treatments for the three *Sphaeralcea* species, with *Sphaeralcea parvifolia* having the highest seed yield. The *Sphaeralcea* species seed yields ranged from 279 to 1062 lb/acre in 2007 without irrigation.

There was no significant difference in seed yield between irrigation treatments for the two *Dalea* species, with *Dalea ornata* having the highest seed yield. Emergence for the two *Dalea* species was poor with plots having poor and uneven stand.

<u>Summary and comparison of 2006 and 2007</u>

Precipitation from March through June was 6.4 inches in 2006 and 2.0 inches in 2007. The 64-year average precipitation from March through June is 3.6 inches.

For *Eriogonum umbellatum*, seed yield was maximized with the 2-inch irrigation rate in 2006 and with the 1- or 2-inch irrigation rate in 2007. For *Penstemon acuminatus*, seed yield was not responsive to irrigation in 2006 and was maximized with the 1-inch irrigation rate in 2007. For *P. speciosus*, seed yields were maximized with the 1-inch irrigation rate in 2006 and 2007. For *P. deustus*, seed yield was not responsive to irrigation in 2006 and 2007. None of the three *Lomatium* species flowered in 2006. *Lomatium dissectum* has been very slow to develop on the experimental site and has not flowered. Seed yield for *Lomatium triternatum* and *L. grayi* were maximized by the highest irrigation rate of 2-inches in 2007. The three *Sphaeralcea* species and the two *Dalea* species were not responsive to irrigation in 2007.

The poor emergence and resulting poor stand cast doubt on the accuracy of the seed yield response to irrigation for *Penstemon deustus*, the three *Sphaeralcea* species, and the two *Dalea* species

Knowledge about native forb seed production would help make commercial production of this seed feasible. Irrigation methods are being developed at the Oregon State University Malheur Experiment Station to help assure reliable seed production with reasonably high seed yields. Growers need to have economic return on their seed plantings, but forbs may not produce seed every year. Due to the arid environment, supplemental irrigation may be required for successful flowering and seed set many years because soil water reserves may be exhausted before seed formation.

Subsurface drip irrigation (SDI) systems are being tested for native seed production because SDI has two potential strategic advantages; a). low water use, and b). the buried drip tape provides water to the plants at depth, out of reach of stimulating weed seed germination on the soil surface and away from the plant tissues that are not adapted to a wet environment.

The total irrigation water requirements for these arid land species has been shown to be low, but varied by species.

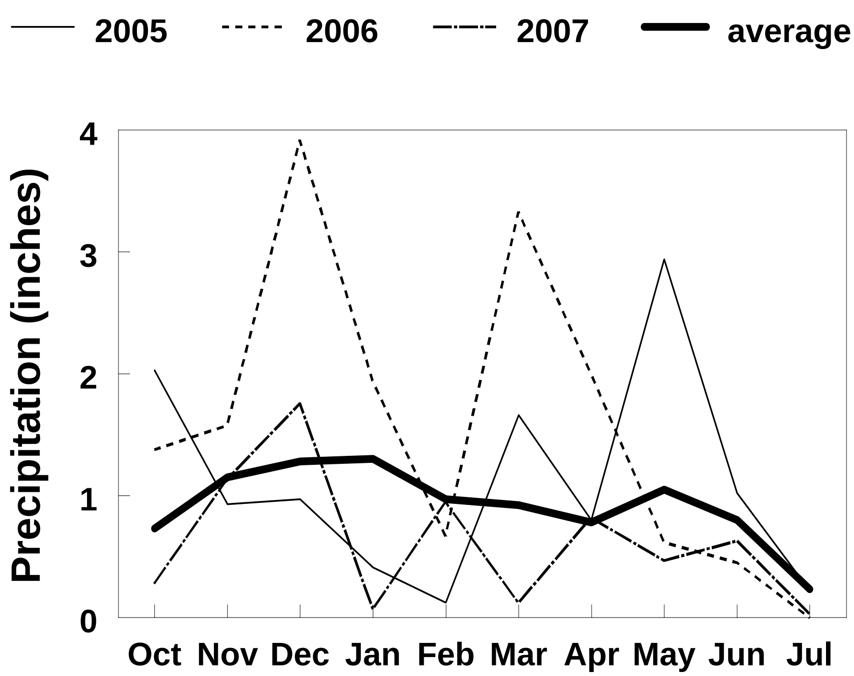

Figure 1. Monthly precipitation from October of the previous year through July for the last three years. Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Table 3. Irrigation treatments and actual amounts of water applied to native forbs in 2006 and 2007. Precipitation from March through June was 6.4 inches in 2006 and 2.0 inches in 2007. The 64-year average is 3.6 inches. Malheur Experiment Station, Oregon State University, Ontario, OR.

Date	Irrigation rates (inches per irrigation)	Actual amount of water applied			
		Lomatium sp.	*Penstemon deustus, P. speciosus*	*Penstemon acuminatus, Eriogonum umbellatum*	*Sphaeralcea sp., Dalea sp.*
		----------------------------- acre inches/acre -----------------------------			
		2006			
19-May	2	2.23	2.23	2.23	
19-May	1	1.31	1.31	1.31	
2-Jun	2	2.16	2.16	2.16	
2-Jun	1	1.23	1.23	1.23	
20-Jun	2	2.04	2.04	2.04	
20-Jun	1	1.23	1.23	1.23	
30-Jun	2	2.26	2.26	2.26	
30-Jun	1	1.12	1.12	1.12	
total	2	8.69	8.69	8.69	
total	1	4.89	4.89	4.89	
		2007			
5-Apr	2	2.00			
5-Apr	1	1.28			
19-Apr	2	2.78	2.78		
19-Apr	1	1.34	1.34		
2-May	2	2.70	2.70	2.70	
2-May	1	1.40	1.40	1.40	
16-May	2	2.62	2.62	2.62	2.62
16-May	1	1.42	1.42	1.42	1.42
30-May	2	2.49	2.49	2.49	2.49
30-May	1	1.22	1.22	1.22	1.22
10-Jun	2	2.46	2.46	2.46	2.46
10-Jun	1	1.09	1.09	1.09	1.09
24-Jun	2	2.59	2.59	2.59	2.59
24-Jun	1	1.41	1.41	1.41	1.41
total	2	17.6	15.6	12.9	10.2
total	1	9.2	7.9	6.5	5.1

Table 4. Native forb seed yield response to irrigation rate (inches/irrigation) in 2006 and 2007. Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Species	Planting date	2006				2007			
		0 inch	1 inch	2 inch	LSD(0.05)	0 inch	1 inch	2 inch	LSD(0.05)
		------------------------------ lb/acre ------------------------------							
Eriogonum umbellatum	Mar 05, Oct 05[a]	155.3	214.4	371.6	92.9	79.6	164.8	193.8	79.8
Penstemon acuminatus	Mar 05, Oct 05[a]	538.4	611.1	544	NS	19.3	50.1	19.1	25.5[f]
Penstemon deustus	Mar 05, Oct 05[b]	1246.4	1200.8	1068.6	NS	120.3	187.7	148.3	NS
Penstemon speciosus	Mar 05, Oct 05[a]	163.5	346.2	213.6	134.3	2.5	9.3	5.3	4.7[f]
Lomatium dissectum	October 05[c]	---- no flowering ----				---- no flowering ----			
Lomatium triternatum	October 05[c]	---- no flowering ----				2.3	17.5	26.7	16.9[f]
Lomatium grayi	October 05[c]	---- no flowering ----				36.1	88.3	131.9	77.7[f]
Sphaeralcea parvifolia	November 06[d]					1062.6	850.7	957.9	NS
Sphaeralcea grossularifolia	November 06[d]					442.6	324.8	351.9	NS
Sphaeralcea coccinea	November 06[d]					279.8	262.1	310.3	NS
Dalea searlsiae[e]	November 06[d]					11.5	10.2	16.4	NS
Dalea ornata[e]	November 06[d]					47.4	27.3	55.6	NS

[a]Areas of low stand replanted by hand in October 2005.
[b]Areas of low stand replanted by hand in October 2005 and whole area replanted in October 2006. Yields in 2006 are based on small areas with adequate stand. Yields in 2007 are based on whole area of very poor and uneven stand.
[c]Whole area replanted in October 2005.
[d]Whole area replanted in November 2006.
[e]Poor and uneven stand
[f] LSD (0.10)

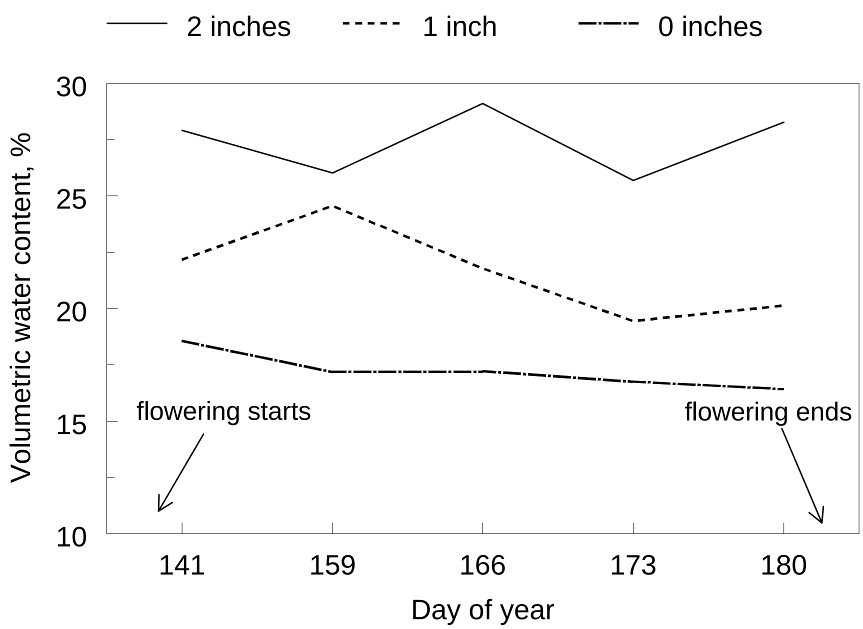

Figure 2. Soil volumetric water content for *Eriogonum umbellatum* over time. Soil volumetric water content is the combined average at the 8-, 20-, and 32- inch depths. *E. umbellatum* was harvested on July 31 (day 212). Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

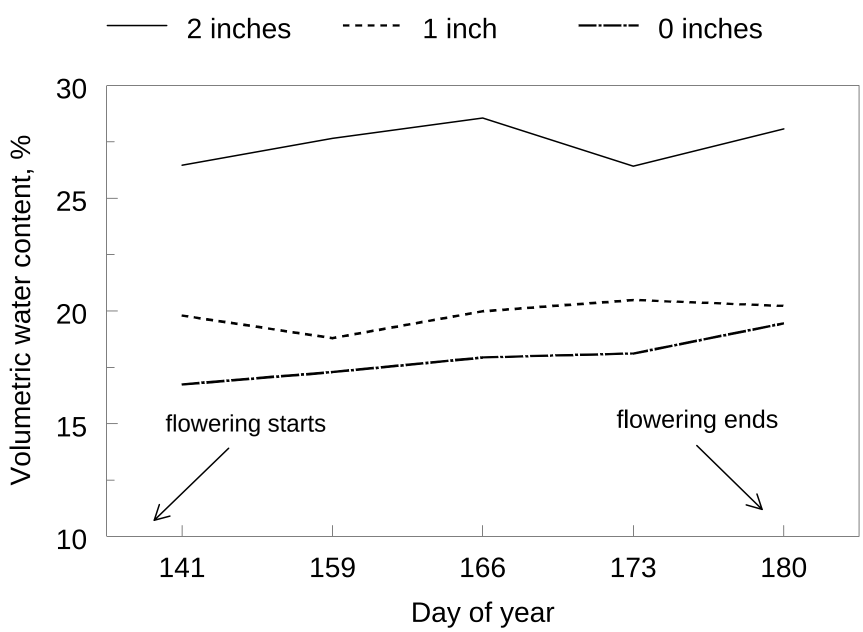

Figure 3. Soil volumetric water content for *Penstemon acuminatus* over time. Soil volumetric water content is the combined average at the 8-, 20-, and 32- inch depths. Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

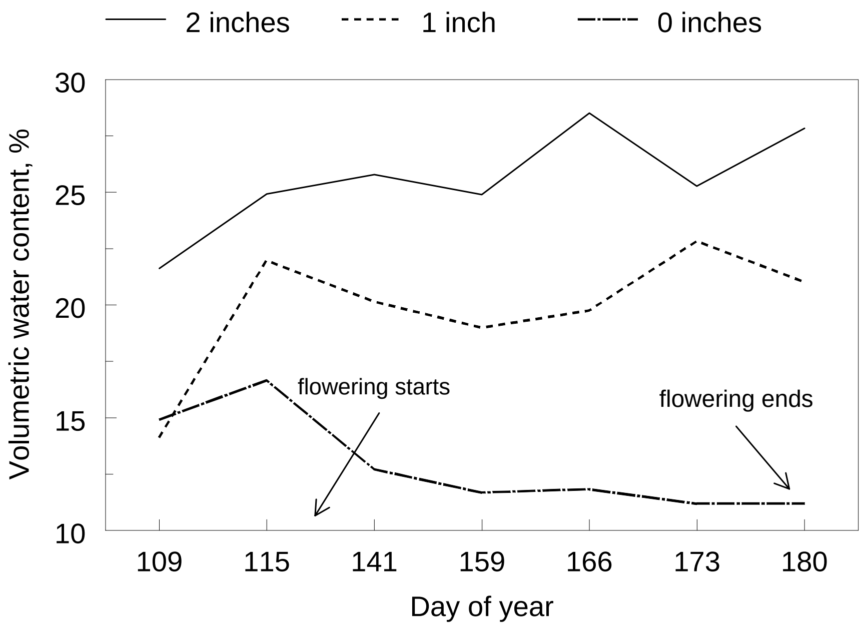

Figure 4. Soil volumetric water content for *Penstemon speciosus* over time. Soil volumetric water content is the combined average at the 8-, 20-, and 32- inch depths. *P. speciosus* was harvested on July 23 (day 204). Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

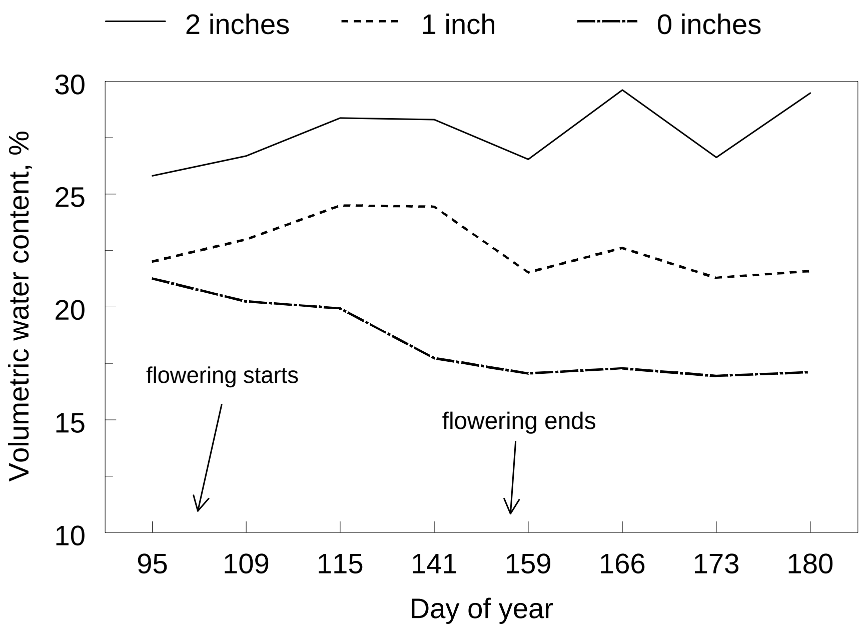

Figure 5. Soil volumetric water content for *Lomatium triternatum* over time. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. *Lomatium triternatum* was harvested on June 29 (day 180) and July 16 (day 197). Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

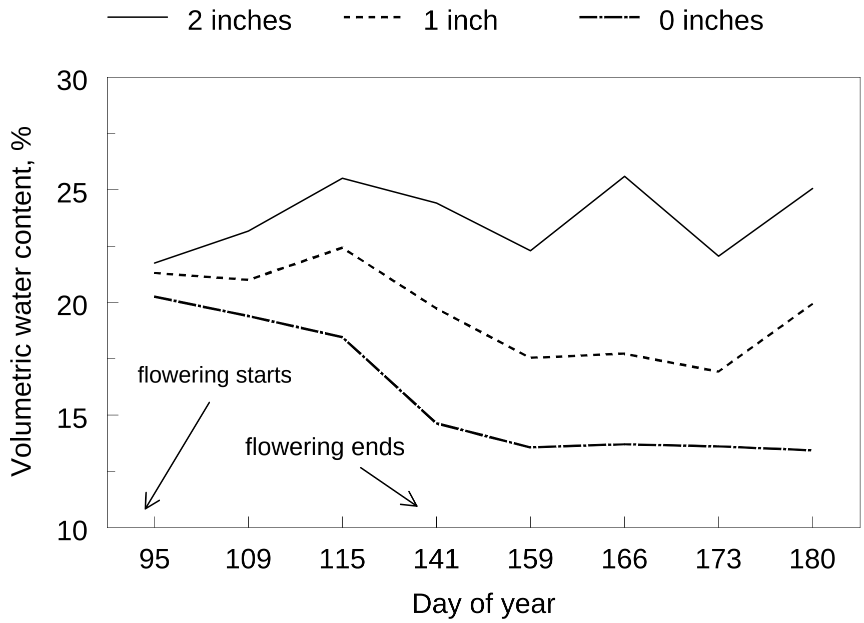

Figure 6. Soil volumetric water content for *Lomatium grayi* over time. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. *Lomatium grayi* was harvested on May 30 (day 151) and June 29 (day 180). Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Publications:

Shock, C.C., E.B.G. Feibert, L.D. Saunders, N. Shaw, and A. DeBolt. 2007. Seed production of native forbs shows little response to irrigation in a wet year. Oregon State University Agricultural Experiment Station Special Report 1075:13-20. http://www.cropinfo.net/AnnualReports/2006/ForbIrrigation2006.htm

Presentations:

Shock, C.C., E.B.G. Feibert, J.K. Ishida, and C.V. Ransom. 2007. Cultural practices for native forb seed production. Developing native plant materials for the Great Basin. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th annual meeting, Reno, NV. Abstract. Invited presentation.

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Shock, C.C. 2007. Oregon progress on the adoption of microirrigation, 2007. Regional working group W1128: Reducing barriers to adoption of microirrigation. Honolulu, HI. Presentation and 4 p. report.

Shock, C.C. 2007. Drip irrigation systems — potential for alternative crops. Winter irrigation workshop: Growing pains in irrigation water management, Ontario, OR.

Klauzer, J., E.B.G. Feibert, H. Parkinson, and C.C. Shock. 2007. Drip irrigation, permanent drip irrigation and wildflower seed production. Malheur Experiment Station annual field day, Ontario, OR.

Products:
Seed was distributed via the Great Basin Native Plant Selection and Increase Project to seed growers.

A handout was distributed to growers at the 2007 field day.

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

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

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Project Description:

<u>Tolerance of Seven Native Forbs to Annual Applications of Postemergence Herbicides</u>

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 the tolerance of native forbs to commercial herbicides.

The trials reported here tested the tolerance of seven native forb species in successive years to conventional postemergence 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.**

Project Status:

Methods and Materials

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

2006 Postemergence 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 ft of the field. Eight treatments including the untreated check were replicated four times in a randomized complete block design (See Tables 2-8). Treatments were applied May 24, 2006 at 30 psi, 2.63 mph, in 20 gal/acre using 8002 nozzles with three nozzles spaced 20 inches apart. Plant injury in 2006 was rated visually on May 31, June 15, and June 30.

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

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. These observations suggest that some degree of phytotoxic damage may be acceptable in establishing native forb seed fields if effective weed control is achieved.

2007 Postemergence Treatments

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

Drip irrigations were applied every 2 weeks starting on April 5 and ending on June 24. Each irrigation applied 2 inches of water.

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

General Considerations

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

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

Table 1. Forb species planted at the Malheur Experiment Station, Oregon State University, Ontario, OR and their origins.

Species	Common name	Origin	Year
Eriogonum umbellatum	Sulfur-flower buckwheat	Shoofly Road (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 for 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 showed herbicide injury on the May 1 evaluation with Goal and Caparol as postemergence treatments (Table 2). There were not significant differences in injury between herbicide treatments on the other evaluation dates. Select and Prowl had among the lowest injury symptoms on the May 11, May 25, and June 12 evaluations.

There were no significant differences in seed yield between herbicide treatments (Table 2). Prowl, the untreated check, and Outlook had among the highest seed yields with no statistical differences between any of the treatments.

Table 2. Tolerance of *Eriogonum umbellatum* to postemergence herbicides applied on April 24, 2007. At time of herbicide applications, plants were 50% dormant. Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Treatment	Rate	Visual estimates of foliar injury, %				Seed yield
	lb ai/acre	May 1	May 11	May 25	June 12	lb/acre
Untreated	--	0.0	0.0	0.0	0.0	91.7
Buctril 2.0 EC	0.125	12.5	22.5	20.0	15.0	38.1
Goal 2XC	0.125	45.0	27.5	17.5	13.8	42.6
Select 2.0 EC + Herbimax	0.094 + 1% v/v	11.7	6.7	3.3	1.7	57.6
Prowl H2O 3.8 C	1	10.0	6.3	3.8	3.8	115.0
Caparol FL 4.0	0.8	28.8	41.3	33.8	26.3	27.3
Outlook 6.0 EC	0.656	2.5	18.8	15.0	15.0	75.1
Lorox 50 DF	0.5	15.0	27.5	27.5	26.3	35.6
LSD (0.05)		19.4	NS	NS	NS	NS

Penstemon acuminatus (Sand penstemon)

No injury symptoms were observed on the May 1 evaluation. On May 11, only Caparol resulted in significantly higher injury symptoms than the check (Table 3). On May 25, Caparol and Buctril resulted in significantly higher injury symptoms than the check. On June 12, Caparol, Buctril, and Select resulted in significantly higher injury symptoms than the check.

Seed yields for Buctril, Select, Caparol, and Lorox were significantly lower than the untreated check (Table 3). Plots treated with Prowl, Outlook, and the untreated check had among the highest seed yields.

Table 3. Tolerance of *Penstemon acuminatus* to postemergence herbicides applied on April 24, 2007. At time of herbicide applications, plants were beginning to flower. Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Treatment	Rate	Visual estimates of foliar injury, %				Seed yield
	lb ai/acre	May 1	May 11	May 25	June 12	lb/acre
Untreated	--	0.0	0.0	0.0	0.0	520.4
Buctril 2.0 EC	0.125	0.0	11.3	16.3	17.5	305.7
Goal 2XC	0.125	0.0	2.5	2.5	7.5	417.8
Select 2.0 EC + Herbimax	0.094 + 1% v/v	0.0	2.5	5.0	17.5	304.6
Prowl H2O 3.8 C	1	0.0	0.0	0.0	0.0	509.4
Caparol FL 4.0	0.8	0.0	18.8	30.0	27.5	162.9
Outlook 6.0 EC	0.656	0.0	0.0	2.5	8.8	502.6
Lorox 50 DF	0.5	0.0	13.8	11.3	17.5	264.9
LSD (0.05)		NS	5.4	8.2	NS	183.4

Penstemon deustus (Hotrock penstemon)

On the first three evaluation dates, Buctril, Goal, Caparol, and Lorox resulted in significantly higher injury symptoms than the check (Table 4). On the last evaluation (June 12), plants treated with Caparol and Lorox still showed injury symptoms.

Seed yields for the Buctril, Goal, Caparol, and Lorox treatments were significantly lower than the untreated check (Table 4). Plots treated with Select, Outlook, Prowl, and the untreated check had among the highest seed yields.

Table 4. Tolerance of *Penstemon deustus* to postemergence herbicides applied on April 24, 2007. At time of herbicide applications, plants were growing vegetatively. Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Treatment	Rate	Visual estimates of foliar injury, %				Seed yield
	lb ai/acre	May 1	May 11	May 25	June 12	lb/acre
Untreated	--	0.0	0.0	0.0	0.0	903.1
Buctril 2.0 EC	0.125	18.3	26.3	18.8	10.0	348.5
Goal 2XC	0.125	18.0	23.8	18.8	17.5	333.0
Select 2.0 EC + Herbimax	0.094 + 1% v/v	1.3	2.5	0.0	2.5	927.3
Prowl H2O 3.8 C	1	0.0	2.5	1.3	2.5	747.6
Caparol FL 4.0	0.8	21.3	48.3	50.0	47.5	86.8
Outlook 6.0 EC	0.656	0.0	1.3	7.5	10.0	835.1
Lorox 50 DF	0.5	21.3	52.5	50.0	38.8	108.5
LSD (0.05)		8.7	14.9	16.4	18.4	334.8

Penstemon speciosus (Royal or sagebrush penstemon)
There were no significant injury symptoms for any of the treatments on the first evaluation (Table 5). Only Caparol and Lorox treatments showed significant injury symptoms, with Caparol having the most severe injury symptoms.

Seed yields for Buctril, Goal, Caparol, and Lorox were significantly lower than the check (Table 5). Plots treated with Select, Outlook, Prowl, and the untreated check had among the highest seed yields.

Table 5. Tolerance of *Penstemon speciosus* to postemergence herbicides applied on April 24, 2007. At time of herbicide applications, plants were beginning to flower. Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Treatment	Rate	Visual estimates of foliar injury, %				Seed yield
	lb ai/acre	May 1	May 11	May 25	June 12	lb/acre
Untreated	--	0.0	0.0	0.0	0.0	55.3
Buctril 2.0 EC	0.125	1.3	2.5	2.5	1.3	24.6
Goal 2XC	0.125	0.0	0.0	0.0	2.5	20.9
Select 2.0 EC + Herbimax	0.094 + 1% v/v	0.0	0.0	0.0	0.0	51.2
Prowl H2O 3.8 C	1	0.0	0.0	0.0	0.0	52.9
Caparol FL 4.0	0.8	0.0	26.3	37.5	42.5	15.7
Outlook 6.0 EC	0.656	0.0	0.0	0.0	0.0	56.6
Lorox 50 DF	0.5	0.0	10.0	6.3	11.3	20.0
LSD (0.10)		NS	4.2	4.1	6.2	29.7

Lomatium dissectum (Fernleaf biscuitroot)
Only plants treated with Buctril showed significant injury symptoms on the first evaluation (Table 6). There were no significant differences in injury between treatments on the last three evaluations.

Lomatium dissectum had a very short growing period before going dormant and did not flower in 2007.

Table 6. Tolerance of *Lomatium dissectum* to postemergence herbicides applied on April 24, 2007. At time of herbicide applications, plants were growing vegetatively. Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Treatment	Rate	Visual estimates of foliar injury, %			
	lb ai/acre	May 1	May 11	May 25	June 12
Untreated	--	0	0	0	0
Buctril 2.0 EC	0.125	5	2.5	3.75	5
Goal 2XC	0.125	1.25	1.25	1.25	0
Select 2.0 EC + Herbimax	0.094 + 1% v/v	0	0	0	0
Prowl H2O 3.8 C	1	0	0	0	5
Caparol FL 4.0	0.8	1.25	1.25	3.75	7.5
Outlook 6.0 EC	0.656	1.25	1.25	1.25	2.5
Lorox 50 DF	0.5	0	0	1.25	0
LSD (0.05)		2.2	NS	NS	NS

Lomatium triternatum (Nineleaf desert parsley)
Only plants treated with Buctril showed injury symptoms (Table 7).

No seed was produced by *Lomatium triternatum* in 2007.

Table 7. Tolerance of *Lomatium triternatum* to postemergence herbicides applied on April 24, 2007. At time of herbicide applications, plants were growing vegetatively. Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Treatment	Rate	Visual estimates of foliar injury, %			
	lb ai/acre	May 1	May 11	May 25	June 12
Untreated	--	0	0	0	2.5
Buctril 2.0 EC	0.125	20	63.75	88.75	92.5
Goal 2XC	0.125	0	0	0	0
Select 2.0 EC + Herbimax	0.094 + 1% v/v	0	0	0	0
Prowl H2O 3.8 C	1	0	0	0	0
Caparol FL 4.0	0.8	0	0	0	0
Outlook 6.0 EC	0.656	0	0	0	0
Lorox 50 DF	0.5	0	0	0	0
LSD (0.05)		2.1	2.5	1.3	2.9

Lomatium grayi (Gray's lomatium)
On the May 1, May 25, and June 12 evaluations only Buctril resulted in injury symptoms significantly higher than the check (Table 8). On the May 11 evaluation, Buctril and Caparol resulted in injury symptoms significantly higher than the check.

No seed was produced by *Lomatium grayi* in 2007.

Table 8. Tolerance of *Lomatium grayi* to postemergence herbicides applied on April 24, 2007. At time of herbicide applications, plants were growing vegetatively. Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Treatment	Rate	Injury %			
	lb ai/acre	May 1	May 11	May 25	June 12
Untreated	--	0	0	0	0
Buctril 2.0 EC	0.125	15	37.5	41.25	28.75
Goal 2XC	0.125	2.5	6.25	1.25	3.75
Select 2.0 EC + Herbimax	0.094 + 1% v/v	0	0	0	0
Prowl H2O 3.8 C	1	0	0	0	0
Caparol FL 4.0	0.8	2.5	11.25	7.5	6.25
Outlook 6.0 EC	0.656	0	0	0	0
Lorox 50 DF	0.5	0	0	0	0
LSD (0.05)		2.7	8.8	8.8	6.7

Summary
All seven species tested were tolerant to Prowl and Outlook applied as postemergence treatments at the rate, timing and soils used in these trials. *Penstemon deustus, P. specious,* and the *Lomatium* species were also tolerant to postemergence applications of Select at the rate, timing and soils used in these trials. Prowl and Outlook are broad spectrum, soil active herbicides that will prevent weed emergence during the season. Select is a foliar contact, grass herbicide. The use of these three herbicides may provide the basis for an effective weed control program for

seed production of these five species. Further tests are warranted to describe the range of safety for these herbicides and whether or not they have any undesirable interactions.

Literature Cited

Shock, C.C. 2006. Drip irrigation: an introduction. Sustainable agriculture techniques, Oregon State University Extension Service. EM8782-E. Revised October 2006. http://extension.oregonstate.edu/catalog/pdf/em/em8782-e.pdf

Shock, C.C., E.B.G. Feibert, L.D. Saunders, N. Shaw, and A. DeBolt. 2007. Seed production of native forbs shows little response to irrigation in a wet year. Oregon State University Agricultural Experiment Station Special Report 1075: 21-32. http://www.cropinfo.net/AnnualReports/2006/ForbIrrigation2006.htm

Publications:

Shock, C.C., J. Ishida and C. Ransom. 2007. Tolerance of seven native forbs to preemergence and postemergence herbicides. Oregon State University Agricultural Experiment Station Special Report 1075:21-32.

Presentations:

Shock, C.C., E.B.G. Feibert, J.K. Ishida, and C.V. Ransom. 2007. Cultural practices for native forb seed production. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th annual meeting, Reno, NV. Abstract. Invited presentation.

Shock, C.C., J.K. Ishida, and C.V. Ransom. 2007. Screening herbicides for use in native wildflower seed production in the Intermountain West. Native wildflower seed production symposium, Orlando, FL.

Shock, C.C. 2007. Oregon progress on the adoption of microirrigation, 2007. Regional working group W1128: Reducing barriers to adoption of microirrigation. Honolulu, HI. Presentation and 4 p. report.

Klauzer, J., E.B.G. Feibert, H. Parkinson, and C.C. Shock. 2007. Drip irrigation, permanent drip irrigation and wildflower seed production. Malheur Experiment Station annual field day, July 11, 2007. Ontario, OR.

Products:

A handout was distributed to growers at the 2007 Oregon State University Malheur Experiment Station field day.

Project Title: Developing Strategies for Selective Herbicide Use in Native Forb Seed Production

Project Location: Utah State University, Logan, Utah

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

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

Materials and Methods
Forb tolerance to preemergence herbicides was tested by planting 50 seeds of each species in 1 ft^2 flats. Seed were scarified between sheets of 80 grit sandpaper prior to planting. Seeds were planted 0.5 inch deep in a soil comprised of a 1:1 ratio by volume of Kidman sandy loam field soil and peat moss and vermiculite potting soil. Herbicides included for evaluation included: Kerb (pronamide), Treflan (trifluralin), Prowl H_2O (pendimethalin), Outlook (dimethenamid-p), Sencor (metribuzin), Plateau (imazapic), Olympus (propoxycarbazone), and Chateau (flumioxazin). Herbicide treatments were applied in an enclosed chamber research bench sprayer calibrated to deliver 20 gpa at 30 psi. After herbicide application, flats were placed in trays filled

with water until the soil was saturated. The flats were then lightly watered from above to incorporate the herbicide. Flats containing *Astragalus*, or *Dalea* species were placed directly in the greenhouse, while flats containing *Crepis* were placed in plastic bags to prevent moisture loss and were stored in a cooler for 3 weeks at 34°F. Flats in the greenhouse were irrigated daily or as needed to maintain moist soil. Plant germination was determined by counting the emerged plants of each species weekly. Any herbicide injury symptoms observed on emerged plants were noted and photographed. Final plant stands will be the determining measurement of whether plants survived the herbicide applications.

Results

Emergence for all species was very low, allowing only preliminary observation of herbicide affects. The number of emerging seedling differed among varieties and herbicides (Table 1). Plants appeared to be tolerant to some herbicides, while few plants of any species emerged in flats treated with Chateau. The higher levels of emergence of *Dalea ornata* and *Crepis acuminata* with Olympus and of *Crepis acuminata* with Plateau are positive as these herbicides could potentially be used to control downy brome in a rangeland setting. Further trials with improved germination will be used to develop conclusions on forb species tolerance to these herbicides.

Table 1. Species germination 5 weeks after preemergence herbicide application.

		Plant germination			
Herbicide	Rate	*Astragalus filipes*	*Dalea ornata*	*Dalea searlsiae*	*Crepis acuminata*
	lb ai/acre	no. plants/flat			
Untreated	--	3.0	6.3	0.5	1.3
Kerb	1.0	4.3	0.3	0.0	3.8
Treflan	0.375	4.3	4.5	0.3	4.3
Prowl H_2O	0.75	3.5	4.8	0.3	1.3
Outlook	0.656	1.3	1.3	0.0	0.0
Sencor	0.375	4.0	0.5	0.3	0.5
Plateau	0.0625	1.0	1.8	0.0	5.5
Olympus	0.0267	2.5	4.5	0.5	4.0
Chateau	0.047	0.3	0.8	0.0	0.0
LSD (0.05)		2.8			

Direction for 2008

Greenhouse testing will continue to evaluate preemergence herbicides and postemergence herbicide treatments. A field of established *Astragalus filipies* provided by Doug Johnson will be treated with postemergence treatments to determine herbicide tolerance of established *Astragalus* plants. Efforts will be made to establish field trials in the fall of 2008.

Management Applications:

The preliminary data suggests that some of the herbicides evaluated will have selectivity on the tested forb species with potential for use in seed production systems.

Project Title: Linking Species and Functional Group Diversity to Resource Capture and Invasion Resistance in Great Basin Plant Communities

Project Location: USDA-ARS, Burns, OR

Principal Investigator and Contact Information:

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Project Description:

Objectives

Understanding the characteristics that make plant communities less susceptible to invasion is a central goal of land managers. Invasibility is expected to be directly linked to the ability of the resident vegetation to sequester limiting resources (Stohlgren et al. 1999; Davis et al. 2000). Resource sequestration may be primarily driven by the most dominant species. Alternatively, resource partitioning may allow dominant and subdominant species to contribute to resource sequestration by the plant community (Grime 1987; Kahmen et al. 2006). For example, spatial and temporal variation in soil nitrogen (N) cycling is substantial in the Great Basin and even small increases in soil N availability can facilitate the establishment of invasive plants (Paschke et al. 2000). Communities with greater species or functional group diversity may partition N to a greater extent than communities with low diversity. As a result, communities with greater species or functional group diversity may be better able to respond to these fluctuating patterns of N supply and maintain lower levels of soil N through the growing season.

The broad objective of this study was to quantify the degree to which soil N is partitioned in time, depth and chemical form (i.e. NO_3^- or NH_4^+) among native species and functional groups (i.e. bunchgrasses and perennial forbs, Table 1) in a sagebrush steppe community and evaluate how these patterns of resource acquisition relate to patterns of resource capture and invasion by annual grasses. I hypothesized that the dominant bunchgrasses and subdominant perennial forbs differ in the timing, depth and form in which they acquire N. Based on expected differences in timing, depth and form of N capture between functional groups, I further hypothesized that plots with all functional groups present will be less susceptible to invasion compared to plots where a functional group is removed.

Methods

This research was conducted in a sagebrush steppe community in eastern Oregon, USA (43 °22′ N, 118°22′ W, 1300 m elevation). Mean annual precipitation in Drewsey, OR, approximately 16 km north of the site is 272 mm. The herbaceous species selected for the experiment are representative of the steppe communities in the Great Basin (Table 1). Bunchgrasses are the major herbaceous component followed by perennial forbs and annual forbs.

Nitrogen partitioning by time, depth and chemical form

To quantify temporal, spatial and chemical patterns of plant N capture I injected ^{15}N compounds into the soil around naturally established target plants of the seven study species three times during the growing season (25 April, 23 May and 20 June 2006), at two different depths (2-7 cm and 17-22 cm) and in two chemical forms (NH_4^+ and NO_3^-). Each treatment combination was replicated five times in a randomized complete block design. Different plants were used for each treatment replicate. To examine how soil water content may influence the pattern of N capture by the study species, a second set of plants were watered with a simulated 25 mm rain event 2 days prior to the N injections in May and June. The water treatment was not applied in April since soils were close to field capacity at this time. Shoot N concentration and ^{15}N enrichment were measured by continuous flow direct combustion and mass spectrometry at the UCDSIF (Europa Integra, London). A mass balance approach following Nadelhoffer and Fry (1994) was used to quantify plant ^{15}N capture, allowing comparisons to be made among species with different biomass or leaf N concentration. Here, plant N capture (mg N plant^{-1}) $= m_f \times [(N_f - N_i)/(N_{lab} - N_i)]$ where m_f is the mass of the N pool (mg), N_f, and N_i are the final and initial Atom % ^{15}N of the sample and N_{lab} is the Atom % ^{15}N of the labeled solution. Spatial, temporal and chemical patterns of N capture by a species were normalized by expressing N capture by a species in a particular treatment as a percentage of the total amount of N capture by a species in all treatments (McKane et al. 2002; Kahmen et al. 2006). The effect of ^{15}N injection time, depth and chemical form on the relative and absolute amount of N captured by a species was analyzed with ANOVA (SAS 1999).

Functional group removal plots

Removal plots were established at two sites in the community to evaluate the degree to which the three most common functional groups in this system resist invasion by the annual grass *Taeniatherum caput-medusae*. Four removal treatments were applied at each site including: 1) Nothing removed, 2) Annual forbs removed, 3) Perennial forbs removed and 4) Bunchgrasses removed. Each treatment was replicated four times at each site in a randomized complete block design. Removal plots were 2 m x 2 m. Functional groups were removed in spring 2004 by brushing a 6% glyphosate solution on all species within the functional group targeted for removal. *T. caput-medusae* was seeded in fall of 2005 at 3000 seeds per m^{-2}. *T. caput-medusae* density in the entire 2 x 2 m plot was counted in June 2006 and 2007. The effect of removal treatment, site and year on density of *T. caput-medusae* was analyzed with ANOVA. Since plots were repeatedly sampled, the ANOVA was conducted as a split-split-plot in time using Proc Mixed with site and time as the split factors (SAS 1999).

<u>2007 Results</u>

Nitrogen partitioning by time, depth and chemical form

Water addition prior to ^{15}N-labeling increased N capture by the study species about 1.3-fold (P = 0.021, data not shown) but did not differentially affect the timing, depth, or form of N capture of the study species ($P > 0.05$). The timing and depth of N capture, however, differed significantly among species ($P < 0.001$ and $P < 0.001$ for species × time and species × depth; Fig. 1). Forbs acquired a greater proportion of N in April compared to May while bunchgrasses acquired a greater proportion of N in May compared to April ($P < 0.001$ and $P < 0.001$, respectively). Annual grasses captured the majority of N in April compared to May ($P < 0.001$). Forbs acquired a greater proportion of N from depth compared to bunchgrasses ($P = 0.006$). Annuals captured more N from shallow soil layers compared to deep soil layers (*P* < 0.001). All study species showed a tendency to acquire more N as NO_3^- compared to NH_4^+.

The total amount of N captured following ^{15}N injection at different times, depths and chemical forms differed significantly among native species (species × time, species × depth, species × form, P < 0.001; Fig. 2). In all treatments, however, bunchgrasses acquired significantly more N than the forbs (*P* < 0.001).

Functional group removal plots

Bunchgrass removal was the only treatment that significantly increased *T. caput-medusae* density compared to the intact control plots. There was no significant effect of site or interaction between removal treatment and site on *T. caput-medusae* density (*P* = 0.671 and *P* = 0.501). Density of *T. caput-medusae* varied across years (*P* = 0.052) but there was no removal treatment by year interaction on *T. caput-medusae* density (*P*= 0.155).

Future Plans

The initial plan for the study was to repeat ^{15}N injection over two growing season to examine the degree to which variation in precipitation amounts influences species patterns of N capture. This approach was revised by exposing half the plants during the first year to a watering treatment. This doubled the sample size the first year but allowed a more explicit test of the influence of precipitation amount on patterns of plant N capture. Therefore, future plans involve a final analysis and publication of 2007 results. These findings also will provide a basis for a planned synthesis paper outlining traits that should be targeted by managers to increase invasion resistance. Greenhouse studies on individual plants also are planned to identify variation in root and leaf physiological traits allowing species to capture nitrogen under different levels of N supply.

Table 1. List of the seven species used in this study. Species are arranged by functional group: invasive annual grass, native perennial bunchgrass and native perennial forb. Nomenclature follows the USDA PLANTS database (http://plants.usda.gov/).

Group	Code	Common name	Scientific name
Annual	BRTE	cheatgrass	*Bromus tectorum* L.
Annual	TACA	medusahead	*Taeniatherum caput-medusae* (L.) Nevski
Bunchgrass	PSSP	bluebunch wheatgrass	*Pseudoroegneria spicata* (Pursh) A. Löve
Bunchgrass	ELEL	bottlebrush squirreltail	*Elymus elymoides* (Raf.) Swezey
Bunchgrass	POSE	Sandberg's bluegrass	*Poa secunda* J. Presl
Forb	LOTR	nineleaf biscuitroot	*Lomatium triternatum* (Pursh) Coult. & Rose
Forb	CRIN	grey hawksbeard	*Crepis intermedia* Gray

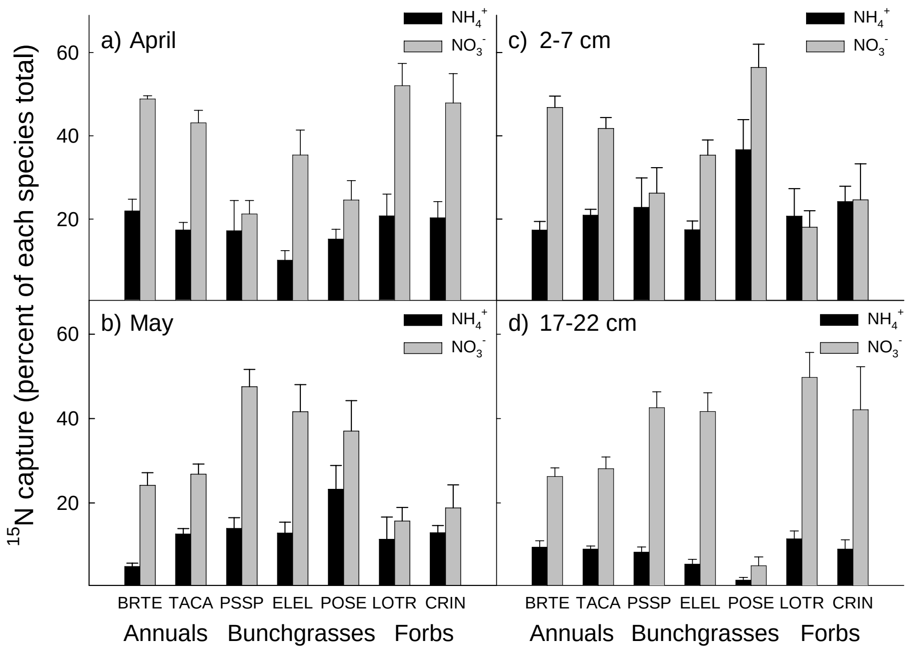

Figure 1. ^{15}N capture by the seven study species as influenced by the time, depth and form of ^{15}N tracer addition. Based on the ANOVA results, panels (a) and (b) show the simple effects of time and N form on species N capture while panels (c) and (d) show the simple effects of depth and N form on species N capture. Plant N capture data are expressed as a percentage of each species total ^{15}N capture. Percentages were calculated individually for each block (mean + SE, n = 10).

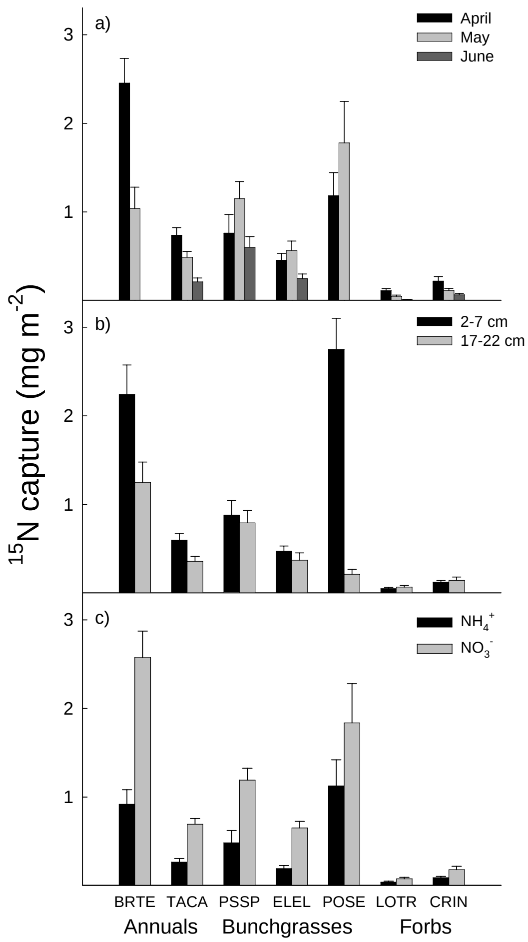

Figure 2. Total N capture by the seven study species as affected by the time (a) depth (b) and form (c) of ^{15}N injections. Values in (a) are averaged over the different depths and chemical form of tracer addition (mean ± SE, *n* = 20). Values in (b) are averaged over the different times and form of tracer addition (mean ± SE, *n* = 40 for BRTE and POSE and *n* = 60 for the other species). Values in (c) are averaged over the different times and depth of tracer addition (mean + SE, *n* = 40 for BRTE and POSE and *n* = 60 for the other species).

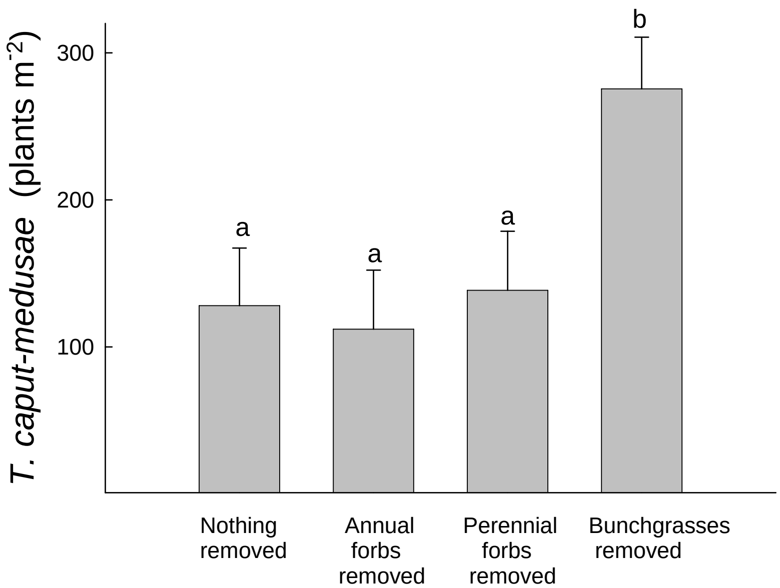

Figure 3. *Taeniatherum caput-medusae* densities in plots where functional groups had been removed at two sites (mean + SE, n = 8). Different letters indicate differences among treatments as determined by LS-means (P < 0.05).

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Presentations:

James, J. 2007. The potential for resource-based niches to contribute to invasion resistance in a semi-arid plant community. Society for Range Management 60th annual meeting, Reno, NV. Abstract 213.

Management Applications:

Understanding mechanisms of invasion resistance is critical for conservation biology and land management. This research demonstrates that at natural levels of species abundance resource partitioning may facilitate species coexistence but not necessarily contribute to invasion resistance by the plant community. This suggests managers should not expect a general mechanism of invasion resistance across systems. Instead, the key mechanism of invasion resistance within a system will depend on trait variation among coexisting species and on how species abundance is distributed in the system. In short, establishing desirable species that can produce the most biomass during the first growing season likely will be the best way to minimize establishment of annual grasses. Establishing a diverse plant community will only be likely to increase invasion resistance if these additional species contribute significantly to the overall biomass of the community.

Products:
Provided part of the basis for a $ 3.6 million USDA-ARS demonstration project.

Contributed to ongoing efforts to develop reseeding guidelines for annual grass infested rangeland.

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

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1. Increase seed germination of *Astragalus utahensis* by inoculation with *Aspergillus* and *Alternaria* fungi

Project Description:
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%) in laboratory conditions. Therefore, *Astragalus utahensis* seeds were inoculated with *Aspergillus* and *Alternaria* fungi to determine if fungal species increase *Astragalus utahensis* germination in natural settings.

Project Status:
Materials and Methods
Field tests were completed in 2007 to determine if the effects of increased germination by *Aspergillus* and *Alternaria*, which were observed in Petri and greenhouse conditions, could be observed in natural conditions. Three sites were chosen for planting with a variety of conditions: 1- Fountain Green on cultivated ground is nestled in the mountain valleys (leeward side of the first group of mountains in the Wasatch range) with an elevation of 1800m, this site receives moisture in the form of snow and remains covered in snow for more time in spring when compared to the other two sites; 2- Nephi is on cultivated ground and is out on an open valley floor at an elevation of 1500m, snow is the main form of moisture but the area loses snow cover early in the spring due to elevation and location in the valley; 3- BYU research farm is on the windward side of the Wasatch range at an elevation of 1300m on cultivated ground, this is likely the most moderate site with snow and rain through the fall as well as winter and into spring. Sites were selected according to availability though they represent a range of elevations and locations throughout Utah.

Results and Discussion

Winter 2005 trials were planted in Nephi and Fountain Green. The response was erratic, but showed a significant effect by the scarified control at the Nephi location (Fig. 1 A). This may be due to the effects of stratification as well as leaching by soil moisture during the winter period, but was most likely due to the fact that the scarified control was planted with a mechanical planter and all other treatments were hand planted. Results at Fountain Green were not significantly different from each other (Fig. 1 B). Spring trials were planted at BYU, Nephi, and Fountain Green. However, they were planted in May, too late to have the benefit of any soil moisture that may have been prevalent early in the spring. These trials showed minimal to no response. This minimal response occurred despite the fact that the BYU farm was irrigated daily for the first month, and twice a week thereafter. This may not have been enough moisture to keep the seed wet and imbibing.

A. **B.**

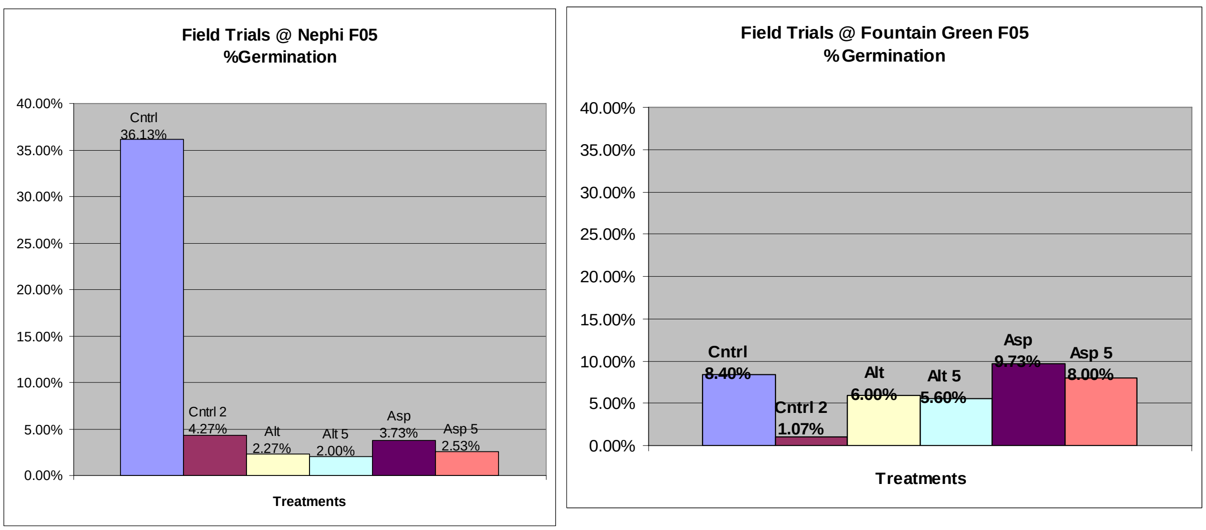

Figure 1: Germination response of *Astragalus utahensis* seeds inoculated with *Aspergillus* or *Alternaria* at differing field locations in 2005, **A** – Field trials in Nephi 2005; **B** – Field trials in Fountain Green 2005.

Winter 2006 trials were planted at BYU, Nephi, and Fountain Green. The response was more defined during 2006 – 2007 growing season, showing similar patterns within the Nephi and BYU sites where the treatment effects were better than the control (Fig. 2 A and B). This response by the treatments indicates that conditions may have been optimal for fungal growth and that these treatments allowed greater germination because of a break-down in the seed coat. SEM photographs of the interaction of *Alternaria* at the seed coat show significant breakdown of integuments by the fungus. The unscarified seed lacked much of a response as would be expected considering that the seed coat had not been compromised enough to enhance germination. The scarified, water soaked control showed germination patterns consistent with the scarified seed, though slightly lower, indicating that there might be a minimal effects by leachable inhibitory substances and more of an imbibition response where seeds exposed to copious amounts of water build up internal pressures which serve to allow the radical to break through the seed coat. In the case of this distinction in-vitro tests, where soaking for 24 hrs in H_2O occurred, showed significant responses over the scarified unsoaked seed that were placed in controlled moisture conditions (7 mL H_2O soaked on a germination blotter paper) from the start.

The soaking treatment, though extreme, may indicate that conditions are more likely to be similar to those where the seed has maximum exposure to H_2O, as with the soaking experiments, because of the snow melt and spring rains that penetrate the soil exposing the seed to a higher moisture regime. This allows imbibition and in turn increases internal pressures, permitting the radical to burst through the seed coat. Fountain Green showed minimal response to treatments and controls. This may have been due to suboptimal germination conditions with temperature playing a primary role in lack of germination and fungal involvement therein.

A. **B.**

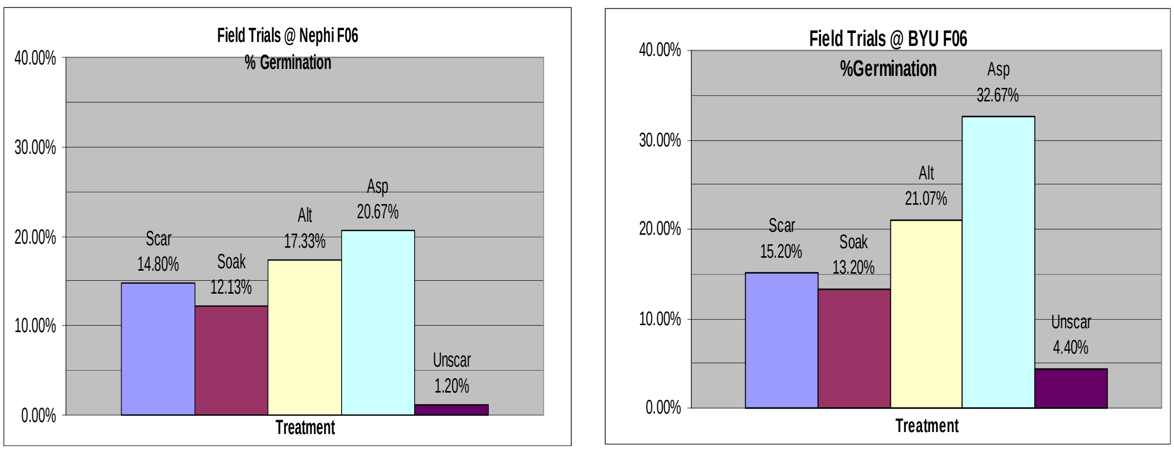

Figure 2: Germination response of *Astragalus utahensis* seeds inoculated with *Aspergillus* or *Alternaria* at differing field locations in 2006, **A** – Field trials in Nephi 2006; **B** – Field trials in Spanish Fork 2006.

Despite the fact that spring trials were planted mid-March, in time for the seeds to have maximum exposure to spring moisture they yielded minimum responses. Fountain Green showed the most response of the three sites with no significant differences among the treatments (Fig. 3). The Fountain Green site may have retained more soil moisture over the course of the spring due to elevation and perhaps other factors. This response indicates that the best time to plant is in the fall and that responses are minimal when planted early spring.

<u>Conclusions</u>

Field trials showed variability between sites and inconsistency in treatment response as compared with the in-vitro and greenhouse trials of this study. However, when all treatments were planted in the same manner and planted in the fall, inoculated seeds, particularly with *Aspergillus*, seemed to do the best (Fig. 2 A and B). Availability of moisture and other factors during fall plantings supply a greater benefit than spring plantings. The practical application of inoculating *Astragalus utahensis* seeds for revegetation would be to utilize the treatment as a part of preparing seedlings rather than direct seeding, but data from Nephi and BYU Spanish Fork farm suggest that when seeded in the fall the fungal inoculums may increase seed germination and establishment.

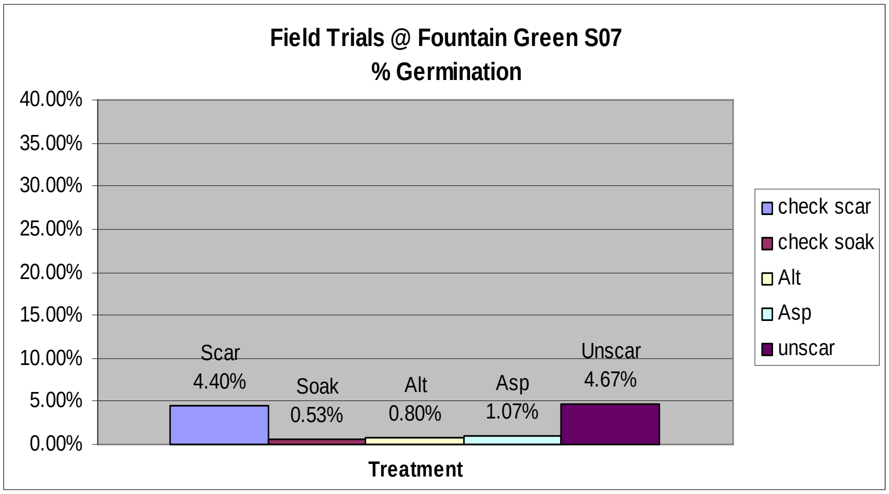

Figure 3: Germination response of *Astragalus utahensis* seeds inoculated with *Aspergillus* or *Alternaria* in field trials planted in the spring of 2007.

Products

Publications:

Manuscripts:

Eldredge, S. D. 2007. Beneficial fungal interactions resulting in accelerated germination of *Astragalus utahensis*, a hard-seeded legume. Brigham Young University, Provo, UT. Thesis.

Eldredge, S. D., B. Geary, and S. Jensen. Beneficial fungal interactions resulting in accelerated germination of *Astragalus utahensis*, a hard-seeded legume. Plant Ecology (in prep.)

Eldredge, S., B. Geary, J. Gardner, and S. Jensen. Mechanisms of fungal accelerated germination of the hard-seeded legume, *Astragalus utahensis* by *Aspergillus* and *Alternaria* fungi. Plant Ecology (in prep.)

Eldredge, S. D., and B. Geary. Seed germination as influenced by microorganisms and the associated natural resource management implications. Plant Ecology (in prep.)

Eldredge, S., B. Geary, and S. Jensen. 2007. Field and greenhouse trials relating complex soil environments with accelerated germ responses of *Astragalus utahensis* to *Alternaria* and *Aspergillus* fungi. American Phytopathological Society. San Diego, CA. Phytopathology 96:S32.

Presentations:

Eldredge, S., B. Geary, and S. Jensen. 2007. Field and greenhouse trials relating complex soil environments with accelerated germ responses of *Astragalus utahensis* to *Alternaria* and *Aspergillus* fungi. American Phytopathological Society annual meeting, San Diego, CA.

2. Comparison of cultured *Rhizobium* to commercial *Rhizobium* as inoculants in various Lupinus species to promote root nodulation and nitrogen fixation

Project Description:
Rhizobium is important for legume plant growth and health because of the nitrogen that it provides for the plant. Many *Rhizobium* species have evolved together with their host plants to form important symbiotic relationships. It has been determined in some legume plant species that specific *Rhizobium* isolates help the plant to grow better through improved plant health. Therefore, this project explores the best way to germinate *Lupinus* seeds and determine if *Rhizobium* cultured directly from *Lupinus* plants increases plant growth over commercial *Rhizobium* products that were not collected from *Lupinus* species.

Project Status:
Materials and Methods
Using metabolism tests on artificial media, collected bacterial isolates are determined to be *Rhizobium* or another genus of bacteria. If the bacterial isolates are *Rhizobium*, then those isolates will be inoculated onto *Lupinus* plants that are grown in sterile rooting media. All plants will be monitored for growth by dry biomass and number of nodules per plant.

Results and Discussion
Based upon growth and metabolism tests on artificial media, 5 of 14 bacterial isolates have been identified as possible *Rhizobium* isolates. These 5 isolates will be inoculated onto *Lupinus* species plants.

Lupinus seeds are not germinating and growing well in the sterile growth media. Seeds were started in perlite and Turface® growth media, neither seemed to have high germination and when seeds did germinate they died within a few weeks. Multiple treatments were explored to aid germination; seeds were scarified with a scalpel, soaked in ethanol, soaked in various bleach concentrations, boiled, soaked in giberellic acid, or a combination of treatments were applied. Establishing germination and seedling survival is now the primary concern before the *Rhizobium* study is initiated.

3. Improved germination of *Stipa comata* through fungal inoculations

Project Description:
Sean Eldredge's studies with *Astragalis utahensis* in association with *Aspergillus* and *Alternaria* have indicated that seed germination can be enhanced with fungal infections. In germination trials of *Stipa comata*, it was observed that an increase in germination often followed a fungal infection of the seeds. Therefore, the purpose of this study is to, 1- determine if *Aspergillus* and *Alternaria* inoculated seeds can increase germination of *Stipa comata*, and 2 - culture out fungi that naturally grow on non-sterilized seeds for identification and testing to determine if there is a fungus that improves germination of *Stipa comata* seeds.

Project Status:

Materials and Methods

Stipa comata seeds were sterilized with ethanol and bleach; seeds were rinsed in distilled water 5 times for 30-60 seconds each time then placed on moistened blotter paper in Petri dishes. Petri dishes contained 20 seeds each (15 plates of 20, with 5 plates in each group). The plates were stratified in the refrigerator for 3 weeks. Each group of 100 seeds was then treated differently. One group was inoculated with an *Alternaria* spore solution of 1.79×10^6 spores/mL. The second group was inoculated with an *Aspergillus* spore solution of 1.65×10^6 spores/mL. The third group was not inoculated.

Results and Discussion

After 4 different germination trials, varying the time the seeds were submersed in ethanol and bleach and varying the concentrations of bleach, it was determined that ethanol is very effective at killing the seed. Seeds that are sterilized in 10% bleach without ethanol had the best germination.

Seven days following inoculation with *Aspergillus* and *Alternaria*, all of the inoculated *Stipa comata* seeds had fungal infections. After 1 week, 22 seeds in the *Alternaria* group, 16 seeds in the *Aspergillus* group, and 15 seeds in the control group had germinated (Table 1). There were 5 seeds in the control group that had grown a fungus after 1 week.

After 17 days following inoculation, 40 seeds out of 100 in the *Alternaria* group had germinated, 20 seeds in the *Aspergillus* group had germinated, and 22 seeds in the control group had germinated (Table 1).

Table 1. Percent germination of *Stipa comata* seeds following inocuation with *Alternaria* and *Aspergillus* fungi.

Post inoculation	***Alternaria***	***Aspergillus***	**Control**
Seven days	22	16	15
Seventeen days	40	20	22

Conclusions

These preliminary studies were to determine if differences exist between the treatments, however they were not blocked or repeated properly for statistical analysis. It appears *Alternaria* may influence *Stipa comata* seed germination, further research will continue to determine if differences are significant.

Project Title: Forb Seeding Depths, Managing Wildland Shrub Stands, Seed Yield Losses in *Asteraceae*, and Established Grasses Effects on Shrub and Forb Emergence

Project Location: Brigham Young University, Provo, UT

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Project Description:
The following projects had activity during 2007.

- Seeding depth study
- Manipulation of wild bitterbrush and sagebrush stands
- Seed yield losses due to tephritid fruit flies in Asteraceae
- Shrub and forb establishment in a competition matrix of native and introduced grasses

1. Seeding depth study

The seeding depth study is designed to determine optimal planting depth of native forbs at depths of 1, 1/2, 1/4, 1/8, and 0 inches in a clay-loam and sandy soil. There is almost no data published addressing this important issue for native forb species.

The following species were investigated in 2007:

Balsamorhiza sagitatta
Crepis acuminata
Crepis intermedia
Perideridia bolanderi

This study was conducted twice during 2007 (*Crepis acuminata* was not repeated during the second run as we already had data from a previous run of the experiment.). During both runs, each species was planted in 6 different flats, 3 of sandy soil and 3 of clay soil. Each flat was planted with 5 rows of 30 seeds each (with the exception of *B. sagittata* which had 25 seeds per row due to limited seed). The rows were randomly selected for the following 5 depths: 0, 1/8”, 1/4", 1/2", and 1". All flats were given 6 weeks of cold stratification prior to being placed in the greenhouse. Flats were watered with an automatic mist adjusted as needed to keep the soil moist.

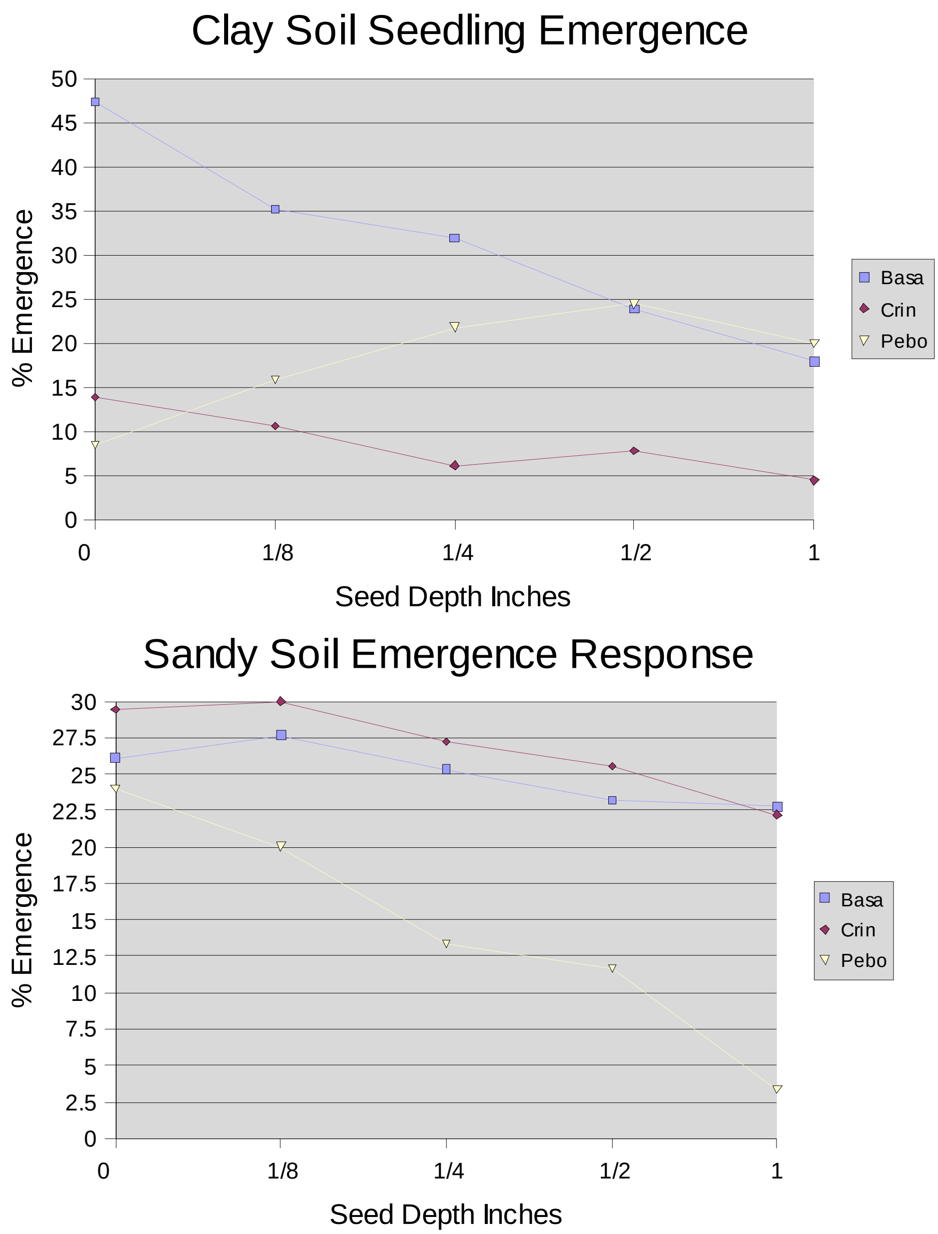

Figure 1. *Balsamorhiza sagitatta*, *Crepis intermedia*, and *Perideridia bolanderi* seedling emergence at different seeding depths.

Results from the 2007 data as well as for previous years are in the process of preparation for publication.

Management Applications:
Typical reseeding projects using seed drills plant seed at depths that may not be optimal for emergence. Our research reveals that most seed emerge best at shallow depths. The challenge then is to plant seed at depths that provide the best moisture availability but still with acceptable emergence. There are thresholds where no seed will emerge. Knowing the emergence range of various forb species in native soils will assist in not only identifying the optimal depth per species, but also which species can share the same planting depth and therefore the same seed box in a seed drill. The high cost of native forb seed requires judicial placement of that seed at the depth that will most contribute to an acceptable outcome for the monetary investment.

2. 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 antelope bitterbrush and Wyoming big sagebrush. 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.

Results of this project were reported in 2006 and published in thesis format in 2007. Also, data on treatment results were collected for a third season in 2007 with final results pending analysis.

Publications:
Armstrong, J .C. 2007. Improving sustainable seed yield in Wyoming big sagebrush. Brigham Young University, Department of Plant and Animal Sciences, Brigham Young University, Provo, UT. Thesis. 28 p.

Roberts, F.L. 2007. Investigation into seed collection practices and shrub manipulations to improve sustainable seed yield in wildland stands of bitterbrush *(Purshia tridentata).* Brigham Young University, Department of Plant and Animal Sciences, Brigham Young University, Provo, UT. Thesis. 35 p.

Presentations:
Anderson, V.J., R.L. Johnson. 2007. Maximization of Great Basin wildland forb seed production using variations of cultural practices. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th Annual Meeting, Reno, NV. Abstract. Invited presentation.

Johnson, R.L. and V.J. Anderson 2007. Influences on wildflower seed yields by row spacing and mulching practices, and improving seed production in wild populations for seed harvesting. Native Wildflower Seed Production Research Symposium, Orlando, Florida. Invited speaker.

Roberts, L., V.J. Anderson, and R. L. Johnson. 2007. Investigations into seed collecting practices and stand manipulation to maintain seed production in wildland populations of antelope bitterbrush and Wyoming big sagebrush. Developing native plant materials for the Great

Basin. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th Annual Meeting, Reno, NV. Abstract. Invited presentation.

3. 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.

In 2007, *Wyethia amplexicaulis*, *Crepis acuminata*, and *Agoseris glauca* sites were sampled for the occurrence of flower visitors. Capitula were also sampled for rearing trials to determine the extent of seed damage by seed predators as well as the predator composition and predator-parasitoid relationships. Imidachloprid was applied to a sample population as a soil drench and a foliar spray and capitula sampled in similar fashion. For the second season in a row, a late freeze killed the flowers from the *Balsamorhiza* sites. Some 2-year summary results of seed damage and imidachloprid application are provided (Fig.1).

Future plans include a follow-up study in seed predator infestation rates in *Balsamorhiza* following a 2-season hypothesized seed predator decline due to late frosts. Also, there is a flower size preference difference observed in to sympatric pests on *Wyethia amplexicaule*. We intend to investigate that phenomenon further.

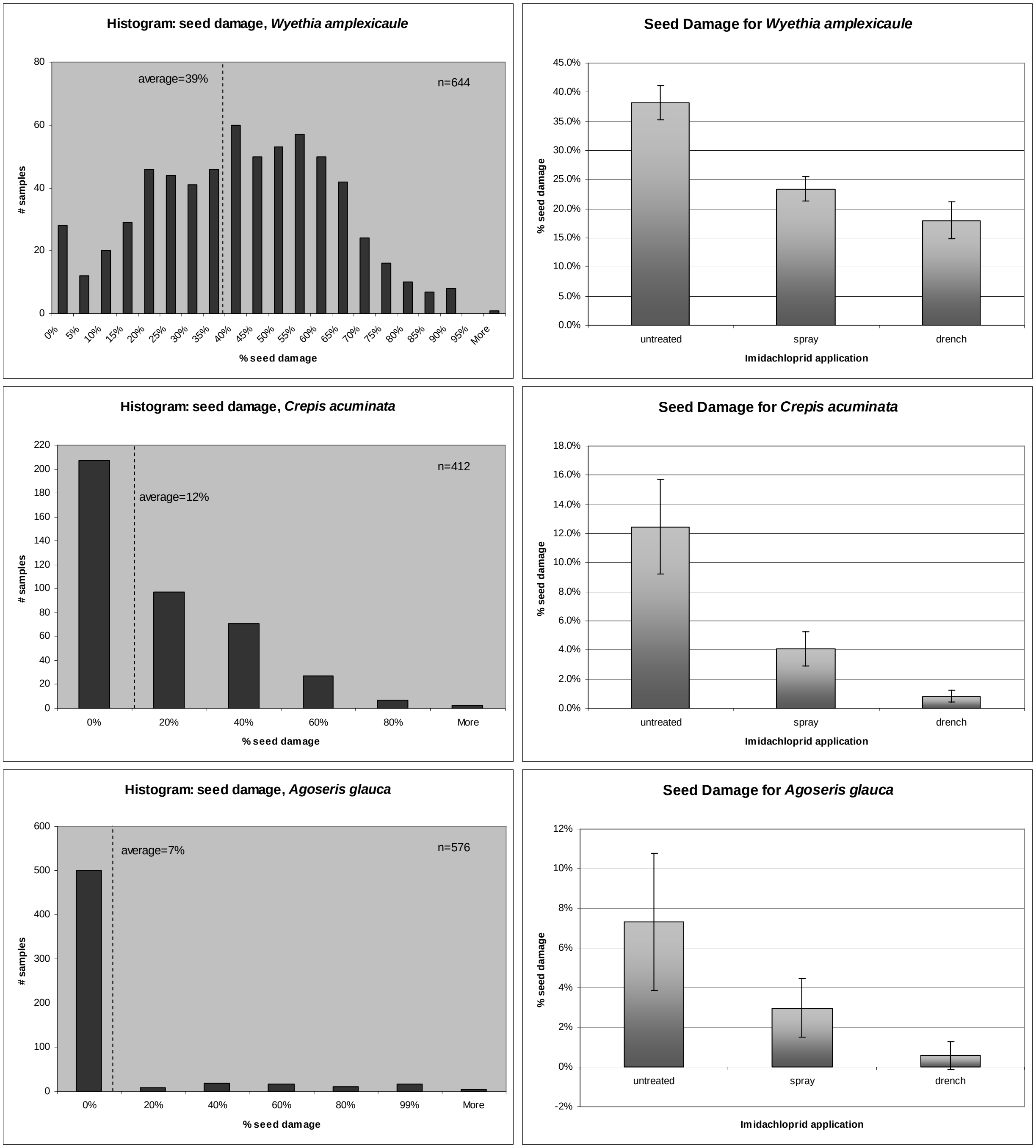

Figure 1. Two year summary results of *Wyethia amplexicaulis*, *Crepis acuminata*, and *Agoseris glauca* seed damage and seed damage from imidachloprid application.

Presentations:

Johnson, R.L., V.J. Anderson. 2007. Controlling insect seed damage in wildland composite populations in the Intermountain West. Developing native plant materials for the Great Basin. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th annual meeting, Reno, NV. Abstract. Invited presentation.

Management Applications:
Agricultural production systems consistently deal with yield reductions due to pest species. The agronomic production of native species for seed production has witnessed the same phenomenon for those few species grown over large acreage. The question remains as to what pest problems can be expected in species previously not commercially grown. By looking at the occurrence of pests that directly affect seed yield in native populations, you can make predictions of infestation rates likely to be exceeded in agricultural monocultures. The fact that *Wyethia amplexicaule* has a consistent and high degree of seed pest damage in wildland settings forewarns future seed producers the need to implement Integrated Pest Management Plans (IPMP). The use of imadachloprid gives evidence of at least an average 20% reduction in seed yield losses. Other chemicals may prove more effective. The other species studies reveal similar requirements for attention to existing pest problems.

Another approach to increasing available seed is to manage dense wild populations for wild seed production. Since pesticide application had positive effects on seed yield in wild stands, managing such stands for increased yields has merit.

4. Shrub and forb establishment in a competition matrix of native and introduced grasses

This project looks at the competitive effect of established grasses on seedling emergence and establishment of native shrubs and forbs. Seeds are cached in the interspace of established grass species planted at ¼ meter spacings. The competitive effect is measured as pre-dawn water potential in the emerging plants leaf tissue. The competitive matrix comprise the following species:

Sporobolus airoides (alkali Sacaton)
Elymus salinus (Salina wildrye)
Pseudoroegneria spicata (bluebunch wheatgrass)
Elymus cinereus (basin wildrye)
Psathyrostachys juncea ‘Bozoiski’ (Russian wildrye)
Agropyron desertorum 'Vavilov' (Siberian crested wheatgrass)

Within the grass matrix, seed caches of the following species were planted in 2007 at 1/8-1/4 inch deep depending upon the species.

Purshia tridentata (bitterbrush)
Chyrsothamnus viscidiflorus (viscid rabbitbrush)
Amelanchier alnifolia (Utah serviceberry)
Cercocarpus montanus (mountain mahogany)
Achillea millefolium (yarrow)
Penstemon strictus (Rocky Mountain penstemon)
Sphaeralcea munroana (Munroe’s globemallow)
Heterotheca villosa (hairy golden aster)

Management Applications:
The competitive nature of some established plant species may preclude the establishment of additional interseeded species, especially without competitive release. Because grass species have cheaper seed, are more amenable to traditional revegetation practices, and have demonstrated an easier ability to establish in wildland settings, they often form the primary cover in successful restoration projects. Adding forb and shrub diversity to a standing grass cover may be an important next-step in restoration goals. Knowing which species can successfully be interseeded and established within various standing grass species will assist managers in their decision making processes of seed selection. Also, knowing the competitive effect of the species comprising the grass matrix can help determine the appropriateness of seed selection for desired long-term outcomes.

Project Title: Characterizing Multi-species Interactions in Response to Disturbance

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

Principal Investigators and Contact Information:

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Project Description:
Big sagebrush communities (*Artemisia tridentata* Nutt.) in the Great Basin have been degraded by the synergistic consequences of chronic disturbance and annual weed invasion (Young and Evans 1978). Repairing ecosystem function is an overarching goal of restoration efforts, but it remains unclear which species most effectively resist weed invasion and how disturbance mediates weed invasion. We evaluated whether disturbance similarly facilitates invasion in single-species grass, forb, and shrub plots.

Project Status:
Materials and Methods
Experiments were conducted at Millville, UT (41°39.44'N, 111°48.88'W, 1402 m). The soil is a gravelly loam series. Plots (1.5 m x 1.5 m, 1 m aisles) were established in May 2003 from transplants reared in a greenhouse, and consisted of 24 plants in a 5 x 5 square arrangement equally spaced (30 cm apart), with the center plant absent. Three plot-types were randomly located with 30 replicates: grass (*Agropyron cristatum* [L.]), forb (*Achillea lanulosa* [Nutt.] Piper), and shrub (*Artemisia tridentata* var.*wyomingensis* [Beetle & A. Young] Welsh). A disturbance treatment was applied in mid November 2004 to 15 replications by removing four plants from the 1 m^2 center of plots with a shovel to potentially increase above and below-ground resources and create safe seed sites for the two invasive species. Plots were seeded an invasive annual grass (*Bromus tectorum* L.) and an invasive forb (*Isatis tinctoria* L.) autumn 2004 and 2005 (400 seeds per species). Total weed seedling density was determined in summer 2005 and 2006. Total (non-weed) shoot dry mass, soil nitrate and solar radiation (400-700 nm) at the soil surface was determined for plots in summer 2006.

Results
Disturbance significantly increased weed density for all three growth forms except for *Agropyron* in 2006 (Fig. 1). Within a treatment, weed density was less variable in 2005 than 2006. Weed density also sharply increased between 2005 and 2006 in all plots except *Agropyron*. In fact, weed density declined within disturbed *Agropyron* plots during the study. In contrast, *Achillea* and *Artemisia* plots had 2-3 fold greater weed density than *Agropyron*. Total plot non-weed shoot dry mass (g) of *Achillea* (1957 ± 542) was lower (P<0.01) than

Agropyron (4608 ± 542), which was lower (P<0.01) than *Artemisia* (14,594 ± 542). The disturbance treatment did not consistently increase soil nitrate (mg kg^{-1} soil) or solar radiation at the soil surface (μmol m^2s^{-1}). However, *Achillea* plots had significantly greater (P<0.01) mean soil nitrate and solar radiation (5.2 ± 0.05 and 382 ± 50) than *Agropyron* (1.3 ± 0.05 and 355 ± 50) and *Artemisia* (0.9 ± 0.05 and 155 ± 50) plots, respectively.

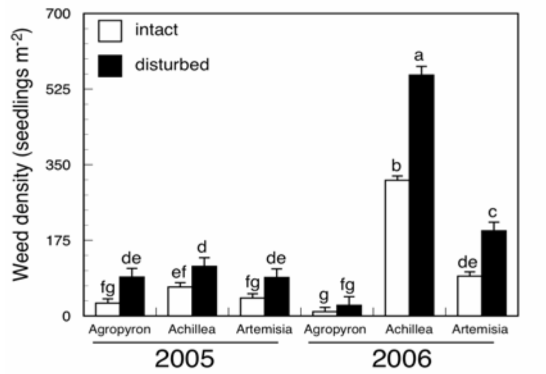

Figure 1. Mean (+1 SE) weed density in autumn. Lowercase letters indicate differences (P<0.01).

Conclusions

The importance of disturbance to mediating weed invasion is clearly corroborated by our results. The capability of the long-lived perennial grass (*Agropyron*) to resist invasion appears to be associated with greater biomass productivity. In contrast, high susceptibility to weed invasion of *Achillea* plots was due to significantly greater amounts of underutilized above and belowground resources (Davis et al. 2000). Our results agree with the general contention that disturbance events increase available resources or safe sites for weed invasion. Perennial grasses appear to be a necessary component of minimizing underutilized resources. Our results also emphasize that managerial efforts to reduce the recurrence of disturbance events should be a primary goal to reduce the impacts and prevent continual dominance of invasive annual species in the sagebrush-steppe ecosystems of the Great Basin.

Literature Cited

Davis, M.A., Grime, J.P., Thompson, K. 2000. Fluctuating resources in plant communities: a general theory of invisibility. Journal of Ecology 88:528-534.

Young, J.A., Evans, R.A. 1978. Population dynamics after wildfires in sagebrush grasslands. Journal of Range Management 31:283-289.

Publications:

Leonard, E. 2007. Competition for soil nitrate and invasive weed resistance of three shrub-steppe growth forms. M.S. thesis, Utah State Univ., Logan, Utah. 77 p.

Leonard, E.D., T.A. Monaco, J.M. Stark, and R.J. Ryel. 2008. Invasive forb, annual grass, and exotic shrub competition with three sagebrush-steppe growth forms: acquisition of a spring ^{15}N tracer. Invasive Plant Science and Management 1(2): *in press.*

Management Applications:

This research identifies that disturbance in big sagebrush-steppe should be avoided to prevent weed invasion. Perennial grass establishment is critical to prevent weed invasion.

Project Title: Diversification of Crested Wheatgrass Stands in Utah

Project Location: Brigham Young University, Provo, UT
Research Sites: Skull Valley and Lookout Pass, 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 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 2007 and state directions for 2008.

<u>Crested wheatgrass diversification:</u>
Two sites in Tooele Co., Utah were selected for large-scale manipulation of crested wheatgrass stands. The Skull Valley site, which borders 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 is 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 Taylorsflat 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 (UD) or received a partial control mechanical treatment (1-way disking; PCM); or full control mechanical treatment (2-way disking; FCM); or partial control herbicide treatment (16 oz/ac [1.1 L/ha] Roundup Original Max; PCH); or full control herbicide treatment (44 oz/ac [3.2 L/ha] Roundup Original Max; FCH) to reduce or eliminate 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 ground. 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. Utah Division of Wildlife Resource supplied all seed for the study except for 'Eagle' 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's 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
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 3000 samples per site. Both transects and quadrats were placed in a stratified random manner by selecting a random starting point and then placing the transects and the quadrats at consistent intervals. At Lookout Pass, transects were spaced every 12 meters beginning at meter 13. Quadrats were then 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.

Data were collected in June 2006 and May 2007 using 0.25 m^2 quadrats. Within each 0.25 m^2 quadrat, density was determined for all species. Percent cover for perennial species and cheatgrass was estimated ocularly using cover classes. Nested frequency was determined for cheatgrass, exotic annual forbs, and crested wheatgrass seedlings.

Data Analysis:
Data relating to crested wheatgrass control were analyzed separately from data relating to seeded species. Data were also analyzed according to first year response to treatment (Year 1: treatments implemented 2005, data collected in 2006; and Year 2: treatments implemented in 2006, data collected in 2007) and repeated measurements of Year 1 plots (data collected in 2006 and 2007). Crested wheatgrass control variables included: mature crested wheatgrass and residual perennial grasses (density, cover); crested wheatgrass seedling and exotic annual forbs (density, frequency); and cheatgrass (density, frequency, and cover). Seeded species 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 (UD, PCM, FCM, PCH, FCH), and seeding (seeded vs. unseeded), with site considered fixed and both block and treatment considered random affects. We used an arcsin transformation to normalize the cover 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 and B). Compared to the control plots (UD) in 2006, data collected from treatments implemented in 2005 showed that two-way disking (FCM) decreased wheatgrass cover from 14% to 6% at Lookout Pass, and from 14% to 4% at Skull Valley. In 2007, data collected from the treatments implemented in 2006 showed that FCM reduced wheatgrass cover from 6% to 3% at Lookout Pass and from 7% to 1% at Skull Valley (Table 2). Compared to the UD plots, FCH (3.2 L/ha) reduced mature crested wheatgrass cover from 14% to 5% at Lookout Pass and from 14% to 11% at Skull Valley in 2006. In 2007, crested wheatgrass cover increased in the FCH plots at Lookout Pass from 6% to 8%; at Skull Valley, FCH reduced crested wheatgrass cover from 7% to 4% (Table 2).

Mature crested wheatgrass density was not significantly different among treatments ($P > 0.05$) at either the Lookout Pass site in 2006 and 2007, or at the Skull Valley site in 2007. However, at the Skull Valley site in 2006, mature crested wheatgrass density decreased from 13.4 to 5.9 plants/m^2 in FCM plots ($P < 0.05$; Table 2).

Crested seedling density was not significantly different among treatments ($P > 0.05$) at either site in the first year post-treatment. Between 2006 and 2007 at Lookout Pass, crested wheatgrass seedling density increased significantly ($P < 0.05$) in the UD plots (4.6 to 20.7 plants/m^2) and PCH plots (4.3 to 12.3 plants/m^2) (Fig. 1C). Between 2006 and 2007, crested wheatgrass seedling density was not significantly different at the Skull Valley site between treatments ($P > 0.05$; Fig. 1D).

Weed invasion. At both sites, weed invasion was greater in mechanical treatments versus herbicide treatments (Fig. 1E and F). At Lookout Pass, cheatgrass density increased significantly ($P < 0.05$) between 2006 and 2007 on the PCM plots (1.2 to 10.8 plants/m^2) and on the FCM plots (2.1 to 29.6 plants/m^2). At Skull Valley, cheatgrass density increased significantly ($P < 0.05$) between the two years on the UD plots (33.6 to 123.3 plants/m^2), PCM (36.8 to 231.6 plants/m^2), FCM (34.7 to 202.2 plants/m^2) and PCH (8.9 to 55.1 plants/m^2) (Fig. 1F). The overall increase of cheatgrass across all treatments at Skull Valley may be attributed to a fall germination event due to higher precipitation in September and October of 2006 (Fig. 2). Areas treated with herbicide had lower densities of cheatgrass relative to mechanical plots. In 2007 at Lookout Pass, FCM plots had significantly ($P < 0.05$) higher amounts of cheatgrass than both herbicide treated plots. At Skull Valley in 2007, mechanical treatments had significantly higher amounts of cheatgrass than both herbicide treated plots (Fig. 1F).

Between 2006 and 2007, exotic annual forb density increased significantly at Lookout Pass (7.4 to 140 weeds/m^2; $P < 0.05$). At Lookout Pass, *Alyssum alyssoides* accounted for 94% of all exotic annual forbs encountered. *Sisymbrium altissimum* comprised 5.3% while *Salsola iberica*, *Latuca serriola*, *Lepidium perfoliatum*, *Erodium cicutarium,* and *Descurainia sophia* comprised <0.1%. Between 2006 and 2007, exotic annual forbs also increased at Skull Valley from 2.2 to 4.8 weeds/m^2. *S. iberica* comprised 61% followed by *S. altissimum* (17.6%) and *L. perfoliatum* (11.6%). *A. alyssoides* comprised 8.5% while *L. serriola, E. cicutarium*, and *D. sophia* were <0.1%. Due to large quantities of *Ceratocephala testiculata* at both sites, density was not collected, however, it is estimated to have approximately 40% ground cover and was considered to be the dominant exotic annual forb.

Seeded species. None of the crested wheatgrass control treatments affected seeded species emergence (Table 2). There was greater emergence of seeded species at Lookout Pass compared to Skull Valley. This is likely due to higher precipitation at Lookout Pass (Fig. 2). At both sites, seeded grasses had greater emergence than either shrubs or forbs. Drill seeded species encountered most frequently were the grasses bluebunch wheatgrass, Indian ricegrass, and squirreltail, and the forb Lewis flax. Of the species that were broadcast, Sandberg bluegrass was most common; yarrow was noted occasionally. Although shrubs were encountered rarely during data collection, seedlings of Wyoming big sagebrush were noted (Table 3).

Timeline:
Data will be collected in May of 2008 on year 1 and year 2 blocks at both sites.

Technology Transfer:

Hulet, A., B.A. Roundy, B. Jessop, and J. Coleman. 2007. Diversification of crested wheatgrass stands in Utah. Developing native plant materials for the Great Basin. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th annual meeting, Reno, NV. Abstract. Invited presentation.

Hulet, A., B.A. Roundy, B. Jessop, J. Coleman. 2007. Diversification of crested wheatgrass stands in Utah. Utah Society for Range Management annual meeting, Price, UT.

Poster Presentations:

Hulet, A., B.A. Roundy, B. Jessop, J. Coleman. 2007. Diversification of crested wheatgrass stands in Utah. Restoring the West Conference 2007 Sagebrush Steppe Restoration, Logan, UT.

Hulet, A., B.A. Roundy, B. Jessop, J. Coleman. 2008. Diversification of crested wheatgrass stands in Utah. Society for Range Management-AFGC annual meeting, Louisville, KY.

Management Application:

This study shows the difficulty of attempting to control crested wheatgrass, establish native species, and minimize weed invasion simultaneously. Follow-up treatments to control both residual and seedbank wheatgrass as well as weeds may be necessary to convert wheatgrass stands to native communities.

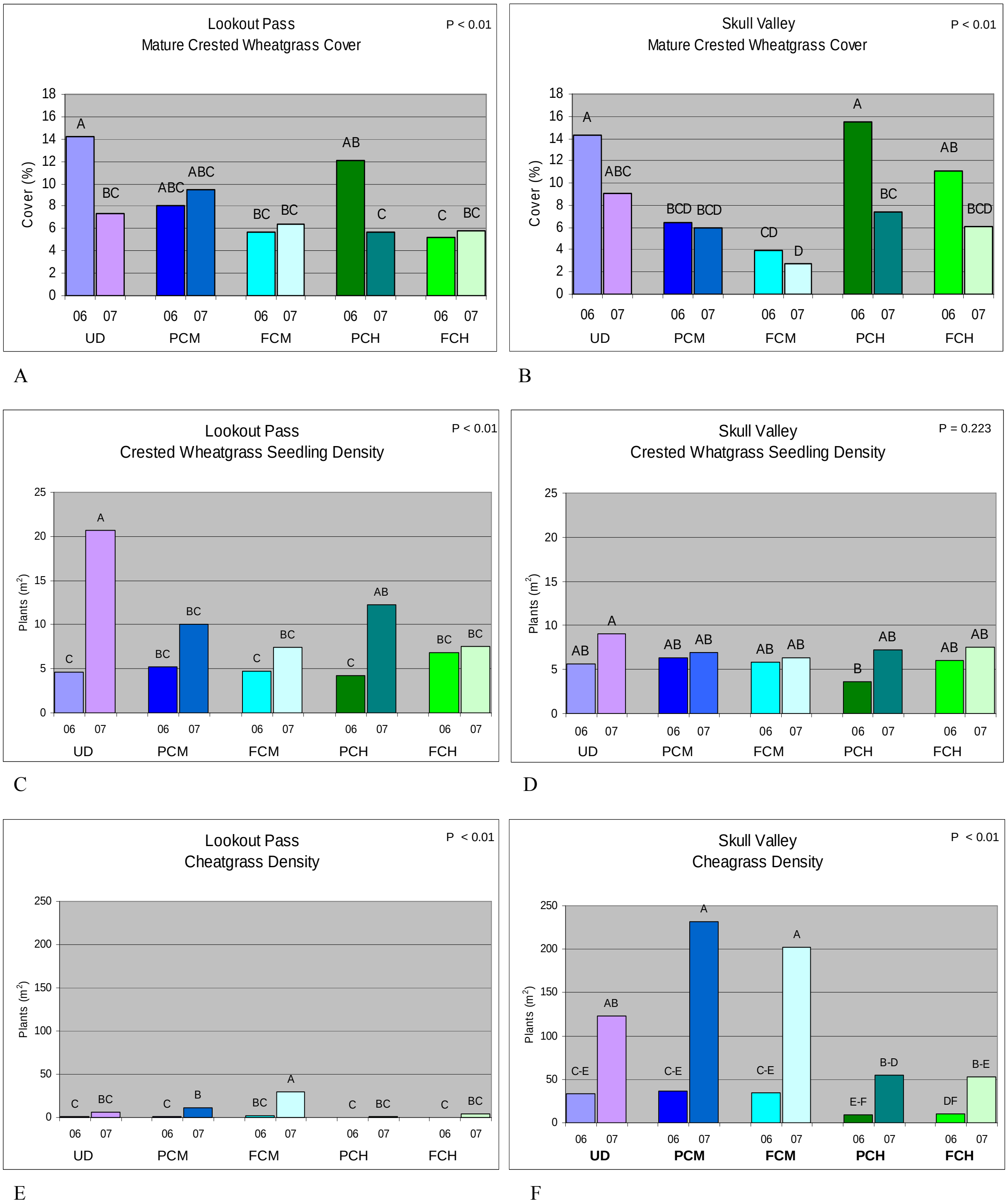
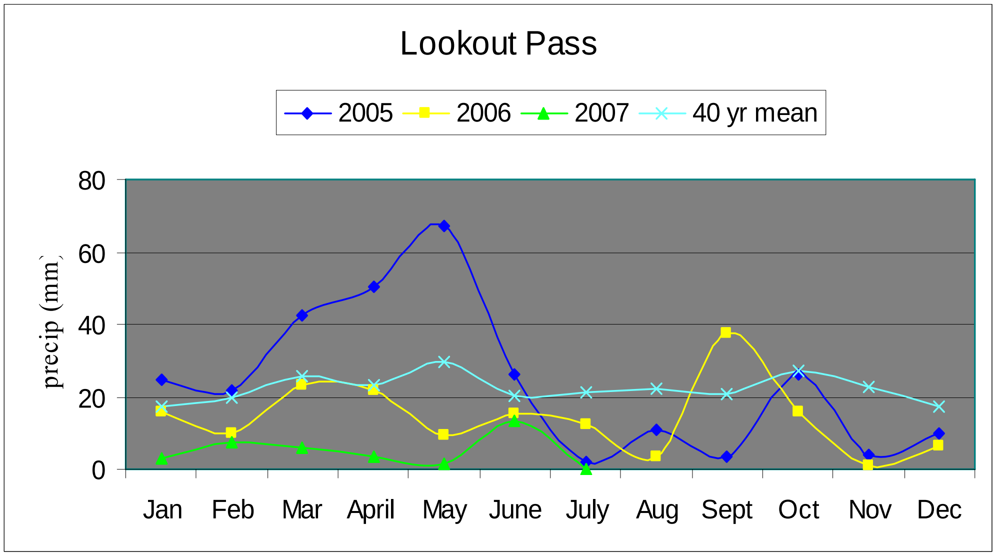


Figure 1. Crested wheatgrass diversification study. Repeated measurement of Year 1 plots (treatment implemented 2005, data collected 2006 and 2007). Undisturbed (UD), Partial Control Mechanical (PCM), Full Control Mechanical (FCM), Partial Control Herbicide (PCH), Full Control Herbicide (FCH).



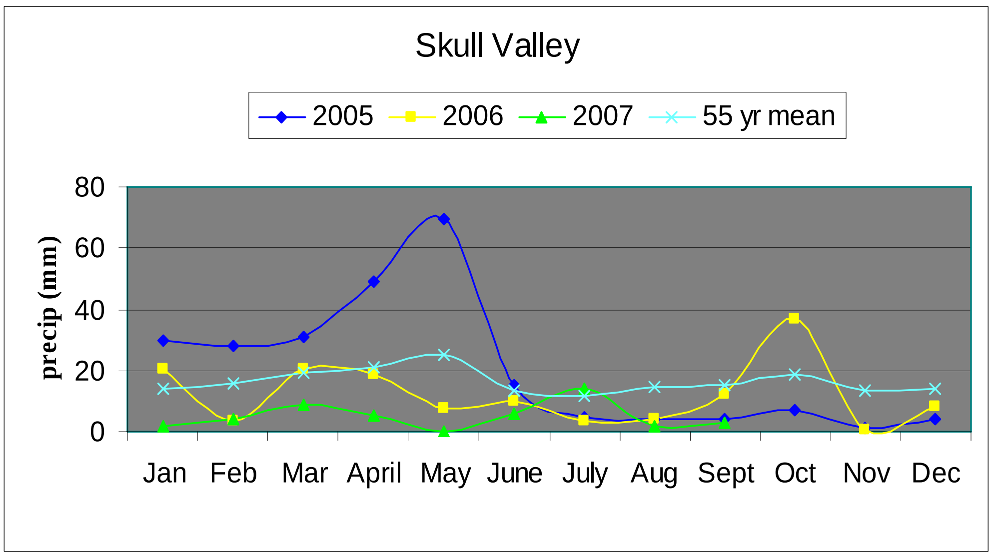


Figure 2. Precipitation in 2005, 2006, and 2007 and average precipitation by month for Lookout Pass and Skull Valley, Tooele Co., Utah.

Table2. Crested wheatgrass diversification study. First year response data. Treatment implement 2005, data collected 2006 (Year 1); treatment implemented 2006, data collected 2007 (Year 2). Undisturbed (UD), Partial Control Mechanical (PCM), Full Control Mechanical (FCM), Partial Control Herbicide (PCH), Full Control Herbicide (FCH).

Parameter	Treatment	Lookout Pass Mean Value		Skull Valley Mean Value	
		Year 1	Year 2	Year 1	Year 2
Mature Crested Wheatgrass Cover Cover (%)	PCH	12.12	13.51*	13.44	10.55
	FCH	5.16*	7.64	11.09	4.45
	PCM	8.1*	3.09	6.47*	2.69
	FCM	5.71*	3.23	3.94*	1.21*
	UD	14.26	6.18	14.25	7.32
Mature Crested Wheatgrass Density Density (m^2)	PCH	10.33	15.05	13.26	13.19
	FCH	13.45	20.61	9.98	10.39
	PCM	10.25	15.23	8.08	15.88
	FCM	10.14	20.16	5.86*	8.88
	UD	11.15	18.53	13.43	13.24
Crested Seedling Density Density (m^2)	PCH	4.27	19.25	3.62	13.19
	FCH	6.85	24.15	6.06	16.21
	PCM	5.17	30.25	6.27	21.87
	FCM	4.68	23.17	5.84	23.68
	UD	4.61	24.00	5.59	10.48
Cheatgrass Density Density (m^2)	PCH	0.24	3.41	8.95	72.47
	FCH	0.31	5.84	10.39	109.77
	PCM	1.20	0.85	36.75	85.64
	FCM	2.09*	0.77	34.71	62.24
	UD	0.57	1.27	33.58	153.69
Total Seeded Species per Treatment Density (m^2)	PCH	22.19	14.67	12.50	9.47
	FCH	29.81	17.65	17.29	8.32
	PCM	28.35	16.48	17.58	11.04
	UD	28.19	15.36	23.91	9.17

* Significantly different from control treatment (UD)

Table 1. Crested wheatgrass diversification study. First year response and repeat measurement data of seeded species. Treatment implement 2006, data collected 2006 and 2007 (Year 1); treatment implemented 2006, data collected 2007 (Year 2). Mean value of total density per m². TG (bluebunch wheatgrass, Indian ricegrass, squirreltail); Pose (Sandberg bluegrass); Atca (fourwing saltbush); Chna (white stemmed rabbitbrush); Artr (Wyoming big sagebrush); Lile (Lewis flax); Spmu (Munro's globemallow); Acmi (eagle yarrow).

Parameter	Seeded Species	Lookout Pass Mean Value					Skull Valley Mean Value				
		Year 1			Year 2		Year 1			Year 2	
		2006	2007	2008	2007	2008	2006	2007	2008	2007	2008
Seeded Species Density (m²)	TG (PSSP, ACHY, ELEL)	14.64	7.32	–	10.6	–	8.2	4.04	–	7.76	–
	POSE	4.64	2.12	–	2.08	–	4.32	0.24	–	0.12	–
	ATCA	0.04	0.012	–	0.012	–	0.008	0	–	0.036	–
	CHNA	0.03	0.012	–	0.004	–	0.2	0.024	–	0.02	–
	ARTR	0.1	0.12	–	0.08	–	0.21	0.02	–	0.12	–
	LILE	6.32	1.84	–	2.24	–	2.48	0.08	–	2.84	–
	SPMU	0.13	0.12	–	0.1	–	0.08	0.004	–	0.036	–
	ACMI	0.04	0.08	–	0.012	–	0.21	0.08	–	0.072	–

Project Title: Wet Thermal Time Modeling of Seedling Establishment

Project Location: Brigham Young University, Provo, UT

Principal Investigators and Contact Information:

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Project Description:
Soil temperature and moisture are the most important abiotic factors influencing 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 to reach a certain life stage, the plant or seed requires a certain

amount of time (measured in degree days) above and below specific temperature thresholds where enzymatic activity ceases (Trudgill et al. 2005). Models assuming that seeds progress towards germination and emergence only when water is available have been more accurate in predicting emergence than strictly thermal models (Forcella et al. 2000).

This project involved creating models based on thermal accumulation and a soil moisture threshold to predict germination rate or pre-emergence growth and survivability of 16 different range species, cultivars or accessions (Table 1). Each wet thermal accumulation model is based on germination rates determined through constant temperature trials. First, thermal accumulation models were used to predict species germination compared to actual germination in incubators programmed to mimic three diurnally fluctuating-temperature cycles. These temperature cycles were based on spring soil temperatures in sagebrush-dominated communities of Tintic Valley, Utah (Roundy et. al 2007). Secondly, seedbags of 6 of the 16 plant collections (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 soil moisture and temperature data measured onsite. Finally, small plots adjacent to seedbags were seeded with the same species as were placed in seedbags (Table 1). Prior to seeding, small plots were treated with herbicide to control crested wheatgrass. Predicted and actual germination were compared to emergence and survival data in the small plots.

Project Status:
Germination

Model Development

Constant temperatures. 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). To determine the relationship between temperature and germination rate for each species we conducted germination trials at seven constant temperatures (5, 10, 15, 20, 25, 30 and 35°C) in incubation chambers. Thermal accumulation models were created for species: *Lupinus arbustus* (Dougl. ex Lindl.) (Longspur), *Enceliopsis nudicaulis*, *Linum perenne* L. (Appar), *Linum lewisii*(Pursh), *Achillea millefolium* L. (Eagle and VNS White), *Agropyron cristatum* (L.) Gaertn. X *Agropyron desertorum* (Fisch. ex Link) J.A. Schultes (Hycrest), *Agropyron desertorum* (Fisch. ex Link) J.A. Schultes (Nordan), *Elymus elymoides* (Raf.) Swezey (Sanpete), *Psuedoroegneria spicata* (Pursh) A. Love (Anatone), *Elymus wawawaiensis* J. Carlson & Barkworth (Secar), and *Bromus tectorum* L. Populations of *Bromus tectorum* were collected from Spanish Fork, Skull Valley and Lookout Pass, UT. The time required for 10, 25, and 50% of each species' seed population to germinate was recorded during each constant temperature trial. Plotting the (time to % germination)$^{-1}$ [ex: 1/(days to 10% germination)] at the 7 constant temperatures produces points that can be fit to a curve. The equation for the curve can then be used to calculate the hourly progress toward germination as a function of hourly temperature. Best-fitting curves for germination rate for suboptimal, optimal and supraoptimal temperatures were carefully selected using Table Curve® 2D (Hardegree 2006) for each species. These curves were the basis of the thermal accumulation model. Optimal germination temperatures were found to be at 25°C for most species. *B. tectorum* populations experienced the fastest germination rates at 20°C.

Model Verification

Comparison with actual germination under fluctuating temperatures in incubators. Field conditions were simulated in the lab to test model accuracy. Incubation chambers were programmed with three fluctuating diurnal temperatures (Fig. 2) simulating a warm and two cooler springs in sagebrush-dominated communities in Tintic Valley, Utah. Thermal accumulation models made from constant temperatures tended to overestimate time to germination under fluctuating temperatures. This was especially true of forb species (Fig. 3).

Seedbags. The wet thermal model was tested in the field at two sites located in north-central Utah. The Skull Valley site is located at 5000' with annual precipitation ranging from 8 to 12". 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'. The annual average for precipitation and air temperature is 10-12" and 7-11°C. Soils are classified as a Taylorsflat loam. Both sites have no slope and are dominated by crested wheatgrass (*A. cristatum*). These areas were originally dominated by sagebrush communities.

At both sites, four blocks (Fig.1) were established. The blocks were divided into two subplots and seeded in year 1 or year 2. 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 block. These sensors were attached to microloggers that calculated hourly averages. Precipitation and air temperature were also measured on site.

Nylon mesh seedbags of each species were buried and retrieved from each block on both sites 19 times between October 2005 and April 2007. For *Bromus tectorum*, we only seeded and buried seed that had been collected from that site. After retrieving the seedbags, percent of germinated seeds was compared to model predicted percent germination (10, 25, or 50%) based on the surface soil moisture and water potential during each period that seedbags had been in the ground.

We tested both intermittent and continuous wet thermal accumulation toward germination. Intermittent thermal accumulation assumes that seeds thermal accumulate toward germination across intermittent wet periods while continuous accumulation assumes that every time the seed dries out it must restart thermal accumulation toward germination. For continuous thermal accumulation, seeds must accumulate enough degree-days within at least one wet period to be predicted to germinate during that time period. Gypsum blocks do not experience the same wet and dry conditions that seeds do. Therefore we tested three wet thresholds for thermal accumulation or three base water potentials:-0.5, -1.0,-1.5 MPa.

We analyzed model accuracy by determining whether the model accurately predicted germination of the 10, 25, or 50% seed subpopulations. We found that summing thermal accumulation across intermittent wet periods (∑ wet periods) best predicted germination (Fig 4). Using the -1.5 MPa moisture base threshold was more accurate than the other water potential thresholds (Fig. 5). The model was over 80% accurate for most species and subpopulations when using -1.5 MPa and summing thermal accumulation (Fig.6). Model accuracy was significantly less in fall and winter than spring (Fig. 7). Over 90% of inaccurate predictions were overestimations of time required for germination. This was seen also in our fluctuating temperature simulations conducted in the lab. This suggests that fluctuating temperatures not only accelerate breaking of dormancy and priming of seeds (Allen et al. 2007; Vleeshouwers and Kropff 2000; Forcella et al. 2000) but can also increase germination rate. At both sites, the model was able to predict whether seedbags would reach 10, 25, or 50% germination of for all species except for *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.

Small plots

Herbicide Treatment Effect

The effectiveness of two herbicide treatments applied prior to seeding in decreasing mature plant crested wheatgrass cover and density and increasing seeded species germination, emergence and survival was evaluated. Each block of the field sites contained three rows of 6 (1 plot for each species) 1.2 x 1.8 m 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 Original Max 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 in mid-to-late October in both 2005 and 2006. Seedling density and survival were monitored in the spring and summer of 2006 and 2007.

One year post-treatment. On both sites, the full control herbicide treatment significantly reduced mature *A. cristatum* cover and density in plots treated in 2005 (p=0.0006 and p=0.0164) and 2006 (p=0.0014 and p=0.0008) in the spring following application. The herbicide application during a wet fall and spring (2005) was significantly more successful in reducing cover than in a below average year.

Two years post-treatment. The full control herbicide application of 2005 continued to significantly reduce cover (p =0.0003) and density (p =0.0350) in 2007, but its effect was significantly less the second year after application (p<0.0001 and p=0.0158).

We are currently analyzing effects of crested wheatgrass control on seedbed temperature and moisture conditions, seeded species seedling emergence and survival.

Emergence and Survival

Seedbag germination rates and emergence in small plots was high (Fig. 8-11) at both sites. Higher mortality rates occurred at Lookout Pass in 2006 for all species due to lack of precipitation events in July and August. Survival in August 2007 was similar for plots seeded in year 1 and year 2, despite the much higher emergence in year 1 plots during 2006. For the two years of this study, seeded species seedling survival was much more limiting to plant establishment than germination and emergence.

Future Research 2008:

Germination

Data Analysis

This coming year, the temperature and moisture data from sensors buried lower in the soil profile will be analyzed and related to seedling survival and emergence. Germination requirements of introduced versus native species will be analyzed.

Manuscript Preparation

Two manuscripts will be prepared and submitted for peer review.

Manuscript 1. The first manuscript will focus on wet thermal accumulation germination modeling. Model development and verification (lab and field) of the 14 species/cultivars/populations will be discussed. We will also report the effect of fluctuating temperatures on the different species.

Manuscript 2. The second paper will focus on the effect of the different treatments on crested wheatgrass cover and density, and seeded species emergence and survival. We will report how the soil microclimate in the upper 30 cm affected seeded species emergence and survival. We will also compare results of this small study to the larger 'crested wheatgrass diversification' study done in Utah.

Seedling root growth

Model Development

Root growth experiments to predict seedling growth and survival capability of the different species using thermal accumulation have been initiated and will be conducted this final year of the study. Clear tubes 2.9 cm in diameter by 20 cm in length will be filled with bulk sand or soil collected near Lookout Pass, previously sieved through a 0.6 cm screen and mixed in a cement mixer for uniformity. Using multiple soils will allow for determination of root response to soil texture and allow correlation of results from this study to field sites. Collected soil is Borvant gravelly loam collected at 375,322.79 E 4,453,008.66 N NAD 83 UTM 12 N. The bulk sand came from Standard Masonry Supply in Provo, UT.

Seminal root penetration rate (days to 5, 10, 15, 18 cm soil depth) will be measured for 13 species and related to degree-days of thermal accumulation, as was done for germination. Root depths will be measured daily to weekly in 5 replicate planting tubes, 4 blocks, and 2 soil types in a growth chamber programmed for 6 constant temperatures (5, 10, 15, 20, 25, 30 and 35°C). Soil or sand filled planting tubes will be placed at 45° angle inside black plexiglass chambers with the top of the tubes protruding.

Planting tubes will receive three seeds of one species to ensure plant growth in each tube. Seeds will be placed 0.5 cm below the soil surface against the lower side of the planting tubes. The first germinating seed will be measured while later germinating seeds will be culled. Depth of root penetration into soil will be measured from the initial point of root appearance on lower side of the planting tube. Plants will be measured until seminal roots reach the bottom of the planting tubes. The plant species include: *Achillea millefolium*, *Agoseris heterophylla* (Nutt.) Greene, *Astragalus utahensis* (Torr.) Torr. and A. Gray, *Linum perenne*, *Lupinus arbustus*, *Elymus elymoides*, *Elymus wawawaiensis* J. Carlson & Barkworth (Secar), *Pseudoregneria spicata, Agropyron cristatum* (Hycrest), *Agropyron desertorum* (Nordan), and *Bromus tectorum* (Lookout Pass and Skull Valley). Tubes will be top or sub irrigated to maintain soils near field capacity.

Measuring depth of root penetration into soil over constant temperatures allows modeling of root depth relative to thermal time. Thermal-accumulation predicted and actual days to seminal root depth will be compared for seedlings grown under 3 different fluctuating temperature regimes in a growth chamber.

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Presentations:

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Coleman, J., Roundy, B., and Jessop, B. 2007. Wet thermal accumulation modelling of several Great Basin species germination. Society for Range Management annual meeting, Reno/Sparks, NV. http://www.fs.fed.us/rm/boise/research/shrub/projects/PowerPoint_Presentations/ColemanandOthers.pdf)

Coleman, J., Roundy, B., and Jessop, B. 2006. Thermal Modeling of Range Species. Society for Range Management annual meeting, Vancouver, BC.

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. Both 2005 and 2006 were relatively wet years while 2007 was a relatively dry year, the model was able to predict the high germination and subsequent emergence that occurred. The high mortality of both year plots at the end of year 2 demonstrates that selecting species for areas that fulfill their germination and emergence requirements does not guarantee their establishment and that more than one wet year is needed for species establishment. A model that can predict their survivability under spring and summer temperature and moisture conditions is needed.

Table 1. Species list: ^germination was modelled; *was seeded in seedbags; +will be used in root growth study.

Species	Common Name/Cultivar	Source	Year Collected	Seeding Rate (lb/ha)	
				PLS	Bulk
Achillea millefolium^*+	'Eagle' yarrow	Eastern WA	2003	33	50
Achillea millefolium^*+	'VNS white' yarrow	Granite Seed, Eastern WA	2003	N/A	N/A
Agoseris heterophylla+	Annual agoseris	unknown	2007	N/A	N/A
Astragalus utahensis+	Utah milkvetch	unknown	2002	N/A	N/A
Enceliopsis nudicaulis^+	Nakedstem sunray	Blind Valley,	2003	N/A	N/A
Linum lewisii^	Lewis flax	Provo, UT	2001	N/A	N/A
Linum perenne^*+	'Appar' blue flax	UDWR-Lot# LHSIGNIA-245-1R	2003	33	36
Lupinus arbustus^+	Longspur lupine	Wells common garden	2004	N/A	N/A
A. cristatum × A. desertorum^*+	'Hycrest' crested wheatgrass	UDWR-Lot# 1377-9-127223	2003	33	47
Agropyron desertorum^+	'Nordan' desert wheatgrass	UDWR Lot# 31347, MT	2003	N/A	N/A
Elymus elymoides^*+	'Sanpete' bottlebrush squirreltail	Sanpete Co., UT	2003	33	47
P. spicata spp. spicata^*+	'Anatone' bluebunch wheatgrass	UDWR-Lot# LHSID3-445	2003	33	36
Psuedoroegneria spicata^*+	'Secar' bluebunch wheatgrass	UDWR-Eastern WA	2003	N/A	N/A
Bromus tectorum^*+	Cheatgrass	Skull Valley, UT	2005	38	-
Bromus tectorum^	Cheatgrass	Spanish Fork, UT	2005	N/A	N/A
Bromus tectorum^*+	Cheatgrass	Lookout Pass, UT	2005	38	-

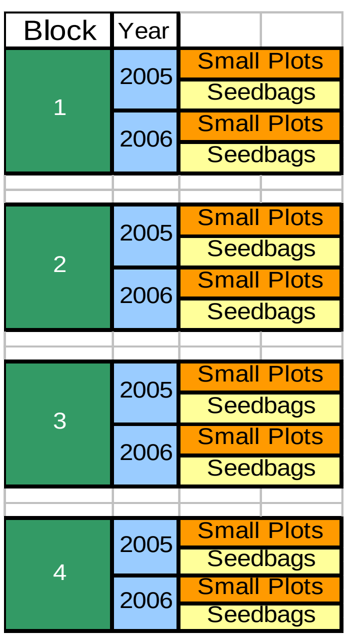


Figure 1: Small block diagram

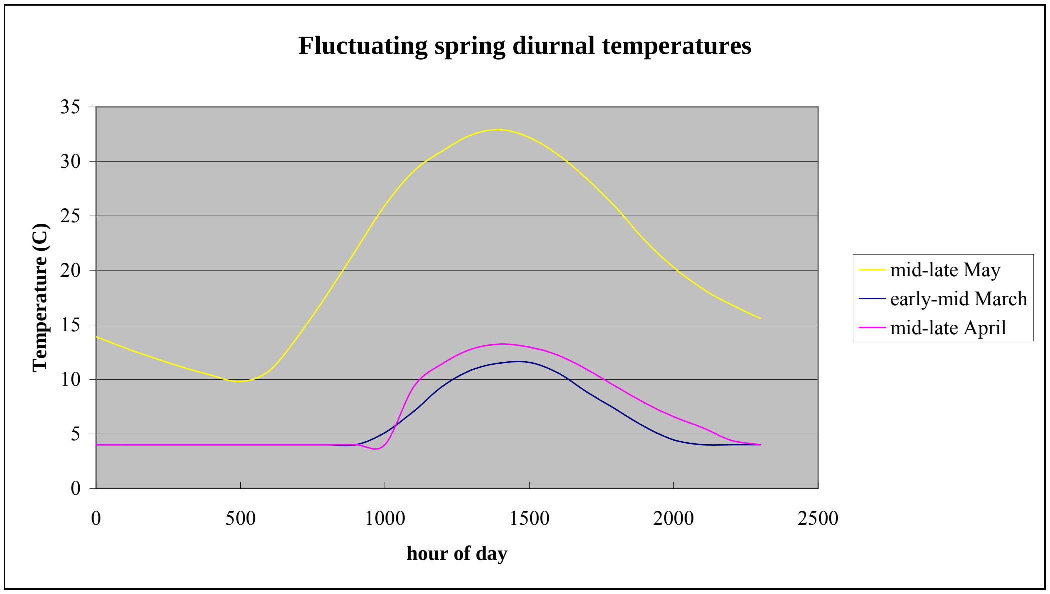


Figure 2: Three diurnal spring temperature fluctuations developed from field data collected during mid to late May; early to mid March; and mid-late April, in sagebrush-dominated communities in Tintic Valley, Utah.

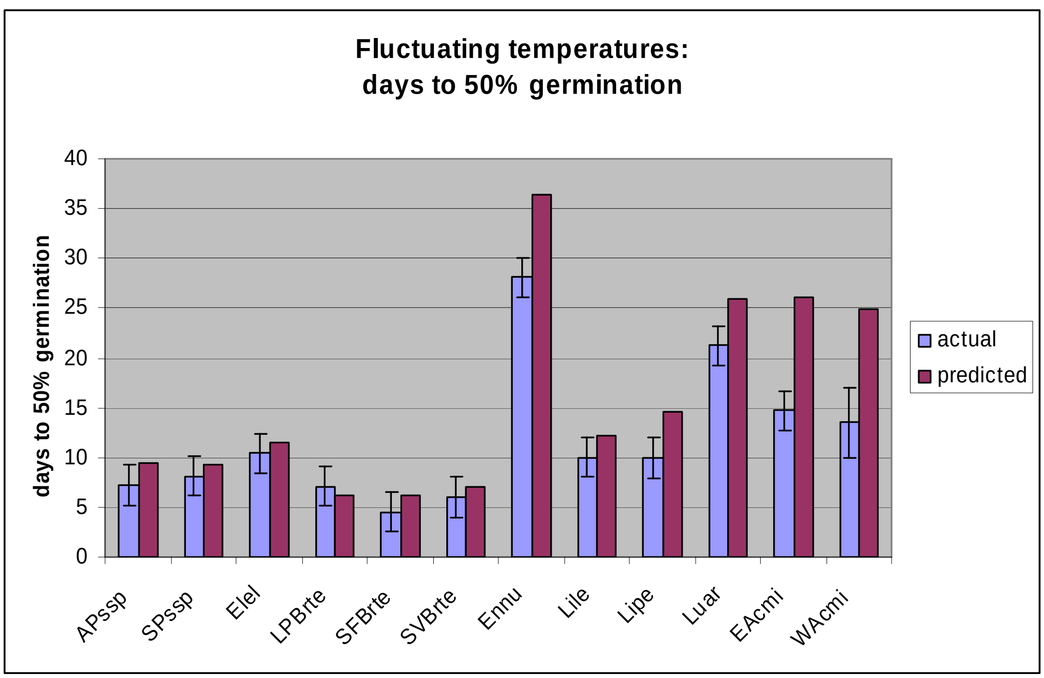


Figure 3: Predicted vs Actual days required for 50% germination under fluctuating temperatures

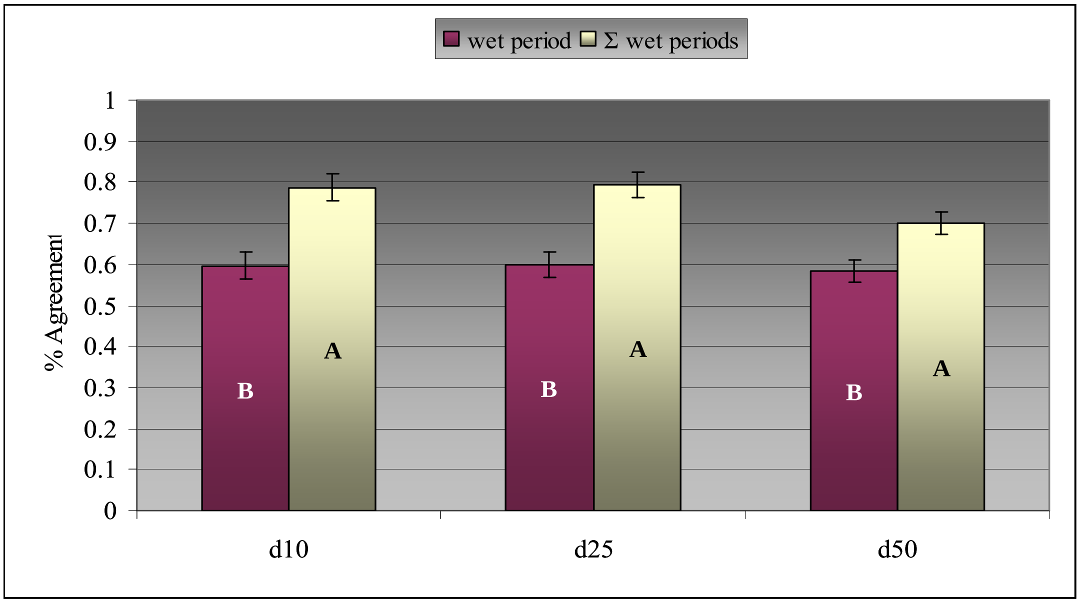


Figure 4. Percent agreement of model-predicted and actual germination for 19 seedbag placement and retrieval periods. Summing thermal accumulation across intermittent wet periods was more accurate than requiring thermal accumulation to restart with each wet period.

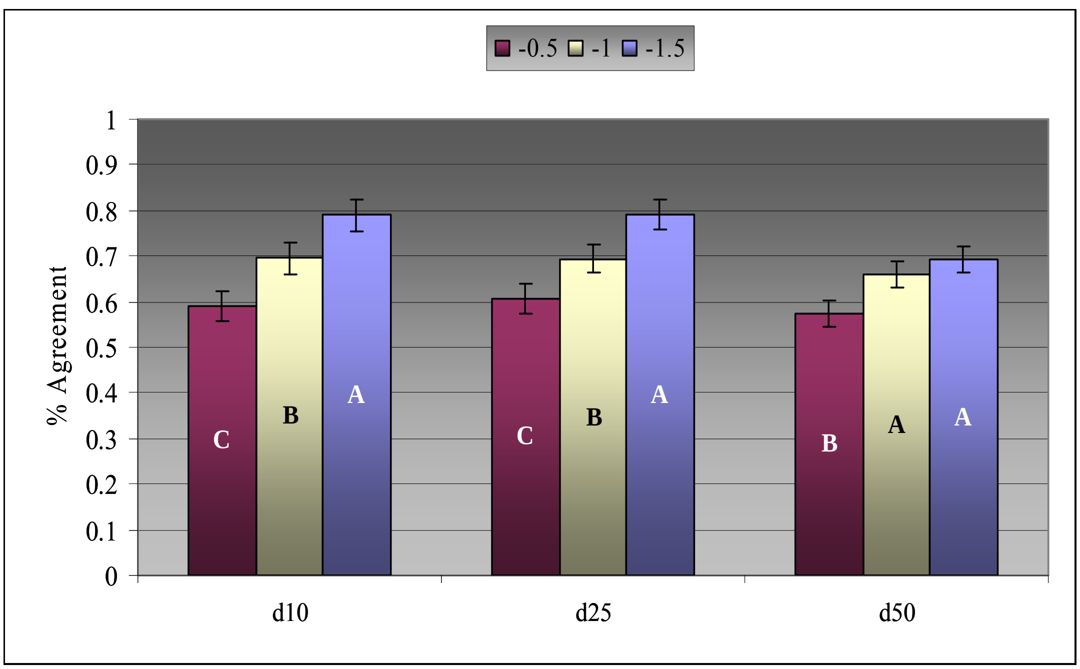


Figure 5: Percent agreement of model-predicted and actual germination in seedbags for 19 placement and retrieval periods. A water potential threshold of -1.5 MPa was more accurate than -0.05 and -1.0 MPa. d10, d25, and d50 refer to the fastest-germinating 10, 25, and 50% subpopulations of seeds.

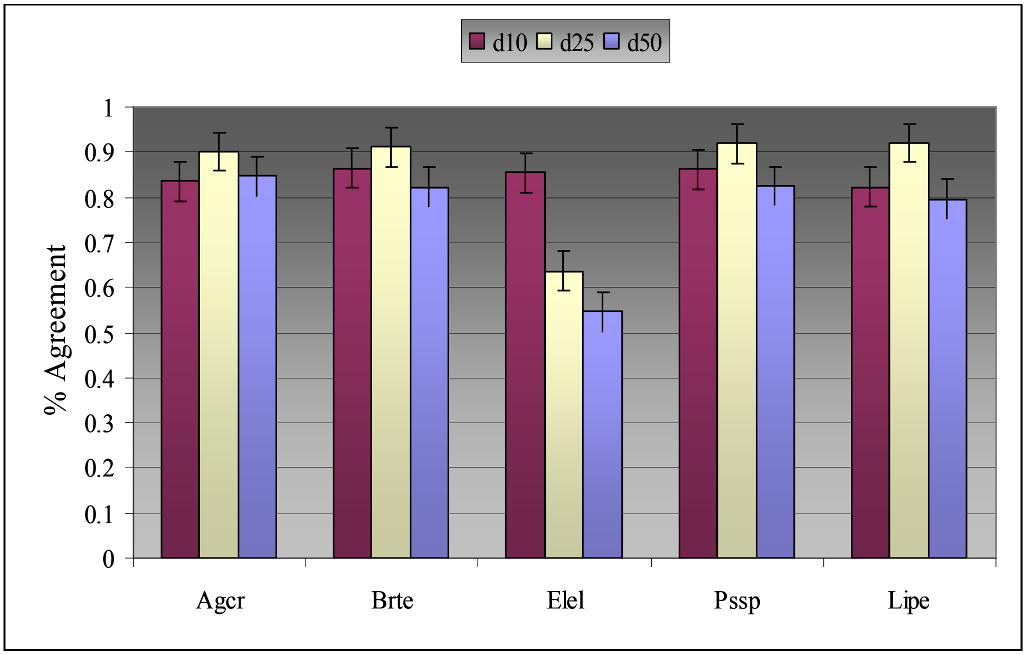


Figure 6: Percent agreement of model-predicted and actual in germination in seedbags for 19 placement and retrieval periods for four grass (Agcr- crested wheatgrass, Brte= cheatgrass, Elel= squirreltail, Pssp= bluebunch wheatgrass) and one forb (Lipe= blue flax). d10, d25, and d50 refer to the fastest-germinating 10, 25, and 50% subpopulations of seeds. The model used continuous thermal accumulation across all wet periods and a water potential threshold of -1.5 MPa.

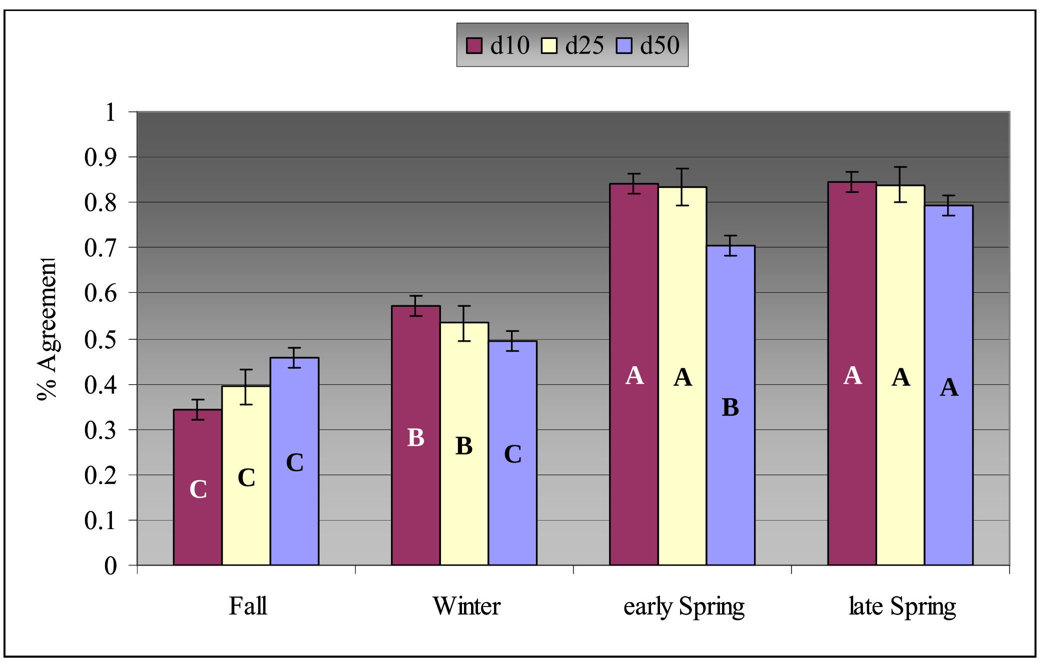


Figure 7: Percent agreement of predicted and actual germination in seedbags for 19 placement and retrieval periods. d10, d25, and d50 refer to the fastest-germinating 10, 25, and 50% subpopulations of seeds. The model used continuous thermal accumulation across all wet periods and a water potential threshold of -1.5 MPa.

Figure 8.

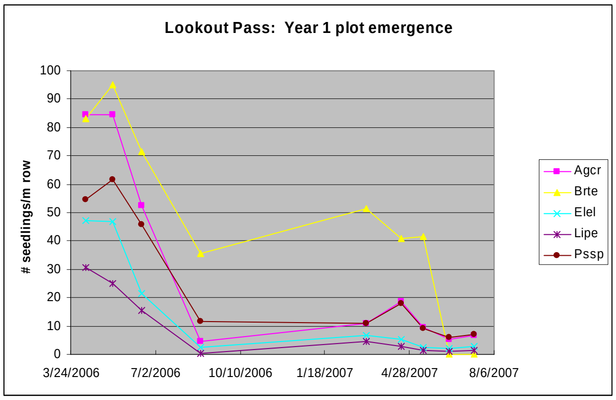


Figure 9.

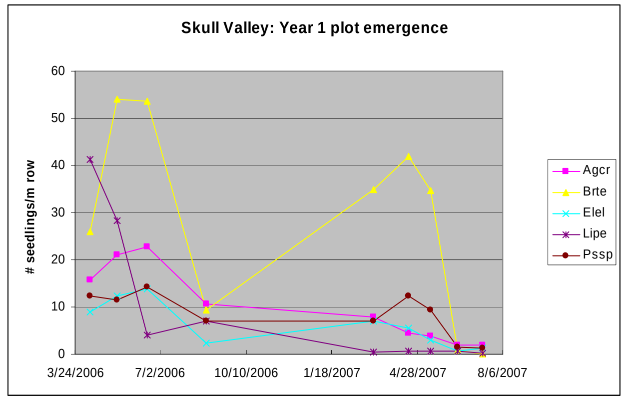


Figure 10.

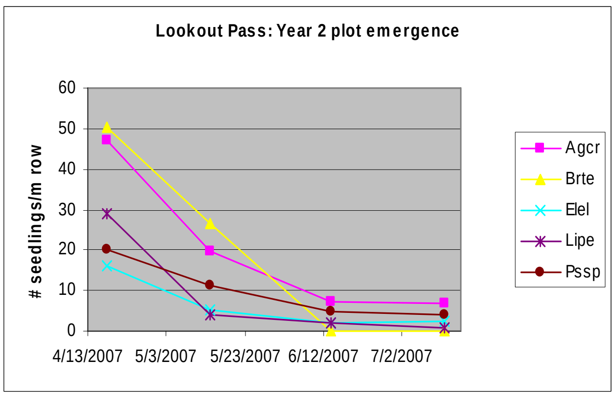
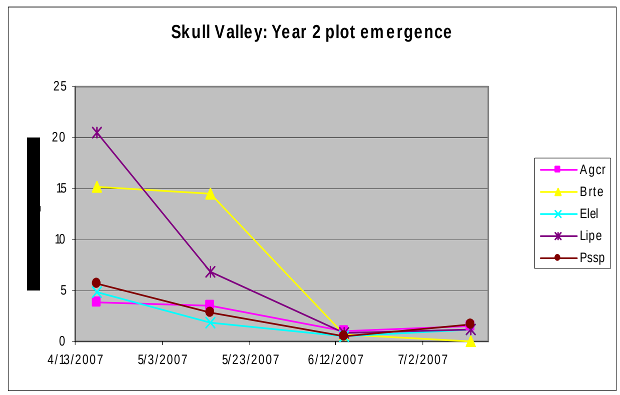


Figure 11.



Figures 8-11: Seedling density in Lookout Pass (Figs. 8 & 10) and Skull Valley (Figs. 9 & 11), in plots seeded in Year 1 (2005) and Year 2 (2006); seedling survival was similar.

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

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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 (*Agropyron cristatum*) approximately 25 years old. Objectives include: 1) determine the effect of crested wheatgrass control methods and revegetation on crested wheatgrass density and cover, 2) determine the effect of crested wheatgrass control methods and revegetation on establishment of native species, 3) determine the effect of crested wheatgrass control methods and revegetation on cheatgrass (*Bromus tectorum*) density and cover, and 4) determine the effects of crested wheatgrass control methods and native plant establishment on seed bank, and 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. Crested wheatgrass control treatments were tested in a randomized block, split-plot design with control method and intensity as whole plots and seeded vs. unseeded as split-plots. Control treatments included mechanical (disking), herbicide (glyphosate application), or undisturbed (no crested wheatgrass control). Control treatment intensity was varied by the number of passes with the disk (partial = one pass, full = two passes) and the rate of glyphosate application (partial = 10 oz ac^{-1}, full = 44 oz ac^{-1}). Half the plot was seeded and half the plot was left unseeded to simulate seeding failure following control treatment. The five treatments [full control mechanical (FCM), partial control mechanical (PCM), full control herbicide (FCH), partial control herbicide (PCH), undisturbed (UD)] 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. Plots were monitored 2006 and 2007.

Surface soil and litter were collected in the spring and fall of each year and bioassayed for seedbank potential of crested wheatgrass, native residuals, seeded species, and cheatgrass. Soil sampling occurred twice each year (April and September). Cover and density of unseeded and seeded species was collected in June for 2 years on plots established in 2005 and for 1 year on plots established in 2006.

Project Status:

Accomplishments 2007

Seed bank and soil sampling

Seed bank and soil was collected in 2005 (i.e. treated/seeded in 2005) and 2006 (treated/seeded in 2006) plots. The seed bank and soil was sampled on April 11. 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 gibberrelic acid was added to stimulate germination of any remaining seeds. Very few seedlings (<10 across all samples) emerged, therefore data were not analyzed. 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. 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 (NO_3^-) and ammonium-nitrogen (NH_4^+).

Vegetation sampling

The following data were collected on June 4-18 for 2005 and 2006 plots: 1) density of crested wheatgrass, cheatgrass, seeded species, any weedy species phenologically competitive with the seeded species, and any other species present; 2) cover of crested wheatgrass, cheatgrass, any significant weedy species, any other perennial species that was not seeded, bareground, 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 foliar 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 along transects was randomly determined. Distinction between bluebunch wheatgrass (*Pseudoroegneria spicata*), Indian ricegrass (*Achnatherum hymenoides*), and bottlebrush squirreltail (*Elymus elymoides brevifolia*) 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.

<u>Data analysis</u>
Data were entered into Excel, compiled, and analyzed with SAS statistical software. A PROC mixed split-split plot analysis was used for all analyses comparing the 2005 plots over a 2-year sampling period (referred to as '2005 plots compared across 2 growing years' in Results). Fixed effects in this analysis included treatment, year, and seeding level. Block was treated as a random effect. A proc mixed split-plot analysis was used for all analyses comparing the 2005 and 2006 plots (referred to as '2005 and 2006 plots compared across 1 growing year' in Results). Fixed effects included treatment and seeding level and random effects included year and block. Seeded grasses, forbs, and shrubs were grouped into "seeded species" for analysis with the large majority of the species being perennial grasses and Lewis flax (*Linum lewisii lewisii*).

Results
<u>Crested Wheatgrass</u>
2005 plots compared across 2 growing years (2006 and 2007). Treatment and year interacted to affect crested wheatgrass density ($P<0.0001$; Fig. 1). In general, crested wheatgrass density increased from 2006 to 2007. The only exception was in the UD treatment, which remained constant at 6.7 plants m^{-2}. In 2006 none of the treatments differed from the UD treatment, but the FCM treatment (7.7 plants m^{-2}) displayed a higher density than the FCH, PCH and PCM treatments (5.7 plants m^{-2}, 6.6 plants m^{-2} and 6.4 plants m^{-2}, respectively). After 2 years, the FCM treatment resulted in the highest crested wheatgrass density at 14.3 plants m^{-2}. This density was roughly two times higher than in any other treatment. The PCM treatment (8.5 plants m^{-2}) in 2007 was higher in density than the FCH (7.2 plants m^{-2}) and UD treatments.

Treatment and year interacted to affect crested wheatgrass cover ($P<0.0001$; Fig. 2). Except for the FCM treatment, all other treatments in 2006 were higher in crested wheatgrass cover than those treatments in 2007. In 2006 the FCM treatment demonstrated the lowest crested wheatgrass cover compared to all other treatments at 9.9%, but increased in 2007 to 12.6%. The FCH and PCM treatments (15.7% and 13.4%, respectively) resulted in lower cover than the PCH and UD treatments in 2006 (18.7% and 18.8%). This pattern continued in 2007. In 2007 the UD treatment was greater in cover than both mechanical treatments.

Comparison of 2005 and 2006 plots across one growing year (2007). Year and seeding level interacted to affect crested wheatgrass densities ($P = 0.0017$; Fig. 3). Overall, the density of crested wheatgrass in the 2006 plots was greater than the density of crested wheatgrass in 2005 plots. The crested wheatgrass density in the seeded plots was greater than the unseeded plots in 2006 (9.9 plants m^{-2} vs. 8.5 plants m^{-2}).

Treatment and seeding level interacted to affect crested wheatgrass density ($P = 0.0312$; Fig. 4). Except in the FCH treatment where seeded plots were higher in density with 9.6 plants m^{-2} than unseeded plots with 7.3 plants m^{-2}, crested wheatgrass density was similar between seeded and unseeded plots in all treatments. In the seeded plots, all treatments displayed similar crested wheatgrass densities except for the FCH and FCM (9.7 plants m^{-2}) treatments, which were higher in density. The highest crested wheatgrass density in unseeded plots occurred in the FCM treatment with 9.5 plants m^{-2}. Finally, unseeded plots of the PCM treatment were higher in crested wheatgrass density than the unseeded plots of the UD treatment (8.0 plants m^{-2} vs. 6.3 plants m^{-2}).

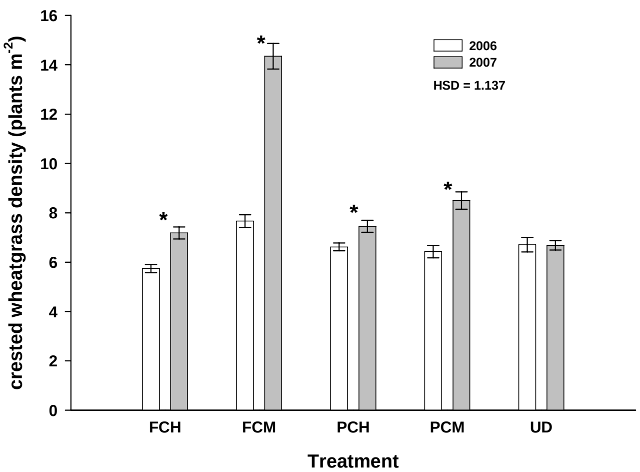

Figure 1. Crested wheatgrass density (plants m^{-2}) as affected by treatment and year in a 2005 plot comparison across two growing years. * denotes differences across years within a treatment. HSD separates means between treatments within a year. Error bars equal ± 1.0 SE. FCH = full control herbicide. FCM = full control mechanical. PCH = partial control herbicide. PCM = partial control mechanical. UD = undisturbed.

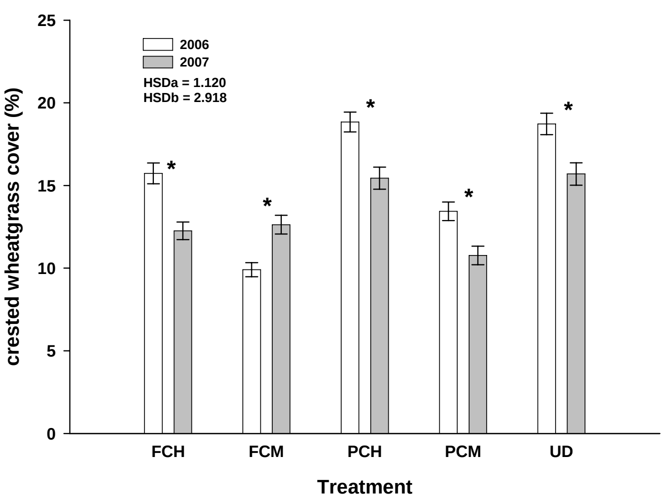

Figure 2. Crested wheatgrass cover (%) as affected by treatment and year in a 2005 plot comparison across 2 growing years. * denotes differences across years within a treatment. HSDa separates means between treatments within a year. HSDb separates means between treatments across years. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment abbreviations.

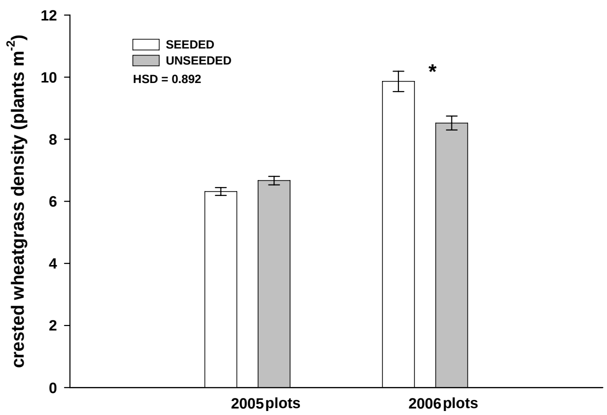

Figure 3. Crested wheatgrass density (plants m^{-2}) as affected by year and seeding level in a comparison between 2005 and 2006 plots across one growing year. * denotes differences across seeding levels within a year. HSD separates means across years within a seeding level. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment abbreviations.

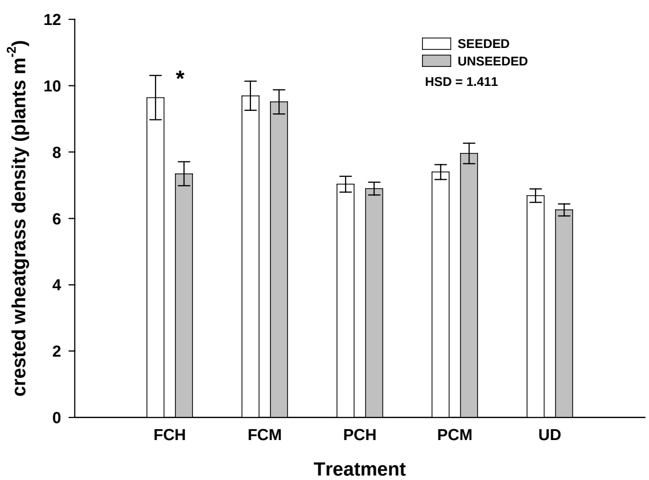

Figure 4. Crested wheatgrass density (plants m^{-2}) as affected by treatment and seeding level in a comparison between 2005 and 2006 plots across one growing year. * denotes differences across seeding levels within a treatment. HSD separates means between treatments within a seeding level. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment abbreviations.

A three-way interaction among treatment, seeding level and year affected crested wheatgrass cover (P = 0.0079; Fig. 5). This interaction suggested that seeded and unseeded PCH and UD treatments in the 2005 plots and the unseeded PCH and seeded UD treatments in the 2006 plots resulted in greater crested wheatgrass cover than all other treatments. All treatments in the 2005 plots, regardless of seeding level, were higher in cover than those same treatments in the 2006 plots, except in the seeded FCM treatment. In general, cover in both the 2005 and 2006 plots were similar between the seeded and unseeded plots. Exceptions to this included: in the FCM treatment in the 2005 plots, seeded plots had lower crested wheatgrass cover than unseeded plots (8.0% vs. 11.8%); in the UD treatment in the 2005 plots, seeded plots displayed a lower cover value than unseeded plots (17.9% vs. 19.6%); in the PCH treatment in the 2006 plots, seeded plots resulted in lower cover than unseeded plots (12.4% vs. 16.3%); and in the UD treatment within the 2006 plots, seeded plots were greater in cover than unseeded plots (15.9% vs. 12.5%).

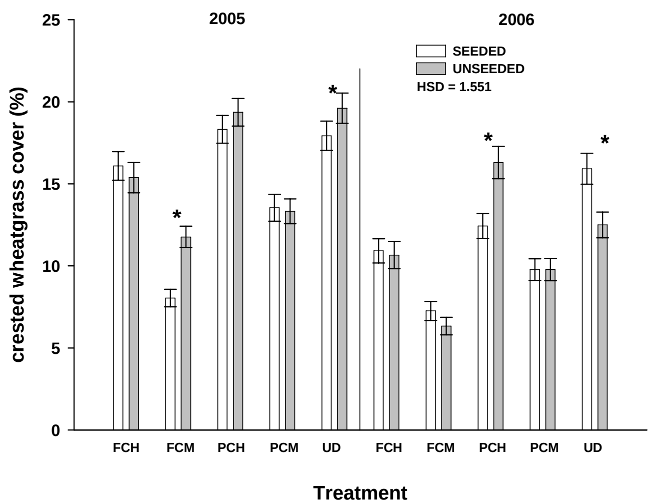

Figure 5. Crested wheatgrass cover (%) as affected by treatment, seeding level and year in a comparison of 2005 and 2006 plots across one growing year. * denotes differences between seeding levels within a treatment within a year. HSD separates means across treatments and years. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment abbreviations.

Seeded Species

2005 plots compared across two growing years (2006 and 2007). Year interacted with treatment to affect seeded species density ($P < 0.0001$; Fig. 6). In all treatments except the UD, seeded species densities in 2006 were greater than in 2007. The UD treatment resulted in 18.2 plants m^{-2} in 2006 and 2007. In 2006 the FCM displayed the highest seeded species densities with 43.9 plants m^{-2} followed by the PCM treatment with 30.1 plants m^{-2}. By 2007, none of the treatments differed in seeded species density.

Comparison of 2005 and 2006 plots across one growing year (2007). Seeded species density was affected by the interaction between treatment and year ($P = 0.0002$; Fig. 7). As mentioned above, the FCM and PCM treatments exhibited the highest densities in the 2005 plots. In the 2006 plots, all treatments had similar density (mean = 26.3 plants m^{-2}) except the comparison between the PCH and PCM treatments (30 vs. 22.7 plants m^{-2}).

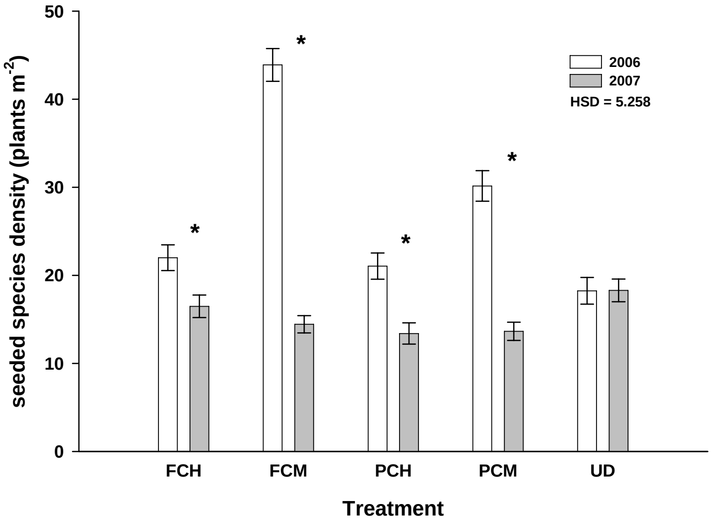

Figure 6. Seeded species density (plants m^{-2}) as affected by treatment and year in a 2005 plot comparison across two growing years. * denotes differences across years within a treatment. HSD separates means between treatments within a year. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment abbreviations.

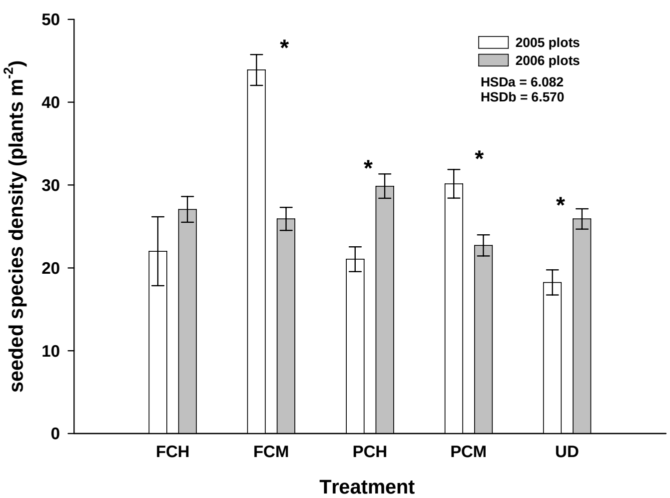

Figure 7. Seeded species density (plants m^{-2}) as affected by treatment and year in a comparison of 2005 and 2006 plots across one growing year. * denotes differences across years within a treatment. HSDa separates means between treatments within a year. HSDb separates means between treatments across years. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment abbreviations.

Cheatgrass

2005 plots compared across two growing years (2006 and 2007). Treatment and year interacted to affect cheatgrass density ($P < 0.0001$; Fig. 8). Except in the PCH and UD treatments, which were similar across years, cheatgrass density tended to increase between 2006 and 2007. In 2006, cheatgrass densities were similar except in the FCM treatment, which exhibited a lower density than the PCM treatment (52.0 vs. 104.3 plants m^{-2}). In 2007 all cheatgrass densities were similar except for the PCM treatment, which was higher than the UD treatment (116.4 vs. 66.8 plants m^{-2}).

Cover of cheatgrass was affected by a three-way interaction of treatment, seeding level and year ($P = 0.0225$; Fig. 9). Treatments and seeding levels that differed between years had higher cover values in 2006; these treatments included the unseeded FCH (6.0% vs. 3.5%) and UD (3.2% vs. 2.4%) and the seeded PCH (3.4% vs. 2.5%) and PCM (3.7% vs. 2.9%). The only treatment that increased in cheatgrass cover from 2006 to 2007 was the unseeded FCM (2.5% vs. 3.2%).

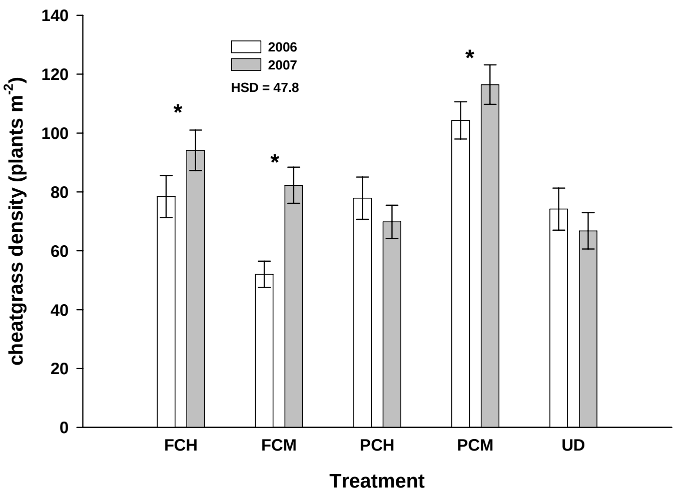

Figure 8. Cheatgrass density (plant m^{-2}) as affected by treatment and year in a 2005 plot comparison across two growing years. * denotes differences across years within a treatment. HSD separates means between treatments within a year. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment abbreviations.

Comparison of 2005 and 2006 plots across one growing year (2007). Treatment, seeding level and year interacted to affect cheatgrass density ($P < 0.0001$; Fig. 10). About half of the treatments, regardless of seeding level, had cheatgrass densities similar to one another across the 2005 and 2006 plots. The other half of the treatments, regardless of seeding level, had greater densities in the 2005 plots than the 2006 plots; these treatments included the unseeded FCH (106.3 vs. 21.1 plants m^{-2}), seeded PCH (77.6 vs. 16.6 plants m^{-2}), unseeded PCH (78.1 vs. 14.5 plants m^{-2}), seeded PCM (100.1 vs. 44.4 plants m^{-2}), unseeded PCM (108.4 vs. 40.5 plants m^{-2}) and seeded UD (75.5 vs. 18.5 plants m^{-2}). In the 2005 plots, cheatgrass density within treatments between seeded and unseeded plots was similar except in the FCH and FCM treatments. In the FCH treatment, cheatgrass density in unseeded plots more than doubled that of seeded plots. The FCM treatment showed opposite results in which seeded plots were greater in cheatgrass density than unseeded plots. Between seeding levels within treatments in the 2006 plots, cheatgrass densities were generally similar except in the UD treatment where density in seeded plots was less than half the density in unseeded plots. In the 2006 plots, the seeded plots of all treatments were similar. In the unseeded plots, however, the density in the UD treatment was more than double the density in FCH, FCM and PCH treatments.

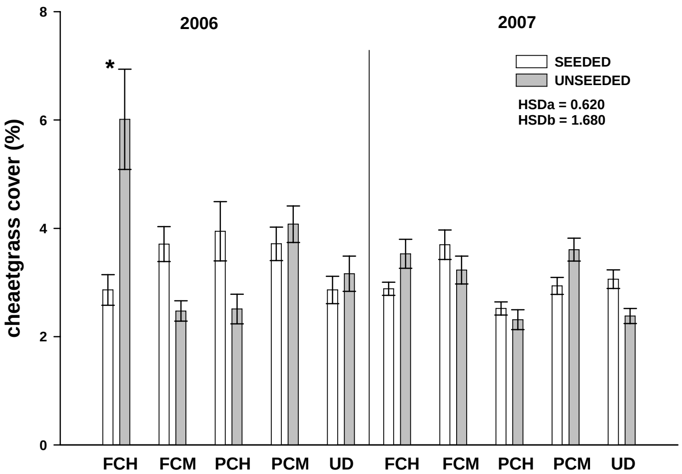

Figure 9. Cheatgrass cover (%) as affected by treatment, seeding level and year in a 2005 plot comparison across two growing years. * denotes differences between seeding levels within a treatment within a year. HSDa separates means between the same treatments and seeding levels across years. HSDb separates means between treatments across and within years. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment abbreviations.

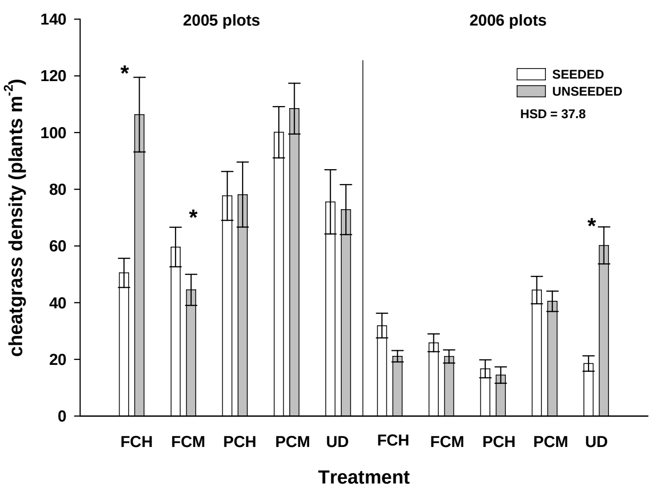

Figure 10. Cheatgrass density (plants m^{-2}) as affected by treatment, seeding level and year in a comparison of 2005 and 2006 plots across one growing year. * denotes differences between seeding levels within a treatment within a year. HSD separates means between treatments across and within years. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment abbreviations.

Cheatgrass cover was affected by the three-way interaction between treatment, seeding level and year ($P < 0.0001$; Fig. 11). Regardless of seeding level, cheatgrass cover between the same treatments was similar in the 2005 and 2006 plots, except for a few treatments with higher cover in the 2005 plots than the 2006 plots. These exceptions included the unseeded FCH treatment (6.0% vs. 2.8%), the seeded PCH treatment (3.9% vs. 1.2%) and the unseeded PCM treatment (4.1% vs. 2.6%). In the 2005 plots, cheatgrass cover among seeded plots was similar across treatments. In unseeded plots, the FCH treatment was higher in cheatgrass cover than all other treatments. In the 2006 plots, cheatgrass cover of different seeding levels within each treatment were similar except in the UD treatment where seeded plots displayed lower cover with 1.6% as compared to unseeded plots with 2.6% cover. With cover of 1.2% in the seeded plots, the PCH treatment was lower in cover than the seeded FCH, FCM and PCM treatments. In addition, the seeded UD treatment was lower than the FCH treatment. In the unseeded plots, all treatments displayed similar cheatgrass cover except for the FCH treatment with 2.8% compared to the PCH treatment with 1.3%.

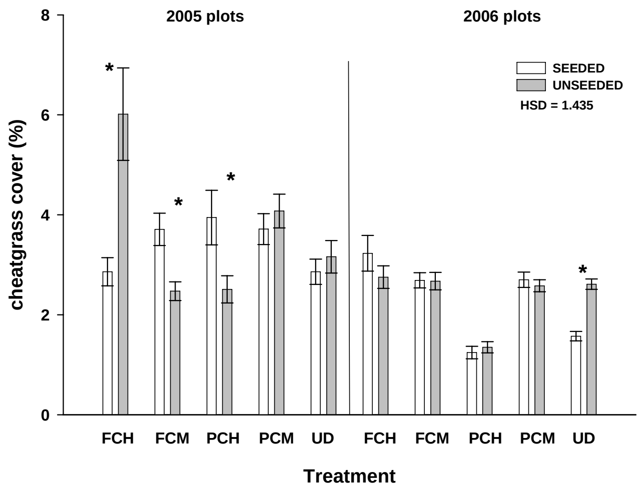

Figure 11. Cheatgrass cover (%) as affected by treatment, seeding level and year in a comparison of 2005 and 2006 plots across one growing year. * denotes differences between seeding levels within a treatment within a year. HSD separates means across treatments and years. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment abbreviations.

Soil NO_3^-, NH_4^+ and Water Content

Soil NO_3^- concentration was generally affected by the main effect of year and its interaction with treatment. In the 2005 plots, NO_3^- was higher in 2007 compared to 2006 (8.2 vs. 0.9 ppm, respectively) and the FCM treatment yielded the highest NO_3^- at 11.7 ppm. Nitrate also increased from 2006 (1.7 ppm) to 2007 (11.9 ppm) in the 2006 plots. When comparing NO_3^- concentration between 2005 and 2006 plots, the main effects of year and seeding were significant ($P = 0.0037$ and 0.0030, respectively). Soil NO_3^- was higher in the 2006 plots than in the 2005 plots (1.7 vs. 0.9 ppm) and higher in the seeded plots (1.4 ppm) than in the unseeded plots (1.2 ppm).

Soil NH_4^+ concentration was also generally affected by year. While NO_3^- increased over time, NH_4^+ decreased from 12.2 ppm in 2006 to 4.2 ppm in 2007 in the 2005 plots ($P < 0.0001$). Ammonium also increased from 2006 to 2007 in the 2006 plots (2.2 vs. 5.8 ppm, respectively; $P = 0.002$). When comparing NH_4^+ between 2005 and 2006 plots, the 2005 plots had higher NH_4^+ concentration at 12.5 ppm than the 2006 plots at 2.2 ppm ($P < 0.0001$).

Soil gravimetric water content was only affected by year in the 2005 plots ($P < 0.0001$). Water content decreased from 19.9% in 2006 to 7.9% in 2007.

Plans for 2008

Sampling

Vegetation cover and density of Year 2 plots will be sampled during June using the same methods as in 2007.

Additional Study

We have also initiated a second study testing the effect of disking, herbicide applications, and their combination on crested wheatgrass and seeded species establishment. Disking treatments were applied fall 2007 and plots were seeded. Herbicide and herbicide plus disking treatments will be applied in spring 2008 with seeding of plots in fall 2008. Procedures are being tested at two sites, at the Malheur National Wildlife Refuge (same site as above) and the Northern Great Basin Experimental Range about 56 km west of Burns, OR.

Publications:

Fansler, V.A. 2007. Establishing native plants in crested wheatgrass stands using successional management. M.S. thesis. Oregon State University: Corvallis, OR. 95 pp.

Presentations:

Mangold, J. and V. Fansler. 2007. Increasing native plant diversity in crested wheatgrass stands. p. 32 *in* Conference program for Society for Ecological Restoration Northwest Chapter/Society of Wetland Scientists Pacific Northwest Chapter joint regional conference, Yakima, WA.

Fansler, V., J. Mangold, M. Borman, and D. Pyke. 2007. Increasing native plant diversity in crested wheatgrass stands. p. 94-95 *in* Proceedings from Society for Range Management 60th annual meeting and trade show, Reno/Sparks, NV.

Mangold, J. 2007. Increasing native plant diversity in crested wheatgrass stands. Society for Range Management- Idaho chapter annual meeting. Boise, ID.

Management Applications:

There have been proposals and in some cases mandates to restore and direct crested wheatgrass stands into more diverse plant communities that meet multiple land-use objectives. Land managers, however, are reluctant to invest time and money into revegetation projects due to the high probability of failure. This study has shown that by addressing site availability and species availability, native plant establishment can be achieved by directly seeding native species into crested wheatgrass stands. When the seed bank is extremely depleted, as it was in this case, the availability of species propagules other than those of crested wheatgrass is critical for establishment of native species. If site availability appears to be adequate (i.e. plenty of bare ground), as was the case at our site, crested wheatgrass control may be unnecessary. Land managers must be prepared, however, for an increase in weedy annual species such as cheatgrass that may result from disturbances, even small disturbances such as those caused by a rangeland drill. Since this was a short-term study, it is difficult to predict the long-term success or failure of such management actions. As with any revegetation project, continuing monitoring and evaluation is critical. Addressing species performance with follow-up management will help to secure the initial investment involved with crested wheatgrass control and seeding of native species.

Products

A tour of the research plots was held on October 17, 2007 for BLM-Burns Distict, BLM-Vale District, and Robert Hopper from BLM-Oregon State Office.

Project Title: Revegetation Equipment Catalog Project

Project Location: College Station, TX

Principal Investigators and Contact Information:

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Project Description:
The Revegetation Equipment Catalog was placed on the World Wide Web in 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 gives a description, application, photograph, and sources of various types of equipment used for rangeland vegetation manipulation, wildlife habitat improvement, and disturbed land rehabilitation. In 2007, there were 10 updates listing new machines and addresses. This is the advantage of a web-based publication. There are over 200 items listed.

Project Status:
Our publicity and inquires from search engines such as Google has resulted in significant use of the catalog. Tracking software logged 102,858 visitors in 2007. The United States accounted for 72% of the visitors while the remaining 28% were international. Canada (7%), United Kingdom (5%), Australia (2%), and India (1%) logged the highest counts of the 18 countries listed. In the list of categories, equipment trailers, grass drills, and tractors accounted for the most page visits.

There have been requests for construction plans for grubbers from Australia and Texas, a source for purchasing Tye grass drills, and additional information for a fencing book, seed cleaning equipment, equipment trailers, and a new grass seed-plucking harvester.

The Revegetation Equipment Catalog website (http://reveg-catalog.tamu.edu/) is linked from a number of websites, including:

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

Great Basin Restoration Initiative:
http://www.fs.fed.us/rm/boise/research/shrub/greatbasin.shtml

Society for Range Management:
http://www.rangelands.org/links_plant_resources.shtml

Center for Invasive Plant Management:
http://www.weedcenter.org/restoration/restoration.html

The website is maintained continuously. All links and vendors' contact information are checked at least quarterly.

Publicity:
The website was publicized by a poster and live laptop demonstrations in a tradeshow booth at the Society for Range Management annual meeting in Reno, Nevada, and demonstrated at the RTEC program.

Power-point slides of the poster were included in several technical presentations by Nancy Shaw, Jason Vernon, Mike Pellant, and Scott Lambert.

The publicity poster was displayed at:

- Wildflower Seed Production Research Symposium in Orlando, FL
- Plant Community Restoration Workshop, Grand Junction, CO
- The Society for Ecological Restoration Northwest/Society of Wetland Scientists Pacific Northwest Joint Meeting, Yakima, WA

Project Title: Native Forb Selection, Seedling Establishment, Species Interactions, and Post-fire Seedings

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

Principal Investigators and Contact Information:

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1. Plant materials

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Project Description:
Development of plant materials of *Eriogonum umbellatum*, *Lomatium dissectum*, *L. grayi*, *L. triternatum, Penstemon acuminatus, P. speciosus, P. deustus* and identification of other forbs

suitable for development. Work has been conducted at the Lucky Peak Nursery, Boise Botanic Garden, Orchard Research Site, and Wells Research Site.

Project Status:
Pooled material of *Penstemon speciosus* for the Northern Basin and Range was seeded in a commercial seed field in Utah (3 acres).

Pooled material of *P. deustus* for the Northern Basin and Range was seeded in a commercial seed field in Washington (0.5 acres).

Seed increase plots are being maintained at the Aberdeen Plant Materials Center for all seven species. Seed is being used for research on seeding strategies and equipment and for further seed increase.

Two common gardens of *Lomatium dissectum*, seeded in fall 2006, were established at Lucky Peak Nursery and the Wells Research Site (about 40 accessions each). Data will be collected in 2008 and 2009. Molecular genetics work with these accessions is being conducted by USDA ARS Pullman.

Collaborative studies of *Pseudoroegneria spicata* are being conducted with USDA ARS Pullman and USDA FS PNW Corvallis. One common garden of 140 accessions is being maintained at the Lucky Peak Nursery. See report by Richard Johnson et al. (this volume) for first year results.

Initial seed increase plots of *Agoseris grandiflora, Eriogonum sphaerocephalum, Townsendia florifer,* and *Chaenactis douglasii* seeded in fall 2006 at Lucky Peak Nursery produced good stands. Seed was harvested from the *A. grandiflora* and *Chaenactis douglasii* plots. Seed is being used for further seed increase. The plots will also be used for examining equipment and methods for harvesting small-seeded Asteraceae.

Sixty-one collections of 13 species were harvested from wildland stands in 2007. Forty-two collections of five species were sent to the FS National Seed Laboratory for development of seed germination protocols. Ninety-two collections are being sent to the SOS collection with USDA ARS in Pullman, WA.

2. Assessing the effects of grass competition on Great Basin forbs

Additional Principal Investigators:

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Project Description:
Bromus tectorum exploits water in early spring, competing with native plants for this limiting resource. Competition for water is particularly pronounced for seedlings that do not have an established root system (Harris and Wilson 1970). Competition experiments have been conducted to examine the effects of *B. tectorum* on grasses and shrubs (Humphrey and Schupp 2004, Melgoza et al. 1990, Harris and Wilson 1970), but to date no study has addressed its effects on native forbs. This experiment was designed to examine the relationship between *B. tectorum* density and native forb seedling survival and growth, and to look at the effect of increasing densities of *B. tectorum* on spatial and temporal differences in soil water. The specific objectives were:

1. To identify the density of *B. tectorum* at which significant declines in native forb growth occur.
2. To determine whether the effects of *B. tectorum* density vary based on the identity of the native forb.
3. To determine when and at what depths differences in water content occur with increasing densities of *B. tectorum.*

Project Status:
<u>Methods</u>
The experiment was conducted at two locations in southern Idaho, both within 20 miles of Boise: the Lucky Peak nursery (930 m elevation, annual precipitation 330 mm) and the Orchard Research Site (915 m elevation, annual precipitation 300 mm). The forbs species were *Achillea millefolium* L. (common yarrow), *Eriogonum umbellatum* Torr. (sulfur-flower buckwheat), *Lomatium grayi* (J.M. Coult. & Rose) J.M. Coult & Rose (Gray's biscuitroot), and *Penstemon speciosus* Douglas ex Lindl. (royal penstemon). All were collected in southern Idaho at elevations below 1524 m (5,000'). The plots were 0.9 m x 1.5 m. *Bromus tectorum* was seeded in late September 2006 to achieve densities of 0 (control), 45, 90, 180 and 360 plants m^{-2}. Forbs were seeded in two rows of four for a total of 8 plants in each plot. Ten pure live seeds were planted in each forb spot in late October 2006.

To examine spatial and temporal changes in soil water content changes with increasing densities of *B. tectorum*, a neutron moisture meter was used to measure soil water content in plots seeded at 0 (control), 180, and 360 plants m^{-2} at 20, 40, 60, and 80 cm depths. Sampling began in mid-March at Orchard and late March at Lucky Peak. Plots were sampled weekly until mid-June and then at 2- and 3-week intervals until July 31, 2007 (13 sampling dates total at each site). At the Lucky Peak site, *B. tectorum* was harvested at peak standing biomass on May 23rd. *L. grayi* senesces in mid to late spring, so this species was collected beginning in mid-May through late June as it began to dry. *A. millefolium, E. umbellatum,* and *P. speciosus* were harvested in late July.

At the Orchard site, ground squirrel herbivory, first observed in early April, reduced the size of *B. tectorum* plants by 50-90%, despite efforts to control ground squirrel populations. Orchard site data is still being analyzed and will not be included in this report.

<u>Results</u>

Forb growth in response to B. tectorum

At densities of less than 50 *B. tectorum* plants m^{-2}, growth of *A. millefolium* and *L. grayi* were not significantly different than when growing alone (Fig. 1). *Eriogonum umbellatum* was reduced by 80% at *B. tectorum* densities of 1-100 (Fig. 1). *Penstemon speciosus* had the greatest reduction of biomass in response to *B. tectorum* with reduction between 92-99% for all densities above the control (Fig. 1).

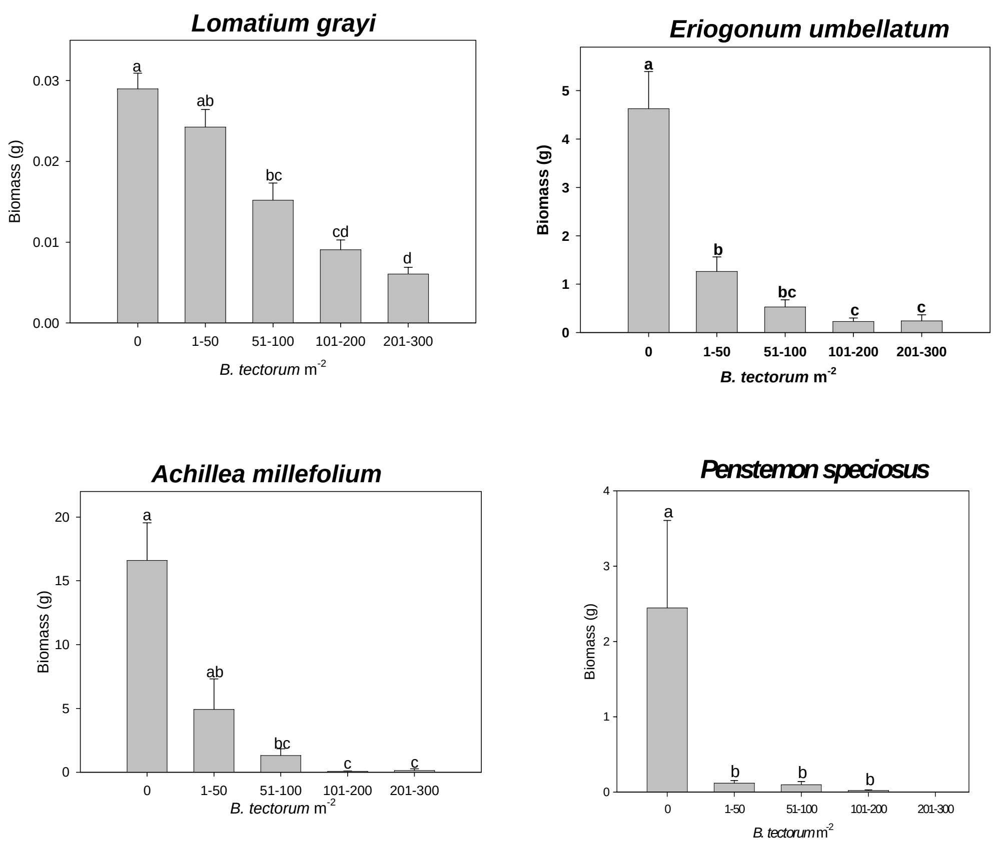

Figure 1. Reduction in forb biomass at increasing densities of *B. tectorum* (+ SE). Within each graph, different letters indicate significant differences.

Water content in response to B. tectorum

Fig. 2 shows volumetric water content at four key sampling dates; March 31st, April 27th, May 13th, and June 13th when differences first occurred between treatments and at depths. The bars indicate *B. tectorum* densities at 0 (control), 150-180, 181-280 and 280+ m^{-2}. These categories are different than the forb data above because water content was only collected in plots seeded at levels of 180 and 360 m^{-2}, so the lowest *B. tectorum* density for water data is 150 m^{-2}. Actual *B. tectorum* densities censused in mid-May were as high as 450+ m^{-2}, but soil moisture in plots with *B. tectorum* density above 300 m^{-2} did not differ.

On March 31st a difference occurred only at the 20 cm depth (between the highest level and control) and the amount was relatively small (0.02). Results were similar for April 5th, with differences increasing on April 13th.

On April 27th, water content in the control plots was significantly greater than all plots with *B. tectorum* and the plot with 150-180 *B. tectorum* plants m^{-2} was significantly different than the highest density. April 27th was the first sampling date where significant differences occurred at the 40 cm depth between control and the highest density only.

On May 13th water content in the control plots was significantly greater than all *B. tectorum* levels at the 20 and 40 cm depths which were not different from each other and this relationship was maintained for all subsequent sampling dates. May 13th was the first sampling date where significant differences between control and *B. tectorum* plots occurred at the 60 cm depth.

On June 13th water content was significantly different between the control and all levels with *B. tectorum* at 20, 40, 60 cm depths. Results were similar for July 6th and July 31st.

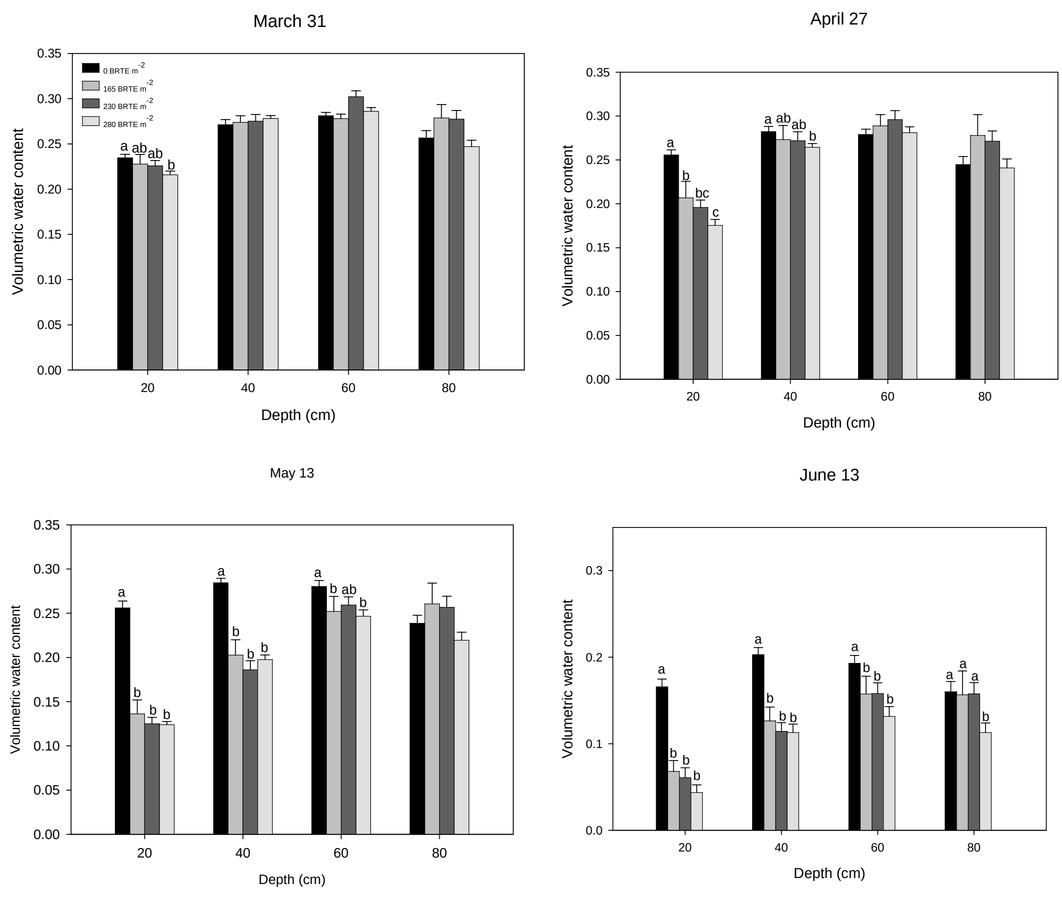

Figure 2. Soil water content by *B. tectorum* density and depth on four 2007 dates.

Discussion

B. tectorum densities the first year after a fire vary widely based on prior densities, autumn and winter precipitation after the fire, and other factors. However, it has been generalized that densities are typically less than 10 plants m^{-2} the first year after fire, but can increase to densities greater than 10,000 plants m^{-2} within 3 years (Dalzell 2004, Young and Evans 1985). The response in forb biomass to increasing *B. tectorum* densities demonstrates the importance of seeding immediately after the fire when *B. tectorum* densities are at their lowest.

Forbs responded differently to *B. tectorum. Lomatium grayi* biomass was the least affected by *B. tectorum. A. millefolium* and *E. umbellatum* were intermediate and *P. speciosus* had the greatest reduction in biomass. While predicting densities of *B. tectorum* is difficult, this data suggests that *P. speciosus* should only be used at sites where densities are expected to be very low.

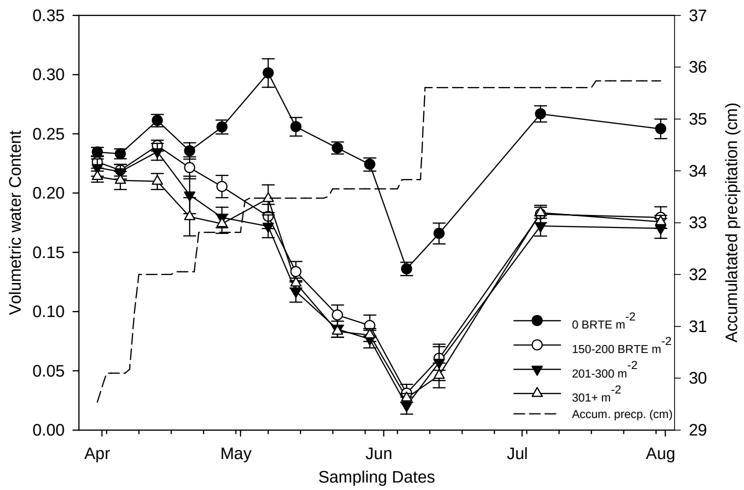

Figure 3. Volumetric water content at the 20 cm depth (left Y axis) for all sampling dates and B. *tectorum* densities and accumulated precipitation (right Y axis) for water year 2007.

The water content data may partially explain why *L. grayi* was the least affected by *B. tectorum.* As noted above, large differences between the control and the highest level of *B. tectorum* did not occur until mid to late April. Species began germinating in the following order: *L. grayi* (mid-February), *E. umbellatum* (mid-March), *A. millefolium* and *P. speciosus* (both mid April to early May). *L. grayi* had 6-8 weeks of growth by the time differences in water content occurred, while *P. speciosus* had less than 1-2 weeks.

Literature Cited

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Harris, G.A. and A. Wilson. 1970. Competition for moisture among seedlings of annual and perennial grasses influenced by root elongation at low temperatures. Ecology 51:530-534.

Melgoza, G., R. A. Nowak, and R. J. Tausch. 1990. Soil water exploitation after fire: competition between *Bromus tectorum* and two native species. Oecologia 83:7-13.

Young, J.A. and R.A. Evans. 1985. Demography of *Bromus tectorum* in *Artemisia* communities. Pages 489-501 in D.J. White, editor. The Population Structure of Vegetation. Dr. W. Junk Publishers. Dordrecht, Netherlands.

3. **Development of procedures to break dormancy in *Lomatium dissectum* seeds**

Additional Principal Investigators:

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and Department of Biology,
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Project Description and Status:

Objective 1:

Analysis of the effect of longer periods of cold stratification on seed germination and characterization of the stratification requirements of different seed populations

To determine whether cold stratification alone can induce high percent germination, we conducted experiments with a seed population collected in Harper-OR, elevation 4419 ft. After 18 to 20 weeks of stratification at 4°C, these seeds reached a maximum germination of 85 to 90%, thus indicating that cold stratification alone can break dormancy of most seeds. *Lomatium dissectum* seeds grow at different elevations ranging from 100 to 8000 ft. The cumulative duration of cold periods varies among these sites. We have begun to investigate the stratification requirements of different seed populations.

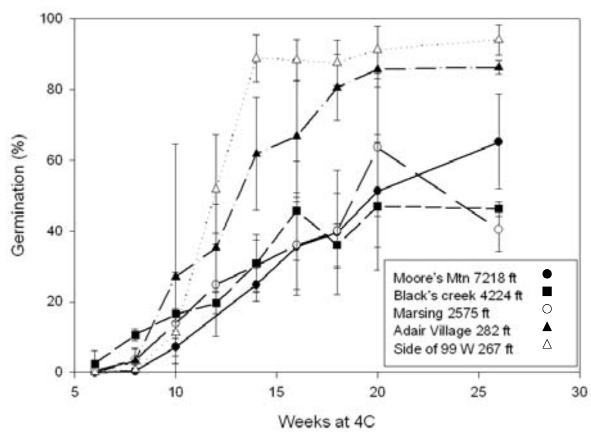

Figure 1. Effect of cold stratification on germination of seeds collected at sites with different elevations. Mean (± SD) of 3 to 5 replications with 50 seeds per replication. Seeds were placed at 4°C for the indicated times and then incubated at 15°C for 2 weeks. The values represent the total germination that occurred under cold conditions and after transfer to 15°C.

Preliminary results suggest that seeds collected at low elevations germinate sooner than those collected at higher elevations (Fig. 1). However, the seeds collected at elevations of 2500 ft or higher did not reach high germination even after 26 weeks of cold stratification. This limits the interpretation of the results because differences in germination may reflect in part differences in seed quality. To further investigate the stratification requirement of different seed populations, we began a new experiment. In June of 2007, we collected seeds from 10 different sites ranging in elevation from 180 to 7200 ft. These seeds have been in cold stratification for 7 weeks and we are measuring their germination in a weekly basis. This experiment involves using 10 replications per site with 100 seeds per replication. The increase in the sample size and the number of replications may allow us to reach a more definitive characterization of the stratification requirements of the different seeds populations.

Objective 2.
Analysis of the effects of fluctuations in temperature on seed germination. Experiments related to this aspect of the project are in progress. We are currently stratifying seeds at 4°C. After 8 weeks of stratification, the seeds will be transferred to growth chambers that would provide the following diurnal temperature fluctuations: 17.5/12.5, 20/10, or 25/5 °C. The effectiveness of these treatments in triggering germination will be compared relative to control seeds kept constantly at 4°C and to seeds transferred to an environment with a constant temperature of 15°C.

We have also begun to analyze the effect of interactions between temperature and seed water status on embryo growth and germination. Dormant seeds were placed in vermiculite equilibrated with different amounts of water to achieve water potentials of -0.03, -0.43, -0.96, and -1.63 MPa. At high water potential (-0.03 MPa) the embryos reached full length after about 12 weeks of cold stratification. A decrease in seed water potential significantly reduced embryo growth (Fig. 2). Even a relatively mild water stress of –0.43 MPa resulted in a lower growth rate than the well-watered treatment. Water deficits during stratification also affected germination. After 24 weeks of cold stratification, the percent germination was 78 (±15), 41 (±11), 0, and 0% for the -0.03, -0.43, -0.96, and -1.63 MPa treatments, respectively.

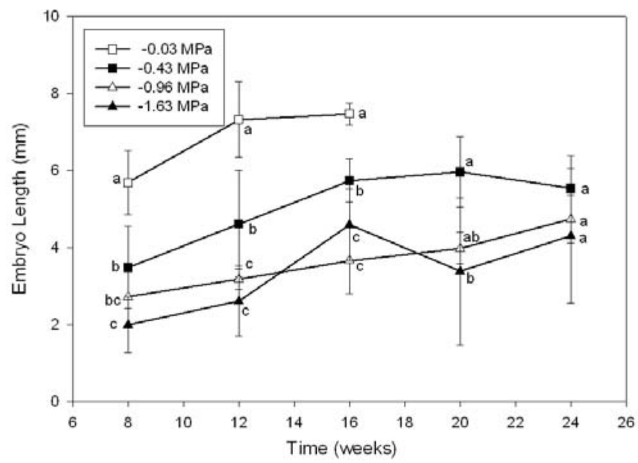

Figure 2. Embryo growth of *Lomatium dissectum* seeds at 4°C and different water potentials. Mean (±SD) of 10 replications with 5 embryos per replication. For a particular week, means not labeled with the same letter are significantly different ($p < 0.05$).

Objective 3.
Determination of the effects of plant growth regulators on seed germination. Attempts were made to reduce the period of stratification using plant growth regulators. None of the solutions tested had a positive effect on germination; several of the treatments significantly reduced embryo growth (data not shown) and germination with respect to the control water treatment (Table 1). In particular, treatment with gibberellic acid 3 alone or in combination with other hormones resulted in a marked inhibition of germination.

Other experiments related to hormones are in progress. We have prepared methanol extracts from seeds that have been stratified for various times. Our plan is to determine the concentration of abscisic acid in the extracts. These may provide an insight into the mechanisms that control embryo growth and germination, which may allow us to design better procedures to break dormancy in *L. dissectum* seeds.

Table 1. Effect of plant growth regulators on the germination of *Lomatium dissectum* seeds. Means ± SD of 3 replications with 60 seeds per replication. Dormant seeds were stratified at 4°C in solutions containing the growth regulators indicated below. Values not followed by the same letter are significantly different ($p < 0.05$).

6-Benzyl amino purine 500 µM	47.8 ± 10.5 a
water	42.0 ± 3.9 ab
6-Benzyl amino purine 250 µM	29.0 ± 11.8 abc
Naphtaleneacetic acid 50 µM	23.0 ± 6.4 bcd
Chloroethyl phosphonic acid 100 µM	22.3 ± 13.9 bcd
Chloroethyl phosphonic acid 250 µM + 6-Benzyl amino purine 250 µM	19.3 ± 8.3 bcd
Chloroethyl phosphonic acid 250 µM	18.3 ± 15.3 bcd
Chloroethyl phosphonic acid 500 µM	14.3 ± 9.4 cd
6-Benzyl amino purine 250 µM + Naphtaleneacetic acid 50 µM	13.9 ± 7.7 cd
Gibberellic acid3 500 µM	10.8 ± 3.1 cd
Naphtaleneacetic acid 100 µM	3.3 ± 3.8 d
Gibberellic acid3 250 µM	1.6 ± 21.4 d
Gibberellic acid3 250 µM + Chloroethyl phosphonic acid 250 µM	1.6 ± 1.6 d
Gibberellic acid3 250 µM + 6-Benzyl amino purine 250 µM	0.9 ± 0.6 d
Chloroethyl phosphonic acid 250 µM + 6-Benzyl amino purine 250 µM + Gibberellic acid3 250 µM	0.0 ± 0.0 d

4. Reestablishing diverse native Wyoming big sagebrush communities: a comparison of seeding equipment and techniques

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Project Description:

Objectives and Methods

To evaluate the capabilities of the Kemmerer rangeland drill and the Truax RoughRider minimum-till 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/m2.

	Seeding Rate, PLS/m^2	
Species	**High**	**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*	*169.8*
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 seeded 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 seeding rates 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.

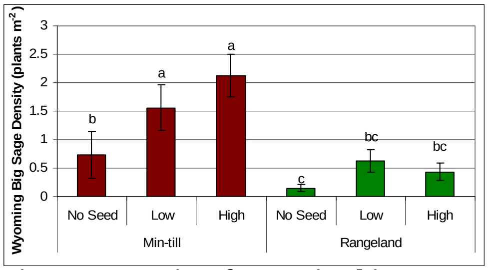

Figure 1. Density of Wyoming big Sage

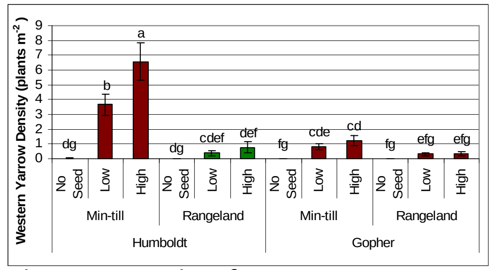

Figure 2. Density of western yarrow

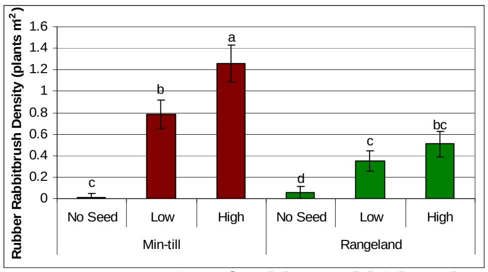

Figure 3. Density of rubber rabbitbrush

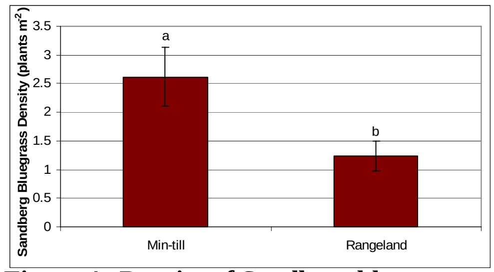

Figure 4. Density of Sandberg bluegrass

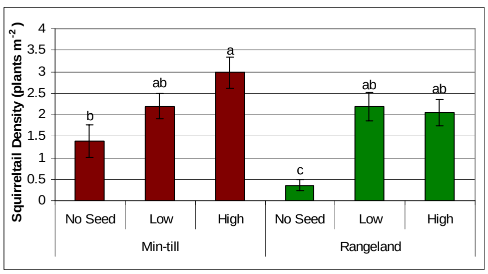

Figure 5. Density of squirreltail

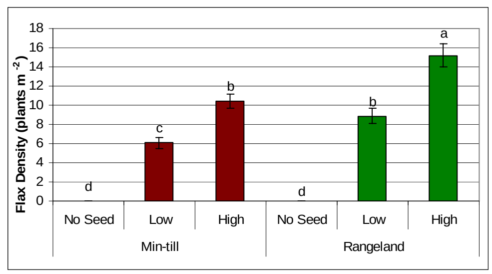

Figure 6. Density of flax

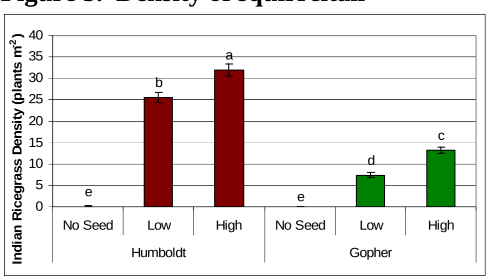

Figure 7. Density of Indian ricegrass

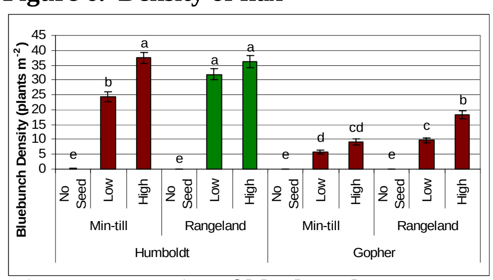

Figure 8. Density of bluebunch

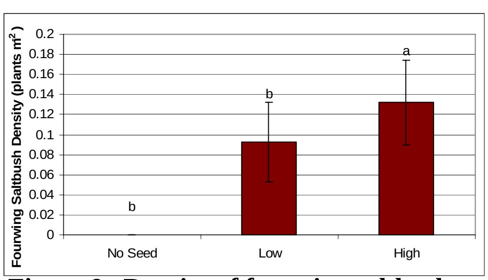

Figure 9. Density of fourwing saltbush

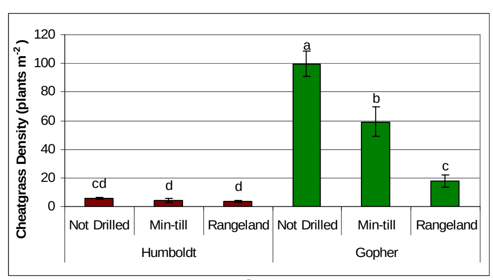

Figure 10. Density of cheatgrass

Project Status:

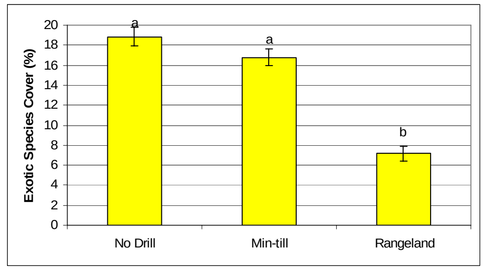

Figure 11. Cover of exotic species

Data collection for this project occurred from June 4-14, 2007. Data were collected based on the template provided by Dr. David Pyke, USGS, for entry into the "Rangeland Database and Field Data Entry System", a cooperative effort between ARS, NRCS, BLM, and USGS. Six 30-m transects were established perpendicular to the drill rows in each plot. On each transect, the density of all seeded species, plus cheatgrass and any native perennial species, were observed and recorded in four, 0.5-m^2 quadrats; species richness was also recorded by noting all unique species in each quadrat. Line-point intercept data was also collected along each transect, by placing a point every meter from a random starting point between 5.0 and 5.9 m along the transect (for a total of 20 points per transect, 120 total points per plot). Finally, basal gap intercept was collected along the same transects, by recording the length of all gaps longer than 20 cm, beginning at the 5-m mark and continuing until the 25-m mark. Data collection involved 8 field workers, and took about 2 weeks.

Data were analyzed with Proc Mixed in SAS, and mean separations were performed with the Bonferroni adjustment (P=0.01). Density of broadcast species (see Table 1 for names and rates) was greatest in plots that were seeded with the minimum-till drill (Figs. 1-4), while density of drilled species was generally not significantly different between the drill types, but did differ significantly between seeding rates and study locations (Figs. 5-9). Cheatgrass density was greatest at the Gopher study site, where it was most dense in untreated control plots, followed by the minimum-till plots (Fig. 10). Cover of seeded species was uniformly low, as this was the first growing season following seeding. Cover of exotic species, however, followed a similar pattern to the density of cheatgrass. In unseeded plots (either undisturbed by the drills, or disturbed by the drills, but with no seed), cover of exotic species was greatest in the control (not disturbed) and minimum-till plots, while plots that experienced the rangeland drill (with no seed) had the lowest cover of exotic species (Fig. 11).

<u>Future Plans</u>

The plots established for this study will be followed for at least 1 more year and data will be collected in May or June of 2008.

Management Applications:

Land managers will benefit from the information produced by this study by using the results to aid in post-wildfire restoration planning. The results of this study should allow managers to better understand how the respective drills differ in their abilities to seed native species in a diverse mix. Such information will help managers in selecting seeding equipment that meets both the site requirements and the seeding goals.

5. Equipment and strategies to enhance the post-wildfire establishment and persistence of Great Basin native plants

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Project Description:

Objectives and Methods

This study, funded through the Joint Fire Sciences Program and the Great Basin Native Plant Selection and Increase Project, 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 establish large-scale plots for long-term monitoring of the effects of grazing on post-wildfire restoration attempts. 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.

2007 Activities and Results

In August and September, 2007, study locations were selected near Mt. Home, ID and Burns, OR. At each location, 5 blocks of 13 plots were surveyed and marked, and seeding of all drill plots was accomplished in the last week of October through the first week of November, 2007. Winter broadcasting was accomplished in the middle of January, 2008. Five blocks of 3 plots each were also established and seeded to provide the ability to monitor grazing in the future. Seeds for the storage study were packaged and stored in May, 2007, with germination and moisture content tests being accomplished in August and November 2007.

Future Plans

Data will be collected from field plots in May or June of 2008 and 2009. A second set of plots will also be established in fall 2008, with data collection for those plots occurring in 2009 and

2010. The seed storage study will also continue, with germination tests and moisture content tests being done every 3 months through May 2008, and every 6 months thereafter.

Management Applications:
Land managers will benefit from the information produced by this study, in conjunction with the previous study, by using the results to aid in post-wildfire restoration planning. The results of this study should allow managers to better understand how the respective drills differ in their abilities to seed native species in a diverse mix. Such information will help managers in selecting seeding equipment that meets both the site requirements and the seeding goals. In addition, by working with the developer of the minimum-till drill, we expect to improve the performance of this equipment.

Products

Publications:

Kinter, C. Lynn; Shaw, Nancy L.; Hild, Ann L.; Mealor, Brian A. 2007. Post-fire seed ecology of rush skeletonweed (*Chondrilla juncea* L.): assessment of invasion potential. Rangeland Ecology and Management. 60:386-394.

Hild, Ann L.; Muscha, Jennifer M.; Shaw, Nancy L. 2007. Emergence and growth of four winterfat accessions in the presence of the exotic annual cheatgrass, p. 147-152. In: Sosebee, R.E.; Wester, D.B.; Britton, C.M.; McArthur, E.D.; Kitchen, S.G., comps. Shrubland dynamics: fire and water: proceedings. Proc.-P-47. Fort Collins, CO: USDA FS Rocky Mountain Research Station

Karrfalt, R.; Shaw, N.L. Checklist for developing native plant materials for restoration (submitted)

Shaw, N.L.; Pellant, M.; Olwell, M.; Jensen, S.; McArthur, E.D. Native plant domestication and restoration program for the Great Basin of western North America. Hohhot, Inner Mongolia, China: International Rangeland Congress/International Grassland Congress Proceedings (in press).

Shaw, N.L.; Hild, A.L.; Kinter, L. Rush skeletonweed (*Chondrilla juncea* L.): Post-fire invasiveness in the shrub steppe of western North America. Hohhot, Inner Mongolia, China: International Rangeland Congress/International Grassland Congress Proceedings (in press).

GBNPSIP Website:

Sherich, K. Webmaster
http://www.fs.fed.us/rm/boise/research/shrub/greatbasin.shtml

Reports, Taskorders, Agreements, Contracts:

Great Basin Native Plant Selection and Increase Project 2006 Report and 2007 Taskorder
Implemented 15 new agreements, 26 amendments and 4 contracts.

Grant Proposals Leveraged by GRBNPSIP Research:

Collection of native grasses for increase and common gardens. USDA FS PNW (R. Johnson, B. St.Clair, R. Cronn), USDA FS RMRS (N. Shaw), USDA ARS WRPIS (R.C. Johnson), and botanists of the USFS and BLM. USDA FS Native Plant Initiative Proposal. (funded)

Equipment and strategies to enhance the post-wildfire establishment and persistence of Great Basin native plants. N.L. Shaw, R.D. Cox, M. Pellant, and D.A. Pyke. Joint Fire Sciences Program Proposal. (funded)

Presentations and Abstracts:

Cox, R.D. 2007. Restoration of damaged wildlands: Requirements for success. Texas Tech University, Department of Natural Resources Management, Lubbock, TX.

Cox, R.D; Shaw, N.L. 2007. Sagebrush, fire, and restoration: new approaches in the Great Basin. In: One hundred fifty years of human activity in sagebrush steppe: ecological and genetic consequences, symposium. AAAS, Pacific Division 88th annual meeting, Boise, ID. Abstract. Invited presentation.

Johnson, R.C.; Hellier, B.; Adair, R.; Cashman, M.; St. Clair, B.; Shaw, N.; Erickson, V. 2007. Uncovering adapted germplasm for the Great Basin: tapertip onion, bluebunch wheatgrass and others. Developing native plant materials for the Great Basin. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th annual meeting, Reno, NV. Abstract. Invited presentation.

Lambert, S; Shaw, N.L. 2007. Native plants and restoration technology for the Great Basin. Integrating science & management on the Colorado Plateau, Flagstaff, AZ. Abstract. Invited presentation.

Muscha, J.; Haferkamp, M.R.; Shaw, N.L.; Vermeire, L.T. 2007. Competitive dynamics among crested wheatgrass and native forbs and grasses. Society for Range Management 60th annual meeting, Reno, NV. Abstract. Poster.

Parkinson, H.; Zabinski, C.; Shaw, N. 2007. Reseeding native forbs in the Great Basin: assessing the effects of grass competition on forb seedling growth. Ecological Society of America/Society for Ecological Restoration joint annual meeting, San Jose, CA. Abstract. Poster.

Pellant, M.; Shaw, N.L. 2007. Introduction to the Great Basin Native Plant Selection and Increase Project. Developing native plant materials for the Great Basin. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th annual meeting, Reno, NV. Abstract. Invited presentation.

Scholten, M.; Serpe, M.; Shaw, N. 2007. Growth and germination in *Lomatium dissectum* seeds. Reno, NV. Society for Range Management 60th annual meeting, Reno, NV. Abstract. Poster.

Scholten, M.; Zimmerman, S.; Shaw, NL; Serpe, M. 2007. Environmental regulation of dormancy loss in *Lomatium dissectum* seeds. Botanical Society of America annual meeting, Chicago, IL. Abstract. Poster.

Shaw, N.; DeBolt, A.; Cox, R. 2007. Native forbs and restoration technology for the Great Basin Developing native plant materials for the Great Basin. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th annual meeting, Reno, NV. Abstract. Invited presentation.

Shaw, N.L. 2007. Native forbs. Idaho Section, Society for Range Management, Boise, ID. Invited presentation.

Shaw, N.L. 2007. Natives, invasives, and restoration ecology: Cooperative research in the Great Basin. National Grassland manager's meeting, Midewin National Tallgrass Prairie, Joliet, IL. Invited presentation.

Shaw, N.L. 2007. Plant materials being developed by the Great Basin Project. Plant community restoration workshop, Grand Junction, CO. Invited presentation.

Shaw, N.L. 2007. Planting in the appropriate season. Plant community restoration workshop, Grand Junction, CO. Invited presentation.

Shaw, N.L. 2007. Update: Great Basin Native Plant Selection and Increase Project. Oregon/Washington BLM botanists meeting, Corvallis, OR. Invited presentation.

Shaw, N.; Pellant, M. 2007. Plant materials and revegetation technology for the Great Basin. National conference on ecological restoration, Kansas City, MO. Abstract. Poster.

Young, S.; Johnson, R.; Shaw, N. 2007. Accelerating seed production applicable to provisional seed zones for the Great Basin. Developing native plant materials for the Great Basin. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th annual meeting, Reno, NV. Abstract. Invited presentation.

Meetings, Field Tours, Workshops, Symposia:

Parkinson, H.: Discussed GBNPSIP forb project, Oregon State University Malheur Experiment Station field day, Ontario, OR.

Shaw, N.L. Organizer: Developing native plant materials for the Great Basin. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th annual meeting, Reno, NV.

Shaw, N.L. Program committee member and Board Member: Society for Ecological Restoration Northwest Chapter and Society for Wetland Scientists joint meeting, Yakima, WA. Co-organizer of session on sage-grouse habitat requirements and co-leader of workshop on native seeds.

Shaw, N.L. Planning committee member: Wildflower seed production research symposium, Orlando, FL. Also attended National native plant materials development program meeting, Orlando, FL.

RMRS Boise personnel: Provided local arrangements for a seed conditioning workshop conducted by Bob Karrfalt, FS National Seed Laboratory, at the Lucky Peak Nursery, Boise, ID.

RMRS Boise personnel: Provided two workshops on wildland seed collection for members of the Duck Valley Indian Reservation and a tour for Duck Valley and Fort Hall Reservation representatives. Three representatives of the Fort Hall Reservation also attended the seed conditioning workshop.

Awards:

N.L. Shaw: National Grasslands Research & Technology Award (USFS and NRCS). For GBNPSIP work.

E.D. McArthur and N. Shaw: Service First Award (USFS and BLM). For GBNPSIP and other plant materials and restoration work.

Exhibits:

The Great Basin Native Plant Selection and Increase Project Exhibit Booth was displayed at:

Society for Range Management 60th annual meeting & trade show, Reno, NV.
Wildflower seed production research symposium, Orlando, FL.
Plant community restoration workshop, Grand Junction, CO.
SERNW/SWS PNW joint meeting, Yakima, WA.

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:

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Project Description:
This project is funded through a Research Joint Venture Agreement between the USFS-RMRS, Boise, ID and the Utah Crop Improvement Association (UCIA), Logan, UT, initiated in fall 2003 and renewed with additional funds in fall 2004 and fall 2007. Seed is 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 (Jan. 1, 2007-Dec. 31, 2007). Table 1 lists forb and grass seed acquisitions, distributions, inventory, field status, and whether seed has been harvested for species germplasms included in the UCIA Stock Seed Buy-back Program from 2002-2007. This has been updated to include the previous AOSCA program that is now being administered by the UCIA. It is expected that in 2008 several additional forbs and grasses will be included in the program. Table 2 lists the standardized market price for contract negotiations updated for 2007.

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

The 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 2007 (see 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., R. Johnson, and N. Shaw. 2007. Accelerating seed production applicable to provisional seed zones in the Great Basin. Developing native plant materials for the Great Basin. Great Basin Native Plant Selection and Increase Project 2007 symposium. Society for Range Management 60th Annual Meeting, Reno, NV. Invited presentation. Abstract.

Young, S. 2007. Tips for native germplasm development and release (presentation and discussion), and Utah's experience with TZ labeling (handouts and discussion). Annual native seed quality symposium 82^{nd} joint annual meeting, Association of Official Seed Analysts and Society of Commercial Seed Technologists, Cody, WY.

Young, S. 2007. Is what's on the tag what's in the bag? Native wildflower seed production research symposium, Orlando, FL. Abstract.

Young, S. 2007. How do you tell what's in the bag? Uncompagre Plateau Restoration Plant Community Workshop, Grand Junction, CO. Handouts and discussion.

Bouck, M. 2007. Improving plant cultivars, rangelands, and plant selection. Ministry of Agriculture, Yanchi County, Ningxia Provence, China. Presentation and Discussion.

Table 1. 2007 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. Previous AOSCA program is now being administered by UCIA.

Kind & Variety / Germplasm	Lot/ Source	Seed acquisition and production status	Generation	Added to Inventory	Date	Distributed from Inventory	Date	Inventory 12/31/2007	State distributed to	Field Status	Seed Harvested
FORBS & SHRUBS				bulk		bulk		bulk			
Achillea millefolium											
Western Yarrow											
Eagle Site	NSW4-1-EMY1-1	*3	G2	6.5lb	9/15/04	0.6	4/25/05	0	WY	Seeded Fall 2007	No
	NSW4-1-EMY1-1	*3	G2			5.8	9/14/05	0	WA	Established	2006
	NWS-1-YAR-FDN	*3	G2	13lb	9/20/05	13	5/30/07	0	OR	Seedling	No
Balsamoriza hookeri	BAHO B1-02	*1*2	G0	271g	Fall 2002	126g	Fall 2002	0.0	ID	Taken out 2006	Yes
Hooker Balsamroot	BAHO B1-02	*1*2	G0	N/A	Fall 2002	145g	Fall2002		CO		2007
	BAHO JS-1	*1*2	G1	181g	9/13/06	0		181g			
Balsamorhiza sagittata	BASA U32-02	*1*2	G0	735	4/15/04	541	4/16/04	194.0	UT	Seeded 2004	No
Arrowleaf Balsamroot											
Crepis acuminata	CRAC U11-02	*2	G0	50g	Fall 2002	50g	Fall 2002	0.0	ID	Est.2002, out 2005	2005
Tapertip hawksbeard	CRAC U10-02	*1*2	G0	160	4/15/04	148	Fall 2002	12.0	UT	Unsuccessful	No
Eriogonum heracleoides	ERIHER1-BSE-03	*1*2	G0	43	4/15/04	22.5	4/16/04	20.5	UT	Unsuccessful	No
Wyeth Buckwheat											
Eriogonum umbelatum	Unknown		G0		2004		2004		ID	Seeded 2004	No
Sulfurflower Buckwheat											
Lomatium dissectium	LODI B7-02	*2	G0	39g	Fall 2002	39g	Fall 2002	0.0	NV	Unsuccessful	No
Giant Lomatium	LODI B14-02	*2	G0	96g	Fall 2002	96g	Fall 2002	0.0	OR	Taken out 2004	2004
	LODI PS-04	*3	G1	60g	11/30/04	0		60g *4			
	LODI11-B7-03	*1*2	G0	91	4/15/04	72.1	4/16/04	18.9	UT	Unsuccessful	No
	LOMDIS18-BSE-03	*1*2	G0	488	4/15/04	188	4/16/04	300.0	UT	Unsuccessful	No
	LOMDIS18-BSE-03	*1*2	G0			453	10/3/05	0.0	WA		
Northern Basin and Range	pooled LODI 11,77,41,78,76	*1*2	G0	907	10/31/06	907	11/22/06	0.0	UT	Seedling 2007	No
Penstemon acuminatus	PEAC2 B4-02	*1*2	G0	102g	Fall 2002	102g	Fall 2002	0.0	ID	Established	No
Sharpleaf Penstemon	PEAC2 B1-01	*2	G0	37g	Fall 2002	37g	Fall 2002	0.0	NV	Unsuccessful	No

Table 1 cont. 2007 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. Previous AOSCA program is now being administered by UCIA.

Kind & Variety / Germplasm	Lot/ Source	Seed acquisition and production status	Generation	Added to Inventory	Date	Distributed from Inventory	Date	Inventory 12/31/2007	State distributed to	Field Status	Seed Harvested
Penstemon cyaneus	PECY2 B6-02	*2	G0	968g	Fall 2002	83g	Fall 2002	0.0	ID	Est 2002 out 2006	2004-2006
Blue Penstemon	PECY2 B6-02	*2	G0			685g	Fall 2002		CO	Established	2004-2006
	PPI-04-1	*1*3	G1	3lb	1/6/05	3lb	9/16/05	0.0	ID	Seeded 2005	No
	2004.0448	*1*3	G1	16lb	2/2/05	16lb	2/2/05	0.0	CO	Seeded 2004	2006-2007
	2006.0413	*1*3	G1	5lb	12/5/06	5lb	3/1/07		WY, ID	Seeded 2007	No
	Unknown	*1*3	G1						ID	Established	2006-2007
Penstemon deustus	PEDE B11-02	*1*2	G0	150g	Fall 2002	150g	Fall 2002	0.0	ID	Established	2005-2007
Hotrock Penstemon	PEDE B10-02	*1*2	G0	123g	Fall 2002	123g	Fall 2002	0.0	OR	Est. 2002, out 2004	2004
	PEDE		G0				Fall 2007	250.0	UT	Seeded 2007	
Penstemon pachyphyllus	PEPA2 U6-99	*1*2	G0	1020g	Fall 2002	340g	Fall 2002	0.0	OR	Est2002, out 2005	2004-2005
Thickleaf Penstemon	PEPA2 U6-99	*1*2	G0			340g	Fall 2002		OR	Est.2002, out 2004	2004
	PEPA2 U6-99	*1*2	G0			340g	Fall 2002		NV	unsuccessful	no
	PEPA2 U6-99	*1*2	G0			340g	Fall 2002		NV	unsuccessful	no
	PEPA PS-04	*3	G1	345g	11/30/04	0		345g *4			
	A5-4-P1	*3	G1	50lb	6/7/05	4.6lb	Fall 2005	38.0	UT	unsuccessful	no
	A5-4-P1	*3	G1			7.3lb	Fall 2005		ID	seeded 2007	no
Penstemon Palmerii	CPP KL-05-1, GBRI 16		F	133lb	3/2/06	2.14lb	3/14/2006	88.5	WY	seeded 2007	no
Palmer Penstemon	CPP KL-05-1, GBRI 16		F			9.7lb	3/14/2006		ID	seeded 2007	no
Cedar	CPP KL-05-1, GBRI 16		F			32.2	11/2/2006		CO	Seeded 2006	no
	CPP KL-05-2, GBRI 26		F	4lb	3/24/06						
	CPP KL-05-3, GBRI 36		F	10lb	3/24/06						
Penstemon speciosus	PENSPE1-BSE-03	*1*2	G0	92	4/15/04	82	4/16/04	0.0	UT	unsuccessful	no
Sagebrush Penstemon	PENSPE1-BSE-03	*1*2	G0	N/A	4/15/04	10	4/16/04		UT	established 2005	2006-2007
	PEN SPE KV-06	*1*3	G1	1360	12/6/06			1360.0			
	PEN SPE KV-07	*1*3	G1	*5	12/6/06						
Northern Basin and Range	PEN SPE NBR USFS-07	*1*3	G0	3052	11/8/07	3052	11/8/07	0.0	UT	Seeded 2007	no
Sphlaeralcea parvifolia	SPGR U19-02	*2	G0	150g	Fall 2002	150g	Fall 2002	0.0	OR	Est 2002, out 2004	Yes
Small Flower Globemallow	SPGR U13-01	*2	G0	150g	Fall 2002	150g	Fall 2002	0.0	OR	unsuccessful	no

Table 1 cont. 2007 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. Previous AOSCA program is now being administered by UCIA.

Kind & Variety / Germplasm	Lot/ Source	Seed acquisition and production status	Generation	Added to Inventory	Date	Distributed from Inventory	Date	Inventory 12/31/2007	State distributed to	Field Status	Seed Harvested
	S04-2-4	*3	G1	1.44lb	8/19/04	0		1.4			
	SPGR PS-04	*3	G1	130g	11/30/04	0		130g *4			
			subtotal	262.3		119.99		132.3			
GRASS				bulk lbs.		bulk lbs.		bulk lbs.			
Sandberg Bluegrass											
Mountain Home Site	557-215-31A	*3	G2	304.0	11/4/03	50.0	9/15/03	0.0	UT	not seeded	no
	557-215-31A	*3	G2			135.0	2003-2005		ID	taken out 2006	2005-2006
	557-215-31A	*3	G2			121.0	2003-2005		WA	Est. 2003, out 2006	2003-2006
	557-215-31A	*3	G2			1.5	4/25/05		WY	Seeded 2007	no
	016-215-611A	*3	G2	112.0	8/9/06	28.0	10/3/06	84.0	WA	Seeded 2007	no
	Poa Sec01-BSE-06	*1	G0	6.5	9/10/06	6.5	9/11/06	0.0	WA	seeded 4 acres 2006	no
Thurbers Needlegrass											
Orchard Idaho Site	SSF-TH-05	*1*2	G1	1.0	1/5/06			1.0			
	2005.0394-1	*3	G1	13.0	1/5/06	13.0	4/17/06	0.0	WA	seeded 2006	2007
	AchThu-BSE1-06	*1	G0	2.5	9/10/06	2.5	9/11/06	0.0	WA	seed sent back	No
	Unknown		G0						ID	Seeded 2004	no
Basin Wildrye											
NBR -Utah sites	UDWR	*1*3	G1	17.0	8/15/07	17.0	8/15/07	0.0	WA	Seeded 2007	no
			subtotal	456.0		374.5		85.0			
			Total lbs.	718.3		494.5		217.3			

*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

*5 Seed harvested and added to inventory but not conditioned

Table 2. Standardized Market Price for Contract Negotiation, Great Basin Native Plant Selection and Increase Project-Utah Crop Improvement Association Buy-back Program.

Scientific Name	**Common Name**	**Feb. 2008 Suggested Market Price**
Forbs		
Achillea millefolium	Western yarrow	$5.00
Balsamorhiza hookeri	Hooker's balsamroot	$40.00
Balsamorhiza sagittata	Arrowleaf balsamroot	$35.00
Crepis acuminata	Taper-tip hawksbeard	$140.00
Lomatium dissectum	Giant lomatium (parsley or biscuitroot)	$40.00
Lomatium triternatum	Nineleaf lomatium	$40.00
Penstemon acuminatus	Sharpleaf penstemon	$40.00
Penstemon cyananthus	Wasatch penstemon	$40.00
Penstemon cyaneus	Blue penstemon	$40.00
Penstemon deustus	Hot-rock penstemon	$40.00
Penstemon pachyphyllus	Thickleaf penstemon	$40.00
Penstemon palmeri	Palmer penstemon	$25.00
Sphaeralcea munroana	Munro globemallow	$60.00
Sphaeralcea grossulariifolia	Gooseberry-leaved globemallow	$60.00
Sphaeralcea parviflora	Small-flower globemallow	$60.00
Tragopogon dubius	Yellow salsify	$30.00
Grasses		
Achnatherum thurberianum	Thurber needlegrass	$40.00
Elymus elymoides	Bottlebrush squirreltail	$25.00
Elymus elymoides	Bottlebrush squirreltail	$25.00
Poa secunda	Sandberg bluegrass	$12.00

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

Project Location: Eastern Oregon Stewardship Services, Prineville, OR

Principal Investigators and Contact Information:

Berta Youtie
Eastern Oregon Stewardship Services Corporation
P.O. Box 606
Prineville, OR 97754
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Project Description:
This project will encourage private sector growers to produce GBNPSIP forbs and selected grasses. The principal investigator will act as a liaison between GPNPSIP and growers to verify that seeds and certification data are distributed, contracts are in place and payments are made in a timely manner. The PI will attend grower meeting to acquaint growers with GBNPSIP, identify grower concerns regarding the native seed industry and visit grower farms to suggest new native plant materials suitable for increase at each location. The PI will collaborate with BLM District Native Plant Materials Programs to conduct meetings and workshops to discuss methods of coordinating seed increase, purchasing to reduce grower risk, present success stories, discuss which species are already in production and which are still needed by ecoregion, and how to write contracts. A seed production database will be developed and distributed. Seed collections prioritized by seed zone will be made in SE Oregon and Northern Nevada.

Management Applications:
Increase production of GBNPSIP native species to be acquired by BLM for seed buys and used in restoration projects. Increase efficiency in seed selection and increase programs. Increase communications between GBNPSIP and native seed growers.

Products:
Future products will include:

- Seed production database including plant materials by seed zones.
- Increase in seed collections and distributions to growers.
- Increase of native species in BLM buys.
- Training sessions and workshops for BLM personnel.

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 testing, conditioning	AGCR diversification	Wildland seedbed ecology, species interactions, seedings	Wildland shrub seed collection	Releases
Apiaceae											
Lomatium dissectum	Fernleaf biscuitroot	GSD-B, PMC-A		GSD-P	BBSL, CSU	GSD-B, OSU	GSD-B, NSL		BSU		
L. graveolens var. *graveolens*	Stinking lomatium	UDWR				UDWR	UDWR, NSL				
L. grayi	Gray's biscuitroot	GSD-B, PMC-A		GSD-P	BBSL	GSD-B, OSU	GSD-B, NSL		MSU, GSD-B		
L. leptocarpum	Slender-fruit lomatium	GSD-B				GSD-B	GSD-B				
L. triternatum	Nineleaf biscuitroot	GSD-B, PMC-A			BBSL	GSD-B, OSU	GSD-B, NSL		EOARC		
Perideridia bolanderi	Bolander's yampah	UDWR				UDWR	UDWR, NSL		BYU, UDWR		
Asteraceae											
Achillea millefolium	Western yarrow							BYU, EOARC, TR	GSD-B, BYU, FRRL, MSU, TR		GSD-B
Agoseris aurantiaca	Orange agoseris	GSD-P				GSD-P	GSD-P				
A. glauca	Pale agoseris	GSD-P			BYU	GSD-P, BYU	NSL, GSD-P				
A. grandiflora	Bigflower agoseris	GSD-P, GSD-B				GSD-P	GSD-P				
A. heterophylla	Annual agoseris	GSD-P				GSD-P	GSD-P		BYU		
A. tridentata wyomingensis	Wyoming big sagebrush		GSD-P	GSD-P				BYU, EOARC, TR	USGS, GBRI, GSD-B, FRRL, TR PMC-GB	BYU, GSD-P	
Balsamorhiza hookeri	Hooker balsamroot	UDWR				UDWR	NSL		UDWR		
B. sagittata	Arrowleaf balsamroot	UDWR		GSD-P	BBSL, CSU	BYU, UDWR	UDWR, NSL				
Chaenactis douglasii	Douglas false-yarrow	GSD-B					NSL				

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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 testing, conditioning	AGCR diversification	Wildland seedbed ecology, species interactions, seedings	Wildland shrub seed collection	Releases
Chrysothamnus viscidiflorus	Yellow rabbitbrush								BYU		
Crepis acuminata	Tapertip hawksbeard	GSD-B, UDWR		GSD-P	BBSL, CSU, BYU	UDWR, BYU, USU	UDWR NSL		UDWR		
C. intermedia	Gray hawksbeard	UDWR			BYU	UDWR	UDWR		EOARC		
C. occidentalis	Western hawksbeard			GSD-P			NSL				
Enceliopsis nudicaulis	Nakedstem sunray								BYU		
Ericameria nauseosus	Rubber rabbitbrush		GSD-P	GSD-P				BYU, EOARC, TR	GSD-B, USGS, GBRI, TR, PMC-GB		
Erigeron pumilus	Shaggy fleabane			GSD-P		UDWR	NSL				
Heliomeris multiflora	Showy goldeneye	GSD-P		GSD-P							
Heterotheca villosa	Hairy false goldenaster								BYU		
Machaeranthera canescens	Hoary aster						NSL		MSU		
Townsendia florifer	Showy Townsend daisy	GSD-B									
Wyethia amplexicaulis	Mule-ears				BYU						
Capparaceae											
Cleome lutea	Yellow beeplant	UDWR			BBSL	UDWR	UDWR				
C. serrulata	Rocky Mountain beeplant				BBSL						
Chenopodiaceae											
Atriplex canescens	Four-wing saltbush	PMC-A	GSD-P	GSD-P				BYU, EOARC, TR	GSD-B, TR		
A. confertifolia	Shadscale		GSD-P								

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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 testing, conditioning	AGCR diversification	Wildland seedbed ecology, species interactions, seedings	Wildland shrub seed collection	Releases
A. torreyi	Torrey's saltbush		GSD-P								
Krascheninnikovia lanata	Winterfat	PMC-A	GSD-P								
Ephedraceae											
Ephedra viridis	Mormon tea	GSD-P									
Fabaceae											
Astragalus eremeticus	Hermit milkvetch						NSL				
A. filipes (A. stenophyllus)	Threadstalk milkvetch	FRRL		FRRL	BBSL, CSU	FRRL, OSU, USU	NSL				FRRL
A. utahensis	Utah milkvetch	GSD-P		GSD-P		GSD-P, BYU	BYU, GSD-P		BYU		
Dalea ornata	Prairie clover	FRRL		FRRL	BBSL, CSU	OSU, USU					
Hedysarum boreale	Boreal sweetvetch	FRRL, UDWR		FRRL, GSD-P	BBSL, CSU	UDWR	UDWR		UDWR		
H. occidentale	Western sweetvetch	FRRL, UDWR		FRRL		UDWR	UDWR				
Lathyrus brachycalyx	Sweetpea			GSD-P							
Lupinus arbustus	Longspur lupine	GSD-P		GSD-P		GSD-P	BYU, GSD-P		BYU		
L. argenteus	Silvery lupine	GSD-P		GSD-P	BBSL, CSU	GSD-P	GSD-P				
L. caudatus	Tailcup lupine	GSD-P		GSD-P		GSD-P	GSD-P				
L. polyphyllus	Bigleaf lupine	GSD-P		GSD-P		GSD-P	GSD-P				
Lupinus prunophilus	Hairy bigleaf lupine	GSD-P									
L. sericeus	Silky lupine	GSD-P		GSD-P	CSU	GSD-P, BYU	GSD-P				
Vicia americana	American vetch			GSD-P							
Liliaceae											
Allium acuminatum	Tapertip onion	ARS-P		ARS-P		ARS-P					
Linaceae											
Linum lewisii lewisii	Lewis flax	PMC-A		GSD-P				BYU, EOARC, TR	BYU		GSD-P

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 testing, conditioning	AGCR diversification	Wildland seedbed ecology, species interactions, seedings	Wildland shrub seed collection	Releases
L. perenne	Blue flax			GSD-P					BYU, TR, GSD-B		
Malvaceae											
Sphaeralcea spp.	Globemallow										
S. coccinea	Scarlet globemallow	UDWR			CSU	UDWR, BYU, OSU	UDWR				
S. grossulariifolia	Gooseberryleaf globemallow	UDWR		GSD-P, FRRL	BBSL	UDWR, BYU, OSU	UDWR				
S. munroana	Munro's globemallow	FRRL		FRRL	BBSL		NSL	BYU, EOARC, TR	BYU, TR, GSD-B, USGS, GBRI, PMC-GB		
S. parvifolia	Small-flower globemallow	UDWR				OSU, UDWR	UDWR				
Poaceae											
Achnatherum hymenoides	Indian ricegrass	FRRL, ARS-P		GSD-P, FRRL, ARS-P		ARS-P		BYU, EOARC, TR	GSD-B, USGS, GBRI, TR, PMC-GB		
A. thurberianum	Thurber's needlegrass	GSD-B		FRRL							GSD-B
Agropyron cristatum	Crested wheatgrass							BYU, EOARC, PMC-A, UNR, TR			
A. desertorum	Desert wheatgrass								BYU		
Aristida purpurea	Purple threeawn	UDWR									
Bromus carinatus	California brome			GSD-P							
B. marginatus	Mountain brome			GSD-P	CSU						
Elymus elymoides	Squirreltail grass	FRRL		FRRL				BYU, EOARC, TR	BYU, EOARC, MSU, TR		FRRL
E. elymoides brevifolia	Bottlebrush squirreltail	FRRL		FRRL					GSD-B, USGS,		

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 testing, conditioning	AGCR diversification	Wildland seedbed ecology, species interactions, seedings	Wildland shrub seed collection	Releases
									GBRI, TR, PMC-GB		
E. multisetus	Big squirreltail	FRRL		FRRL							
E. wawawaiensis	Snake River wheatgrass	FRRL		FRRL							
Hesperostipa comata	Needle-and thread grass	UDWR, GSD-P, FRRL		GSD-P, FRRL		UDWR, GSD-P	BYU, UDWR, GSD-P				
Leymus cinereus	Basin wildrye	UDWR, FRRL		FRRL	CSU	UDWR			BYU		
L. salinus	Saline wildrye								BYU		
L. triticoides	Beardless wildrye	FRRL		FRRL							
Nassella viridula	Green needlegrass										
Pascopyrum smithii	Western wheatgrass	FRRL		FRRL							
Pleuraphis jamesii	James' galleta	UDWR									
Poa fendleriana	Muttongrass	UDWR					UDWR				
P. secunda	Sandberg bluegrass	FRRL		FRRL				BYU, EOARC, TR	GSD-B, EOARC, MSU, TR		GSD-B
Pseudoroegneria spicata	Bluebunch wheatgrass	UDWR, GSD-B, FRRL, ARS-P, PMC-A		PNW, FRRL GSD-B, ARS-P		ARS-P		BYU, EOARC, TR	TR, GSD-B, BYU, EOARC		GSD-B
Sporobolus airoides	Alkali sacaton								BYU		
Polemoniaceae											
P. longifolia	Longleaf phlox	GSD-P		GSD-P		GSD-P, BYU	GSD-P				
Polygonaceae											
Eriogonum heracleoides	Wyeth buckwheat						NSL				
E. ovalifolium	Cushion buckwheat	UDWR				UDWR, BYU	UDWR, NSL				

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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 testing, conditioning	AGCR diversification	Wildland seedbed ecology, species interactions, seedings	Wildland shrub seed collection	Releases
E. sphaerocephalum	Rock buckwheat	GSD-B									
E. umbellatum	Sulfur-flower buckwheat	GSD-B, PMC-A		GSD-P	BBSL, CSU	OSU, GSD-B	GSD-B, NSL		GSD-B, USGS, GBRI, MSU, TR, PMC-GB		
Rosaceae											
Amelanchier alnifolia	Saskatoon serviceberry								BYU		
Purshia tridentata	Bitterbrush	GSD-P	GSD-P						BYU	BYU, GSD-P	
Scrophulariaceae											
Penstemon acuminatus	Sharpleaf penstemon	GSD-B, PMC-A		GSD-P	CSU	GSD-B, OSU	GSD-B, NSL, OSU				
P. cyaneus	Blue penstemon										
P. deustus	Scabland penstemon	GSD-B, PMC-A		GSD-P		GSD-B, OSU	GSD-B, NSL, OSU		GSD-B, USGS, GBRI, TR, PMC-GB		
P. pachyphyllus	Thickleaf penstemon										
P. palmeri	Palmer penstemon			GSD-P							
P. speciosus	Royal penstemon	GSD-B, PMC-A		GSD-P	BBSL, CSU	GSD-B, OSU	GSD-B, NSL, OSU		MSU, SLL-B		
P. strictus	Rocky Mountain penstemon								BYU		

ARS-P = ARS, Western Regional Plant Introduction Station, Pullman, WA (Johnson, Hellier)
BBSL = USDA-ARS Bee Biology and Systematics Laboratory (Cane)
BSU = Boise State University, Boise, ID (Serpe)
BYU = Brigham Young University (Anderson, Roundy, Johnson, Jessop, Geary)
CSU = Colorado State University, Cooperative Extension, Tri-River Area (Hammon)

EOARC = USDA-ARS Eastern Oregon Agricultural Research Center (Mangold, James)
FRRL = USDA-ARS Forage and Range Research Laboratory (Johnson, Monaco)
GBRI = Great Basin Restoration Initiative (Pellant)
GSD-B = USDA-FS-RMRS GraGSDand, Shrubland and Desert Ecosystem Research Program - Boise (Shaw, Cox)
GSD-P = USDA-FS-RMRS GraGSDand, Shrubland and Desert Ecosystem Research Program - Provo (McArthur, Jensen, Sanderson)
MSU = Montana State University, Bozeman, MT (Zabinski)
NSL = National Seed Laboratory (Karrfalt, Vankus)
OSU = Oregon State University, Malheur Experiment Station (Shock, Feibert, Johnson)
PMC-A = Natural Resources Conservation Service, Aberdeen Plant Materials Center, Aberdeen, ID (St. John, Ogle)
PMC-GB = Natural Resources Conservation Service, Great Basin Plant Materials Center, Fallon, ID (Perkins)
PNW = USDA-FS-Pacific Northwest Research Station, Corvallis, OR (St.Clair)
TR = Truax Company, Inc. (Truax)
UCIA = Utah Crop Improvement Association (Young, Bouck)
UDWR = Utah Division of Wildlife Resources (Vernon, Meyer, Summers)
UNR = University of Nevada, Reno, NV (McAdoo)
USGS = USGS Biological Research Division, Corvallis, OR (Pyke)
USU = Utah State University (Ransom, Edvarchuck)

Notes:

1. Seed zones - *Atriplex, Artemisia*, and *Purshia* were identified in the original Task Order (McArthur and Sanderson research). Plant selection research will contribute to seed transfer guidelines for the remaining species.

2. Crested wheatgrass diversification: studies.