GREAT BASIN NATIVE PLANT SELECTION AND INCREASE PROJECT

FY2009 PROGRESS REPORT

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APRIL 2010

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Great Basin Native Plant Selection and Increase Project
2009 Progress Report

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

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

We thank our collaborators for their expertise and the in-kind contributions of their agencies that have made it possible to address many of the issues involved in native plant materials development and use. We especially thank Kelsey Clouse and Erin Denney for their hard work in editing, formatting and assembling this report.

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Great Basin Native Plant Selection and Increase Project:
http://www.fs.fed.us/rm/boise/research/shrub/greatbasin.shtml
Great Basin Restoration Initiative:
http://www.blm.gov/id/st/en/prog/gbri.html

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 2009 Progress

Highlights from the 2009 report are provided below. A current list of research species, GBNPSIP 2009 seed collections and the UCIA Stock Seed Production contract can be found in the Appendices.

- In 2009, GBNPSIP Cooperators, and their crews, made over 300 wildland seed collections of 71 species; including 63 research collections of *Artemisia tridentata* subspecies (see entire list Appendix I).

- A workshop: Sustaining vegetative landscapes in the West: Interactions with climate change was presented at the Ecological Society of America Annual Meeting, August 30, 2009, Albuquerque, NM. Presentations are online: http://www.fs.fed.us/rm/boise/research/shrub/projects/ESA_Presentations/ ESA_presentations_2009.shtml

- GBNPSIP Cooperators organized and participated in the workshop: Developing a Successful Native Plant Program, April 1-2, 2009, Ontario, OR. Over 150 participants came from eight western states. The workshop highlighted partnerships and collaboration, available native plant materials and success stories from Utah, Nevada, Idaho, Oregon and Washington. The workshop included a field demonstration on selecting and calibrating drills for seeding native seed mixes and a field tour of forb seed production research plots at the Oregon State University, Malheur Experiment Station. Presentations are online: http://www.fs.fed.us/rm/boise/research/shrub/projects/Ontario.html

- The Great Basin Native Plant Selection and Increase Project Annual Meeting was held in Boise, Idaho, on March 31, 2009. Presentations are online: http://www.fs.fed.us/rm/boise/research/shrub/GBNPSIP/GBNPSIPpresentations2009.shtml

Plant Materials Development

- Evaluation of 31 species for potential use as restoration materials is currently underway at the Provo Shrub Lab.

- Chemical scarification has proven effective for enhancing *Lupinus prunophilus* germination while mechanical scarification is more effective for *Lupinus argenteus.*

- Common garden trials of two shrub and eight forb species at two sites in Utah facilitated selection of Great Basin native plant species accessions that will be most amenable to ornamental landscape use.

- The Great Basin native species *Dalea ornata*, *D. searlsiae* and *Astragalus filipes* were selected for introduction to the ornamental industry and will be presented at a multi-state meeting of ornamental horticulturists and growers in 2010.

- Certified seed stock of Anatone bluebunch wheatgrass, Snake River Plains fourwing saltbush and Northern Cold Desert winterfat produced by the NRCS Aberdeen, Idaho Plant Materials Center is available though the University of Idaho Foundation Seed Program and Utah Crop Improvement Association.

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

- Seed transfer zones for key native Great Basin plant species are critical to ensure sustainable restoration. Great Basin seed zones have been developed for tapertip onion (*Allium acuminatum*) and Indian ricegrass (*Achnatherum hymenoides*). These seed zones will guide collection and seed increase of these species for future restoration.

- Germinination tests were completed for bluebunch wheatgrass to explore differences in germination rate among populations.

- Preliminary analyses indicate that bluebunch wheatgrass populations differ substantially for traits of growth, reproduction, leaf morphology and floral phenology.

- Moderate correlations of population means with the climates of bluebunch wheatgrass seed source origins suggest that presence of adaptively significant genetic variation that should be considered when moving populations in restoration projects.

- 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, revegetating 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.

Climate Change

- A range-wide seed collection of *Artemisia tridentata* subspecies was made for quantitative and molecular genetic analyses.

- We completed DNA sequencing of the transcriptome in *Artemisia tridentata* subspecies *tridentata* and *vaseyana.*

Seed Increase

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

- The UCIA Buy-back project provides a bridge between a) small-quantity initial accessions and b) commercial marketplace production, by working with specialized growers who are willing to provide land, time and expertise to produce increased amounts of stock seed that are then made available for commercial production. In general, great progress has been made in defining seed accession groupings and knowledge of agronomic seed production techniques.

- Through 2009 we partnered with growers in Utah, Wyoming, Nevada and Oregon to evaluate compatibility between the species planted, soil types and cultural practices, while increasing stock seed. Many test plots have been established among these growers evaluating upwards of 25 species.

- ❖ Ten native seed growers from Oregon, Washington, Idaho, Wyoming and Nevada took on native forb and grass seed for production of new fields.

Cultural Practices

Pollinators and Predators

- ❖ In relatively mild burns of intact sage-steppe plant communities across the northern Basin and Range province, additional standardized samples of bloom and bees indicate excellent prospects for survival (pending data analysis). Where forbs do not bloom in the year following fire (previously depauperate communities or hotter fires), surviving bee communities will need supplemental forage such as alfalfa or something that blooms reliably the year after seeding.

- ❖ Wild bees that are specialists on *Balsamorhiza* proved to be no more discriminating connoisseurs than generalists when foraging among mixed arrays of their limited set of related floral hosts. Seed growers must expect that even specialist bees will hybridize neighboring fields of infertile species (e.g. the balsamroots), so standard spatial isolation practices will be necessary in these limited cases.

- ❖ In chronically overgrazed and degraded sage-steppe plant communities, flowering species and the bees that pollinate them are sparse and lack diversity, whether it historically began as crested wheatgrass or not.

- ❖ Two previously unknown immature stages of two native insects were found to be pests of grass seed production fields. The larvae of a flea beetle, *Chaetocnema subconvexa*, caused significant damage to a field of blue wild rye, *Elymus glaucus*. The larvae of the checkered melon leaf beetle, *Paranapiacaba tricincta*, are presumed to feed on the roots of blue grama, *Bouteloua gracilis*, and galleta, *Hilaria jamesii*, after adult beetles were found in abundance in seed production fields.

- ❖ Two relatively unknown homopterans were found attacking and killing fourwing saltbush, *Atriplex canescens*, plants in native settings in Colorado. An ortheziid mealybug, *Orthezia annae*, was found killing mature fourwing plants near Grand Junction CO. The irregular wax scale was also found killing mature fourwing plants in the same region. Either of these native insects has the potential to become a significant pest in *Atriplex* seed increase blocks.

Stand Establishment

- ❖ Planting bulbs of *Allium acuminatum* in seed fields leads to seed production in the first year while plants grown from seed require 3–4 years to flower and set seed. Bulbs can be successfully planted using a mechanical planter. Timing of seed harvest is critical due to seed shattering.

- ❖ *Balsamorhiza sagittata* requires several years to flower and produce fruit. Plants are being established at high densities in small plots and will be transplanted into seed fields the year prior to first flower production to determine whether this might be a more economical means of establishing seed fields.

- ❖ N-sulfate fabric, a crop protective cover, has proven very valuable in increasing germination in field plantings. At US Natives in Elko, NV plant density in 2009 reached the objective of one plant/linear ft. for 16 of the 22 species planted under fabric. Only four species reached the desired objective without the fabric.

- ❖ Many of the forb species from low precipitation areas need irrigation for reliable seed production, but the supplemental irrigation when needed is in the range of only 100-200 mm.

- ❖ Subsurface drip irrigation systems work well for native forb seed production.

Weed Control

- Several herbicides including 2,4-DB may have potential for us in *Dalea searlsiae* seed production and additional trials should further document treatment effects on seed production and viability.

- Prowl H2O, Outlook, Sencor and 2,4-DB may have potential for Post-emergence use in *Dalea ornata* seed fields. The other herbicides tested may have potential if applied prior to *D. ornata* breaking dormancy as was observed in 2008. Further testing will be required to determine herbicide effects on seed production and viability.

- 2,4-DB may hold promise for use in controlling weeds in *Astragalus filipes* seed fields. However, seed yield and viability were not evaluated and must be tested to certify that candidate herbicides do not have a negative impact on seed production.

- Many post-emergence herbicides tested were effective for weed control. Few foliar or seed yield effects were found when herbicides were applied very early, before substantial forb growth. These herbicides lack registration.

Seed Biology and Technology

- Wyoming big sagebrush seed stored with no loss in germination for 2½ years by storing the seed dry and at -20°C.
    - Seed supplies of this species can be maintained for genetic conservation and restoration.
    - Equilibrium relative humidity technology proved to be an excellent nondestructive way to measure seed moisture for Great Basin species.

- Dormancy breaking procedures for the highly dormant seeded species *Achnatherum hymenoides* (Indian ricegrass) and *Penstemon acuminatus*, *P. deustus* and *P. speciosus* are under investigation so that these desirable species can be used successfully for restoration.

- Dormancy in *Sphaeralcea* spp. is an adaptive trait, but interferes with establishment of uniform stands in seed fields. Treating seeds with boiling water has proven effective in removing the waxy cuticle that prevents water uptake and subsequent germination.

- Plant growth regulators tested did not replace the requirement for cold stratification for embryo growth and germination of *Lomatium dissectum* seeds.

- *Lomatium dissectum* var. *dissectum* seeds from the Willamette Valley, OR had longer stratification requirements than those of *L. dissectum* var. *multifidum* collected from the northern Great Basin and Snake River Plain. Differences may reflect genetic differences between the populations and/or differences in environmental conditions during seed development. The shorter stratification requirements for seeds from the drier sites may provide an ecological advantage. This emphasizes the need for use of seed adapted to the planting site.

- *Lomatium dissectum* var. *multifidum* seeds produced during periods of dry conditions may be less dormant than those produced during periods with greater rainfall. Thus response to seeding date and overwinter conditions may vary among seedlots from the same location produced in different years.

Seed and Seedling Ecology

- Seedling root growth of revegetation species is being modeled using thermal accumulation. Forb roots were sensitive to increasing temperatures and required more degree days at temperatures above 20°C to reach 15 cm root depth. Grass roots were generally less sensitive to temperature and had generally similar degree day requirements to reach 15 cm root depth at all temperatures. This suggests that the forbs are most likely to establish during early spring, while grasses are able to establish under early spring or late spring temperatures, as long as soil moisture is available. As expected, cheatgrass roots grew fastest at cool temperatures. However, crested wheatgrass and Anatone bluebunch wheatgrass grew well enough to compete with cheatgrass.

Species Interactions

- Laboratory germination experiments were conducted to determine whether a suite of eight native annual forbs exhibit winter or spring annual germination syndromes. It was determined that *Amsinckia menziesii* var. *intermedia*, *A. tesselata*, *Descurainia pinnata* and *Lappula occidentalis* should be capable of germinating in the fall, which might make them more competitive with *Bromus tectorum*.

- A greenhouse experiment was conducted to determine whether a native perennial grass establishes more successfully in native annuals than in cheatgrass. Growing with competitors decreased the size of *Elymus multisetus*, however the largest decrease in size was found when grown with *B. tectorum* and *A. tesselata.* In contrast, *E. multisetus* grew best with *Mentzelia veatchiana*. When in competition with *B. tectorum*, *E. multisetus* performed best when *M. veatchiana* was also present. These results support the idea that the presence of certain native annual forbs can enhance the establishment of *E. multisetus* in *B. tectorum* invaded rangelands.

- A seed retrieval study for five native annual forbs is ongoing. Pilot data indicates that *Amsinckia menziesii* var. *intermedia*, and *A. tesselata* are partially dormant in the fall, and enter complete dormancy in winter. *Blepharipappus scaber* is entirely nondormant in the fall and enters dormancy in the winter, and seeds of *Mentzelia veatchiana* and *M. albicaulis* are dormant in fall and winter. This study will be ongoing for 3 years.

Crested Wheatgrass Diversification

- Spring-applied herbicide (glyphosate at 66 oz/acre) significantly reduced crested wheatgrass cover and density ($p<0.05$) as compared to untreated areas.

- Three-way disking did not significantly reduce crested wheatgrass cover ($p>0.05$) compared to untreated areas.

- Crested wheatgrass density was significantly greater ($p<0.05$) on areas that were 3-way disked.

- Four of the six seeded native grass species established during the first growing season after seeding: basin wildrye, bluebunch wheatgrass, bottlebrush squirreltail and Indian ricegrass. Each of the seeded forb species, western yarrow, Lewis flax and Munro globemallow also established.

- As spring growing conditions were nearly ideal, some grass and forb plants produced seed during the first growing season.

Restoration Strategies and Equipment

- The Revegetation Equipment Catalog (http://reveg-catalog.tamu.edu/) was duplicated on the Texas Tech University website, which will become the primary host for the Catalog in 2010.

- A drill calibration video scheduled for completion in spring 2009 by the USDA Forest Service Missoula Technology and Development Center describes drill parts and mechanisms and demonstrates three common methods of drill calibration. It will also illustrate some of the differences among drills. The video will include a glossary of standard terms used in describing seed quality and drill operation.

- Improvements to the minimum-till drill focused on transport safety, planter parallelograms and seed metering. Among design changes were additions of a safety hydraulic lockout valve, a centralized greasing system, an improved delivery spout for the fluffy seed box and a two spout seed meter cup for the cool season box to improve flexibility in seeding methods.

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Crested Wheatgrass Diversification

Restoration Strategies and Equipment

Appendices

Project Title: The Quest for Natives: Cultural Practices, Species Screening and Private Growers

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

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Project Description:
At the initiation of this GBNPSIP, our initial selection of plant materials included a number of species with morphological and/or phenological characteristics that made agronomic production difficult. Subsequently we are developing a screening process to characterize a species' agronomic and restoration potential as a first step in our development program. We see the native seed market in three broad categories: broad use restoration species, special use restoration species and niche species. Generally seed from a plant that yields large quantities can be marketed at a lower cost resulting in wide use. Species that fall into the broad use restoration category will follow this model as well as having good establishment characteristics, temporal persistence and desirability by end users. Special use species may be more difficult to produce resulting in higher seed cost, have a more restrictive geographic distribution or a narrower range of site adaptability than broad use species. Niche species may be difficult to produce in quantity resulting in high seed costs or have a narrow distribution or adaptability.

While several species we have worked with fall into the niche market category our efforts going forward are to focus on species that will fall into the broad use and special use categories.

<u>Species Screening</u>
Since 2006 we have made both opportunistic and targeted collections of plausible species and begun trials. Broader collection and more discrete selecting will occur for promising species. The following genera/species are currently being evaluated:

Genus	Common Name	Genus	Common Name
Agastache	giant hyssop	*Helianthus*	sunflower
Amsinckia	fiddleneck	*Hymenopappus*	hymenopappus
Argemone munita	flatbud pricklypoppy	*Hymenoxys*	rubberweed
Aster	Aster	*Iris*	iris
Astragalus	Milkvetch	*Linum subteres*	sprucemont flax
Balsamorhiza hookeri	Hooker's balsamroot	*Lithospermum*	stoneseed
Calochortus	mariposa lilly	*Lomatium nudicaule*	barestem biscuitroot
Castilleja	paintbrush	*Mentzelia*	blazingstar
Chaenactis	pincushion	*Nicotiana attenuata*	coyote tobacco
Cleome serrulata	Rocky Mountain beeplant	*Oenothera*	evening primrose
Cryptantha	cryptantha	*Packera*	groundsel
Enceliopsis nudicaulis	nakedstem sunray	*Penstemon*	beardtongue
Erigeron	fleabane	*Phacelia crenulata*	cleftleaf wildheliotrope
Frasera albomarginata	desert frasera	*Potentilla*	slender cinquefoil
Gaillardia	blanketflower	*Thelypodium milleflorum*	manyflower thelypody
Helianthella	one flower helianthella		

Individual Species Status

Astragalus utahensis

Niche Market: Prostrate stature makes weed control within the plant canopy difficult and limits mechanical harvest. Handheld or backpack blower-vacs are practical on small plots, a larger tractor mounted unit would be desirable for larger plots. Seed yields are projected to be about 40 lbs/acre.

Agoseris heterophylla

Special Use Market: Extrapolating data from greenhouse production indicates this species can yield as much as 900 lbs per acre. Operational scale production and harvesting difficulties will reduce yields substantially. Still yields on the order of several hundred pounds per acre should be feasible. Handheld or backpack blower-vacs are practical on small plots, a larger tractor mounted unit would be desirable for larger plots.

Fall 2008 plantings at two private growers failed. One plot germinated in December following a rainstorm then frost killed, the other plot experienced poor establishment due to a residual soil herbicide. We increased a G2 Humboldt County, NV source at our production facilities. Approximately 4 lbs of seed is available for distribution to growers in spring 2010.

Hesperostipa comata

Bulk collections were made in 2009 for several top performing sources based on seed yield, similarity in height and ripening date. Additional bulk collections will be made in 2010.

Lupinus spp.
Niche Market: Studies evaluating establishment techniques and yields for four lupine species completed their second year. *L. prunophyllus* and *L. arbustus* exhibit uniform seed ripening and good yields in wild stands. However, neither species has performed acceptably at any of four test sites. Establishment is often poor; the plants suffer from chlorosis, senesce early and require multiple years to reach flowering stage. *L. argenteus* and *L. sericeus* establish readily but exhibit indeterminate seed ripening and shatter. Extrapolated yields estimate harvest at < 50 lbs/acre with either multiple hand harvests or single mechanical harvest at peak seed.

<u>Stock Seed Production</u>
A single Humboldt County, NV source of annual agoseris (*Agoseris heterophylla)* was increased in 2007 (G1- 2 lbs), 2008 (G2 - 9 lbs) and 2009 (G3-4lbs) in our Provo greenhouse.

During the fall of 2009 the following species were seeded in small plots for seed increase:

Scientific Name	Common name	Species Screening	Yields - Row Spacing Trials	Increase	Seeding Rate
Amsinckia	fiddleneck	X			X
Argemone munita	flatbud pricklypoppy	X	X	X	X
Aster sp.	aster	X		X	X
Balsamorhiza hookeri	Hooker's balsamroot	X	X	X	X
Balsamorhiza sagittata	arrowleaf balsamroot		X		X
Cleome serrulata	Rocky Mountain beeplant		X	X	X
Crepis acuminata	tapertip hawksbeard	X	X	X	X
Crepis intermedia	limestone hawksbeard	X	X	X	X
Enceliopsis nudicaulis	nakedstem sunray	X	X	X	X
Frasera albomarginata	desert frasera	X	X	X	X
Heliomeris multiflora	Nevada goldeneye		X	X	X
Helianthella uniflora	oneflower helianthella	X	X	X	X
Ipomopsis aggregata	scarlet gilia	X	X	X	X
Iris missouriensis	Rocky Mountain iris	X	X		X
Lomatium dissectum	fernleaf biscuitroot		X		X
Lomatium nudicaule	barestem biscuitroot	X	X	X	X
Mentzelia sp.	blazingstar	X	X	X	X
Nicotiana attenuata	coyote tobacco	X	X		X
Penstemon sp.	beardtongue	X	X	X	X
Penstemon pachyphyllus	thickleaf beardtongue		X		X
Phacelia crenulata corrugata	cleftleaf wildheiotrope	X	X	X	X
Potentilla gracilis	slender cinquefoil	X	X	X	X
Thelypodium milleflorum	manyflower thelypody	X	X	X	X

Wildland Seed Collections

Seed collection, in 2009, targeted new and additional populations of species being screened, as well as additional populations of the promising candidates scarlet gilia, Nevada goldeneye, Lewis flax and thickleaf beardtongue.

2009 Seed Collections

	Screening		No. collections	Development		No. collections	
	Species	Common Name		Species	Common Name		
In Process	*Balsamorhiza hookeri*	Hooker's balsamroot	2	*Agoseris grandiflora*	bigflower agoseris	2	Materials in Development
	Enceliopsis nudicaulis	nakedstem sunray	3	*Agoseris heterophylla*	annual agoseris	1	
	Frasera albomarginata	desert frasera	2	*Lomatium dissectum*	fernleaf biscuitroot	1	
	Lomatium nudicaule ***	barestem biscuitroot	2	*Lupinus arbustus*	longspur lupine	2	
				Lupinus argenteus	silvery lupine	2	
				Lupinus prunophilus	hairy bigleaf lupine	1	
New Species to Screen	*Linum subteres*	sprucemont flax	1	*Lupinus sericeus*	silky lupine	2	
	Mentzelia	blazingstar	3	*Penstemon deustus*	scabland penstemon	1	
	Phacelia crenulata	cleftleaf wildheliotrope	1	*Penstemon speciosus*	royal penstemon	1	
	Agastache urticifolia	nettleleaf giant hyssop	1	*Sphaeralcea coccinea*	scarlet globemallow	1	
	Cryptantha	cryptantha	1	*Hesperostipa comata*	needle and thread	6	
				Heliomeris multiflora var. *nevadensis* ***	Nevada goldeneye	6	Recent Additions
Early Seral Species	*Amsinckia menziesii*	fiddleneck	3	*Ipomopsis aggregata*	scarlet gilia	6	
	Argemone munita	flatbud pricklypoppy	2	*Linum lewisii*	Lewis flax	3	
	Thelypodium milleflorum	manyflower thelypody	2	*Penstemon pachyphyllus* ***	thickleaf beardtongue	3	
	Nicotiana attenuata	coyote tobacco	3				

****** Distributed to Growers in 2009***

Bulk Collections from Wildland Stands for Research and Distribution to Growers

3 lbs of flatbud pricklypoppy (*Argemone munita*) were collected in Juab County, UT.
28 lbs of coyote tobacco (*Nicotiana attenuata*) were collected in Whitepine County, NV.
40 lbs of barestem biscuitroot (*Lomatium nudicaule*) were collected in Elko County, NV.
3 lbs of cleftleaf wildheliotrope (*Phacelia crenulata*) were collected in Whitepine County, NV.
18 and 28 lbs of thickleaf beardtongue (*Penstemon pachyphyllus*) were collected in Whitepine County, NV.

Soil Replacement Pilot Study

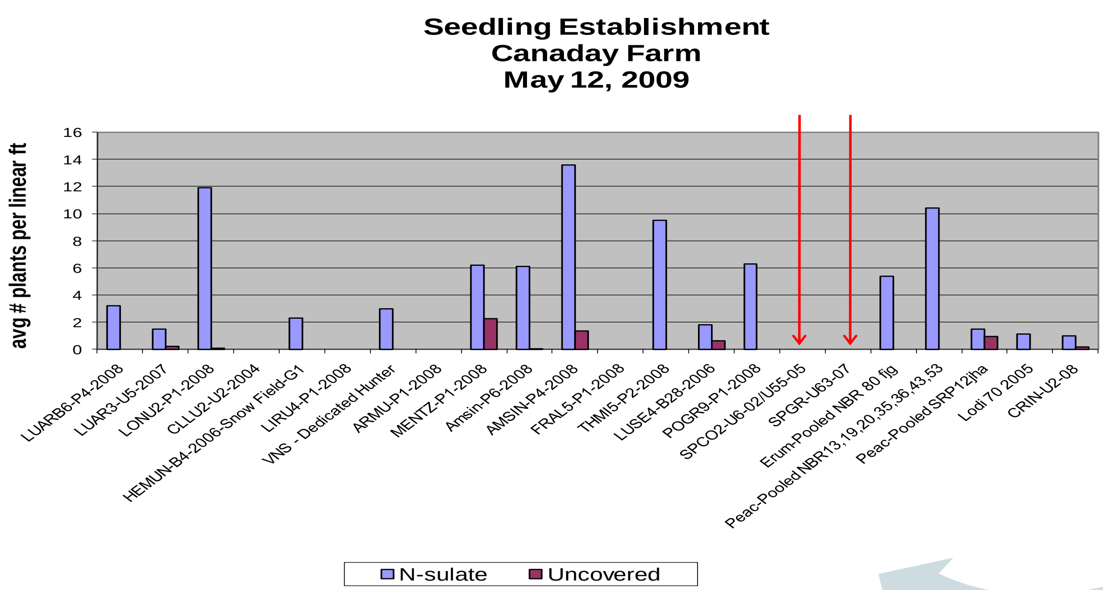
Soil samples taken at a large number of forb collection sites show a predominance of loam to sandy loam soils. Over the years we have seeded many species into clay loam to loam soils at our test facilities with mixed success. We hypothesize incompatibility between species and soil texture may be partially responsible in cases of poor establishment. In a pilot study with five replicated blocks at Fountain Green, UT we seeded four species into the native loam soil and a sandy replacement soil. A furrow opener was used to displace soil in a broad V shaped pattern to a width and depth of approximately 4”. Sandy soil was shoveled into the V. One row in each block/species combination was covered with n-sulate plant protection fabric while the other row was left open yielding four treatments; native soil covered and uncovered with n-sulate, and sandy soil covered and uncovered.

Balsamorhiza hookeri and *Frasera albomarginata* failed to establish under all treatments. *Thelypodium milleflorum* and *Potentilla gracilis* germinated significantly better ($p=0.004$) when covered with n-sulate fabric. While not significant at the 5% level, *P. gracilis* germinated nearly twice as well in native soil as the sandy replacement and *T. milleflorum* demonstrated just the opposite preferring the sandy soil nearly 2:1.

This study was expanded in 2009 to include 25 additional species, replicated at three sites.

N-Sulate Fabric Trials

N-Sulate fabric, a crop protective cover, has proven very valuable in increasing germination in field plantings. The fabric helps retain moisture, increases temperature and limits frost damage to early emerging seedlings. We have used the fabric in a soil texture study, in wildland settings and at several growers’ farms. At the Canaday farm in 2009 plant density reached the objective of one plant/linear ft. for 16 of the 22 species planted under fabric. Four of the remaining six species did not germinate at all and two germinated weeks after the fabric was removed. Only four species reached the desired objective without the fabric.



Cultural Practices

Root Transplant Study

A number of species require several years to reach seed producing stage. Paying weed control and maintenance costs on a nonproducing field for several years is cost prohibitive. Several species have large taproots with good potential for transplanting. We planted *Balsamorhiza hookerii, B. sagitata, Crepis acuminata, C. intermedia, Enceliopsis nudicaulis, Lomatium nudicaule, L. triternatum* and *Lupinus prunophilus* in densely seeded nursery beds to evaluate plant production in this setting and provide stock for transplanting trials. High density plantings grown to seed producing size then transplanted to production fields may be a feasible option for some species.

Seed Distribution to Growers

As of 2009 we have partnered with eight growers in Utah, Wyoming, Nevada and Oregon to evaluate compatibility between the species planted, soil types and cultural practices, while increasing stock seed. Our approach is to select a few species we think are well adapted to the site and grower circumstances for bulk plantings then take a shotgun approach with a lot of other species to determine what will perform well. Based on first year success, we will increase the size of successful plantings. Many test plots have been established among these growers evaluating upwards of 25 species.

Seed Distribution to Cooperators

Oregon State University Malheur Experiment Station. Clinton C. Shock. Seedling establishment and cultural practice studies.

Utah State University, Department of Plants, Soils, and Climate. Cory Ransom. Pre-emergent herbicide trials.

Presentations:

Jensen, Scott L. 2009. Equipment for native forb production. 6th Annual Diversity in Agriculture Conference, 2009 February 26; Delta, UT.

Jensen, Scott L. 2009. Status of plant materials development work for Great Basin species. Intermountain Native Plant Summit, 2009 March 24-25; Boise, ID.

Jensen, Scott L.; Jones, Covy; Vernon, Jason; Summers, Danny. 2009. The quest for natives: Cultural practices, species screening, harvesting equipment and private growers. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2009 March 31; Boise, ID.

Jensen, Scott L.; Jones, Covy. 2009. Status of plant materials development work for Great Basin species. Native Plant Materials and Seeding Workshop, 2009 April 1-2; Ontario, OR.

Jensen, Scott L. 2009. Overview of GBNPSIP. Colorado Plateau Materials Working Group Organizing Meeting, 2009 April 22; Salt Lake City, UT.

Jensen, Scott L. 2009. Overview of GBNPSIP with emphasis on Shrub Lab work. Visiting RMRS Leadership, 2009 July 7; Provo, UT.

Jensen, Scott L.; Jones, Covy; Larsen, Ron; Hanks, Kerry; Whitaker, Alison. Wintersteiger Classic Combine – Maintenance and Operation Guide. PowerPoint Presentation available for combine operators.

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

Project Location: Great Basin Research Center, Ephraim, Utah

Principal Investigators and Contact Information:

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Project Description:

Mission and Goals

We are working on developing cultural practices for several forb species in the Great Basin. Our current focus is improvement of germination techniques through mechanical, chemical and thermal scarification methods. Forging relationships with new growers continues to be a priority, thereby allowing us to increase seed availability from small collections to larger quantities and providing seed for larger production fields and landscape scale restoration projects. We are continuing to find new methods to deal with disease and pestilence issues that have become apparent in agricultural settings. We are also striving to purchase or develop necessary cultivation machinery to enable the success of the project.

Wildland Seed Collections

The focus this year was on bulk seed collections. A bulk collection allows us to experiment with direct seeding methods and provide seed to commercial growers. Seed set was good this year for balsamroot, globemallow and some lupine species; bulk collections were made for multiple accessions of these species. Seed set was poor this year for cushion buckwheat and hawksbeard species; collections were made when possible for these species. We will continue with the bulk collection model in 2010.

Species Status

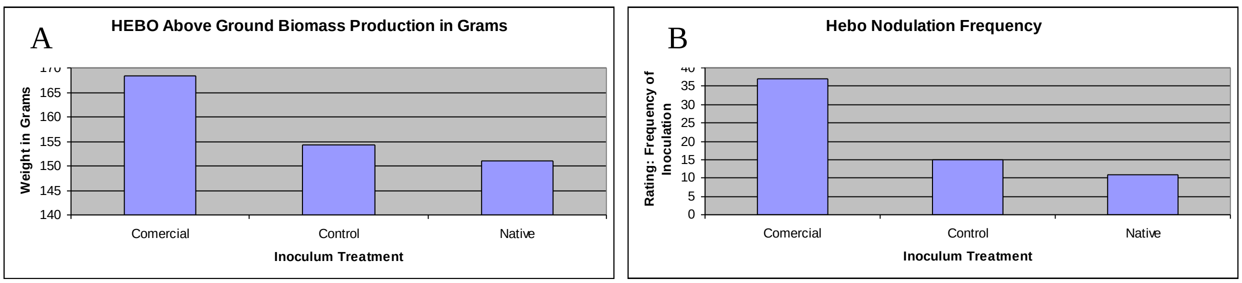
Sphaeralcea spp

New common gardens of globemallow species were established in Nephi and at the Desert Experimental Range (DER), west of Milford. This was done in an effort to confirm seed production data that was collected in 2008 from the Fountain Green common garden. Grasshoppers ate all the foliage at the Nephi site but not before the plants had time to establish. As a result, we suspect they will re-sprout in 2010. Disease presented an issue for globemallow species in 2008. Most of the Fountain Green common garden was decimated by a fungal rust infection and did not re-emerge in 2009. In addition to seed production, we will evaluate genetic resistance to rust at the newly established common garden sites. Due to the possibility of losing a significant number of plants from a particular accession to disease, a pooled source release might not be the best idea for this genus. Further investigation is needed to determine if some accessions are more resistant and would therefore be better suited for cultivation.

Hedysarum boreale

In 2008, preliminary inoculum testing was done on Utah Sweet-Vetch (*Hedysarum boreale*) to evaluate the effect of local native rhizobia vs. the commercially available rhizobia. We noticed that the commercial inoculum seemed to infect a higher percentage of plants. A follow up study this year confirmed preliminary results demonstrating that the commercially available inoculum has equal, or in some cases better, inoculation potential than the native inoculum. Figure 1a and 1b show the overall effect of inoculum on biomass production and nodulation frequency.

Figure 1 Effect of inoculums on A) biomass production and B) nodulation frequency.



Eriogonum ovalifolium

We collected data on the cushion buckwheat common garden using flower height as an indicator of mechanical harvest-ability, and because of the poor seed set, we used flower number as a surrogate for possible seed production. After analyzing the data we discovered that there are significant differences between accessions for both of these categories. We designed a scoring system to incorporate both the flower height and flower number data. We will continue to peruse the top ranking accessions for collections in 2010. To confirm that flower number is a good surrogate for seed set we are building pollination boxes to induce forced pollination and we will harvest actual seed this coming year. Once seed is acquired a pooled source accession increase plot will be established. Evaluation of mechanical harvesting methods will be conducted in order to provide mechanical seed harvesting information for growers.

Balsamorhiza spp

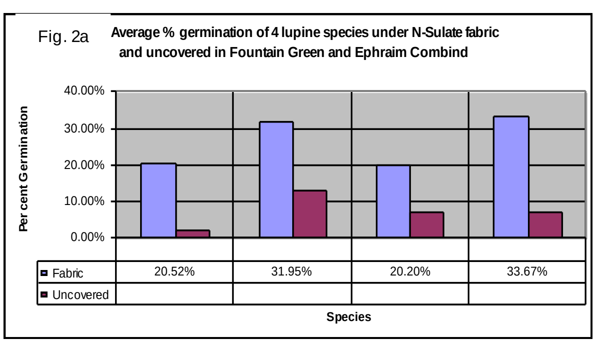
Arrowleaf balsamroot has posed problems primarily because of the time it takes to establish. This year we experimented with a new planting method where we used nursery bedding equipment to create a perfectly flat planting surface and then seeded on the beds with six inch row spacing. We hope to be able to establish a dense stand of plants and then use a root lifter to remove the plants from the bed and transplant them into a field the year before they produce seed. The use of dense beds until establishment would lower the initial land investment for a grower. We continue to work with Hooker's balsamroot and have included it in the above mentioned study. More wildland collections are needed for this species to bulk up stock seed for direct seeding.

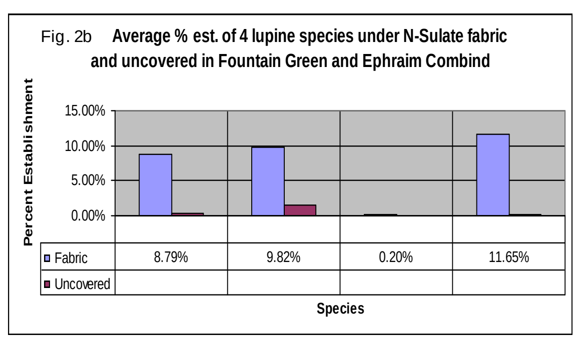
Perideridia bolanderi
We will continue to opportunistically collect wildland seed from superior accessions of this species. Time to establish may make it a good candidate for a transplant study.

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

Lupinus spp
Additional testing has been done on thermal, chemical and mechanical scarification; however, the mechanical scarification failed because the machine would not work with small quantities of seed. This has been corrected and is currently being repeated. Upon completion we will use linear regression to confirm preliminary results that *L. prunophilus* responds best to chemical scarification while mechanical works better on *L. argenteus*. In 2010, the regression will be finalized and used to find the optimal scarification technique for hard-seeded lupine species across several accessions. This will allow us to then use a more complex statistical model to define the best scarification methods over a broad geographic area.

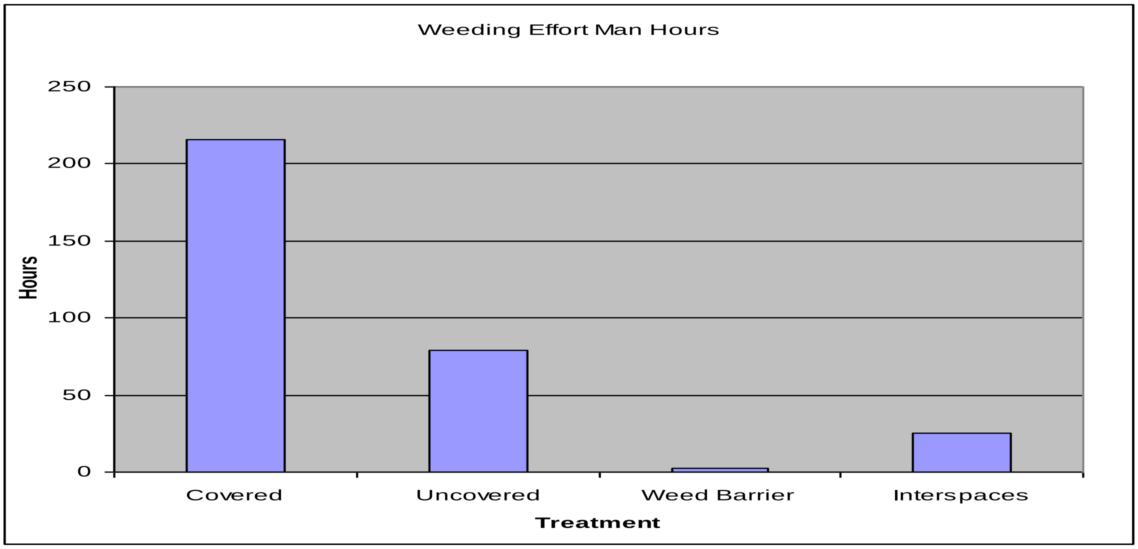
Cultivation Trials
Lupinus spp
We collected and analyzed data comparing two direct seeding methods as well as a transplant into weed barrier method for four lupine species (LUAR, LUPR, LUSE, LUARB). As shown in figure 2a and 2b, increased germination and establishment was shown with the use of N-Sulate fabric for all species. Although LUARB germinated, it quickly showed signs of iron chlorosis, then became necrotic and senesced and did not re-emerge in 2009. LUPR showed the same signs as LUARB but it was able to persist longer before it senesced, which allowed it to put down a root and it did emerge in 2009. We were able to sustain LUPR plants this year with supplemental EDDHA chelated iron treatments; however they did not produce flower or fruit.





Weed control techniques were also evaluated between the two planting methods; the transplant and interspaces method. The evaluation was done in man hours and the plots were a little less than 0.2 acres each. The interspaces were about half an acre. All weeding inside the plots was done by hand. Extrapolated it would take between 500 and 1000 man hours an acre to maintain the plot. Hand weeding is not a viable option. See figure 3.

Figure 3. Weeding time by treatment.



Yields for LUAR and LUSE, the two species that produced seed, were extrapolated into the range of 25 to 40 pounds an acre, which is too low for commercial production. In 2010, we will collect yield data again to see if the plants produce more seed in year three.

Management Applications:

Forb Island Study

The cost of native forbs will always be more than grasses, shrubs and non-native forbs. Because of the additional cost, land managers will be more discretionary about when and where they use these vital plants. We have been using N-Sulate fabric for the past two years in our field plantings and it has made up to 1000x increase in germination for some species. Selecting areas that will hold moisture longer, combined with the use of N-Sulate fabric for added heat and moisture retention, could improve germination and establishment in wildland restoration. To understand how this technology might improve restoration success we put the Forb Island Study in this fall at five locations; three in the Great Basin, one on the Colorado Plateau and one in the Mojave Desert. Each site is set up so that it will statically stand alone but can also be combined with the other sites. Using two seed mixes we will compare germination and establishment of plots that were either covered with N-Sulate fabric or not covered. In 2010, we will take germination and survival readings on the plots. In 2011, we will take establishment data. In subsequent years we will measure survival and recruitment.

Land Managers
Several of the globemallow plantings that we put in 2008 did well. We scaled up in 2009 and added three new growers growing different accessions of the same species. We encourage seed purchasers to keep these growers in mind when buying seed this coming year.

Seed Producers
We are now able to provide seed producers and restoration facilitators with information on scarification of globemallow and lupine species to facilitate stand establishment using less seed.

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

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

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

The Hanks farm located in Grover, Utah is just over 300 acres. Walt Hanks, the owner/operator of the farm, currently has about half of the land in grass pasture or alfalfa production. The farm sits at just over 7,000 feet in elevation. We planted 14 species on the Hanks farm, of which we have the lead on two.

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

The Young farm is located in Sterling, Utah and sits over 5,500 feet in elevation. The farm consists of 40 acres and is managed by Bob Young. We planted three species on the Young farm and have the lead on two of those.

Table 1. Natives seeded by private growers in 2009.

Grower	Species	Common Name	Acreage Seeded
Canaday	*Sphaeralcea grossularifolia*	gooseberryleaf globemallow	2.13
Bell	*Sphaeralcea grossularifolia*	gooseberryleaf globemallow	2
Bell	*Sphaeralcea coccinea*	scarlet globemallow	0.75
Tripp	*Balsamorhiza sagittata*	arrowleaf balsamroot	0.01
Tripp	*Balsamorhiza hookeri*	hooker's balsamroot	0.01
Tripp	*Crepis acuminata*	tapertip hawksbeard	0.01
Tripp	*Crepis intermedia*	limestone hawksbeard	0.01
Hanks	*Sphaeralcea coccinea*	scarlet globemallow	0.75
Hanks	*Sphaeralcea grossularifolia*	gooseberryleaf globemallow	2
Jones	*Sphaeralcea coccinea*	scarlet globemallow	1.5
Young	*Sphaeralcea coccinea*	scarlet globemallow	0.75
Young	*Sphaeralcea grossularifolia*	gooseberryleaf globemallow	2

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

Presentations:

Jones, Covy; Jensen, Scott. 2009. Native crops and seed production. Diversified Agriculture Conference, 2009 February 26; Delta, UT.

Jones, Covy; Jensen, Scott; Vernon, Jason; Summers Danny. 2009. The quest for natives; cultural practices, species screening, harvesting equipment and private growers. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2009 March 31; Boise, ID.

Jensen, Scott L.; Jones, Covy. 2009. Status of plant materials development work for Great Basin species. Native Plant Materials and Seeding Workshop, 2009 April 1-2; Ontario, OR.

Project Title: Demonstration, Education and Outreach Activities Related to GBNPSIP Plant Materials

Project Location: Utah State University, Logan, Utah

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Project Description:
Use of regionally adapted native plants in home and commercial ornamental landscapes can lower water use and decrease demand for limited water supplies. Most of the forbs being developed through GBNPSIP for rangeland restoration applications also have high potential for use as water-conserving ornamentals. Our project is devoted to education and outreach activities related to use of GBNPSIP and other native plant materials in urban low-water landscaping and in rangeland restoration and revegetation.

Objectives

- Incorporate plants developed in the GBNPSIP into evaluation and demonstration gardens in a multi-state area.
- Develop partnerships with state and local agencies and the private sector to educate the general public about GBNPSIP plant materials and their use in expanding biodiversity in the revegetation and restoration of degraded rangelands.
- Generate interest among growers for large-scale seed production of GBNPSIP plant materials, reduction in seed costs and increased availability.
- Facilitate development of a secondary, non-Federal market that would enhance market stability of GBNPSIP plant materials.

Materials and Methods

Common garden trials of two shrub and eight forb species were conducted at two sites in northern and north-central Utah. Ten plants of each accession of *Agastache*, *Cercocarpus*, *Geranium*, *Monardella*, *Penstemon*, *Purshia* and *Stanleya* and 18 plants of each accession of *Astragalus* and *Dalea* were planted at two sites: Utah State University Greenville Farm in North Logan, UT and the Utah Botanical Center in Kaysville, UT. Plants were transplanted from greenhouse-grown plants in fall 2007 (*Agastache*, *Cercocarpus*, *Geranium*, *Monardella*, *Penstemon*, *Purshia*, *Stanleya*) and spring 2008 (*Astragalus*, *Dalea*). Plots were arranged in a randomized complete block design. Seeds were collected in Utah and neighboring states (except as noted in Table 1) and grown to a suitable size for outplanting in a greenhouse on the campus of Utah State University in Logan, UT. Plants were irrigated as needed to insure their establishment during their first growing season (2008). Thereafter, no irrigation was added.

Species included in common garden trials:
Agastache urticifolia (Horsemint)
Astragalus filipes (Basalt milkvetch)
Cercocarpus ledifolius (Curlleaf mountain mahogany)
Dalea ornata (Western prairie clover)
Dalea searlsiae (Searl's prairie clover)
Geranium viscosissimum (Sticky geranium)
Monardella odoratissima (Mountain beebalm)
Penstemon eatonii (Firecracker penstemon)
Purshia mexicana (Cliffrose)
Stanleya pinnata (Prince's plume)

Table 1. Species utilized in the trials and the county, state, and elevation of each accession's origin.

Species	Accession	County	State	Elevation
Agastache urticifolia	TB16	Davis	UT	2438 m/8000 ft
	TB19	Cache	UT	2170 m/7119 ft
	TB21	Bannock	ID	Unavailable
	TB25	Juab	UT	1601 m/5252 ft
	TB36	Cache	UT	1712 m/5617 ft
Astragalus filipes	LH			Seed from L & H Seed Company
	NCO			Seed from a composite mixture of four collections from north-central Oregon
Cercocarpus ledifolius	A-29	Iron	UT	2410 m/7908 ft
	A-22	Millard	UT	1782 m/5848 ft
Dalea ornata	10	Sherman	OR	352 m/1154 ft
	17	Wheeler	OR	1001 m/3284 ft
	23	Jefferson	OR	941 m/3087 ft
	LH			Seed from L & H Seed Company
Dalea searlsiae	8	Lincoln	NV	1796 m/5892 ft
	14	Kane	UT	1695 m/5561 ft
	17	Kane	UT	1749 m/5738 ft
Geranium viscosissimum	TB15	Davis	UT	2438 m/8000 ft
	TB27	Sanpete	UT	2736/8975 ft

Monardella odoratissima	A-32	Iron	UT	2649 m/8691 ft
	A-43	Cache	UT	2134 m/7000 ft
Penstemon eatonii	A-30	Iron	UT	2557 m/8388 ft
	A-40	Carbon, Utah	UT	1581 m/5187 ft
	A-45	Utah	UT	1798 m/5900 ft
Purshia mexicana	A-2	Iron	UT	1948 m/6390 ft
	A-20	Grand	UT	1836 m/6024 ft
	A-24	Garfield	UT	2014 m/6608 ft
Stanleya pinnata	A-1	Iron	UT	2051 m/6730 ft
	A-8	Iron	UT	1778 m/5832 ft
	A-35	Washington	UT	984 m/3227 ft
	SRS	Emery	UT	1586 m/5203 ft

Results

Agastache urticifolia

Agastache seed was collected at sites ranging from 5200 to 8000 ft. in elevation (Table 1). Overwinter survival of all five accessions was greater than 90% (Table 2). The two accessions from the lower elevation collections did not survive the summer without irrigation at either site. Of the plants that survived, none differed in growth characteristics (Table 3).

Astragalus filipes

Basalt milkvetch accessions in our trials were from composite seed collections. The LH accession exhibited poor winter survival in North Logan (Table 2), although survivors were larger, though not significantly so, than plants of the NCO accession (Table 3). Plants of both accessions were nearly in full bloom in early June 2009 (Table 4).

Cercocarpus ledifolius

Littleleaf mountain mahogany accessions originated in central Utah at about 6000 and 8000 ft. (Table 1). Plants of both accessions overwintered successfully, but 50% or less survived the summer without irrigation at either location (Table 2). Plants of the higher elevation accession showed potential for being larger than lower elevation plants (Table 3), and parent plants exhibited a tree form in their native habitat, a characteristic considered valuable for ornamental purposes. This may be a trait useful for selecting a named variety for ornamental use.

Dalea ornata

Western prairie clover accessions originated from north-central Oregon at 1150 to 3300 ft. (Table 1). Nearly all survived the summer without irrigation at both sites, but plant losses occurred over the winter in North Logan (Table 2), the Do-LH accession exhibiting the best overwinter survival at this latitude. Plants from the Do-LH accession were larger at the end of the season at the North Logan site, whereas plants of the Do-17 accession were larger at the Kaysville site (Table 3). Extent of flowering differed among accessions, with two of the accessions (Do-LH and D0-23) at 50% bloom on 9 June 2009. Do-10, the accession from the northernmost county (northern Oregon), was at less than 20% bloom at this time.

Table 2. Overwinter and summer survival of plants (%) established in replicated trials in North Logan and Kaysville, Utah. Plants were installed in fall 2007 (*Agastache*, *Cercocarpus*, *Geranium*, *Monardella*, *Penstemon*, *Purshia*, *Stanleya*) and spring 2008 (*Astragalus*, *Dalea*). Data were collected in 2009.

		North Logan, UT		Kaysville, UT	
Species	**Accession**	**Winter Survival**	**Summer Survival**	**Winter Survival**	**Summer Survival**
		(%)	(%)	(%)	(%)
Agastache urticifolia	TB16	90	56	100	50
	TB19	100	40	90	56
	TB21	100	40	100	30
	TB25	90	0	100	0
	TB36	100	0	100	0
Astragalus filipes	LH	28	60	78	NA
	NCO	83	80	83	NA
Cercocarpus ledifolius	A-29	100	50	100	50
	A-22	100	30	90	44
Dalea ornata	10	78	100	100	100
	LH	94	94	94	100
	23	72	92	100	100
	17	89	100	100	100
Dalea searlsiae	8	89	100	100	100
	17	89	94	89	100
	14	94	100	100	100
Geranium viscosissimum	TB15	90	56	90	44
	TB27	100	40	100	50
Monardella odoratissima	A-32	100	50	90	56
	A-43	100	50	100	50
Penstemon eatonii	A-40	100	70	90	100
	A-45	100	50	100	50
	A-30	100	40	100	50
Purshia mexicana	A-24	70	100	100	20
	A-20	80	38	70	43
	A-2	100	50	90	44
Stanleya pinnata	A-35	50	0	60	0
	A-1	70	29	90	11
	A-8	90	44	70	57
	SRS	90	11	80	25

Table 3. Height (length of longest shoot [cm]) and width (at the widest point [cm]) for plants established in replicated plots in North Logan and Kaysville, Utah. Plants were installed in fall 2007 (*Agastache*, *Cercocarpus*, *Geranium*, *Monardella*, *Penstemon*, *Purshia*, *Stanleya*) and spring 2008 (*Astragalus*, *Dalea*). Data were collected in August/September 2009.

		North Logan, UT				Kaysville, UT			
Species	**Accession**	**Ht**	**STD**	**Width**	**STD**	**Ht**	**STD**	**Width**	**STD**
		(cm)[z]		(cm)		(cm)		(cm)	
Agastache urticifolia	TB16	61.4	5.2	99.6	7.9	53.2	11.4	89.6	22.9
	TB19	72.5	16.6	111.0	37.5	66.0	11.5	93.0	22.1
	TB21	58.2	3.1	95.8	14.6	56.3	16.5	87.7	38.8
Astragalus filipes	LH	37.3	5.7	41.3	20.4	NA	NA	NA	NA
	NCO	22.5	11.8	23.8	20.0	NA	NA	NA	NA
Cercocarpus ledifolius	A-29	74.8	13.5	78.6	16.9	71.2	11.9	82.6	28.5
	A-22	49.7	8.7	49.3	7.6	63.2	17.9	57.0	14.3
Dalea ornata	10	39.0a	8.9	77.2Aa	18.0	43.1ab	5.6	57.9Ba	13.7
	LH	41.1Aa	8.5	76.9Aa	14.2	32.9Bd	5.1	40.6Bbc	10.7
	23	34.5b	4.0	42.1c	9.2	38.5c	9.2	41.9b	12.3
	17	31.0Bb	6.8	58.9b	21.9	41.7Aab	5.4	48.6ab	18.4
Dalea searlsiae	8	37.2Bb	10.8	67.5	20.3	53.2Aa	8.2	71.4a	14.0
	17	52.6a	8.9	75.6A	13.19	50.2a	9.4	59.7Bb	22.6
	14	51.4Aa	13.3	76.6A	21.8	37.9Bb	11.5	53.7Bbc	21.8
Geranium viscosissimum	TB15	72.8Aa	13.1	67.2a	28.7	22.8B	3.6	59.5	10.3
	TB27	25.8b	1.0	52.8b	5.9	26.2	4.1	56.6	8.4
Monardella odoratissima	A-32	34.0	3.7	67.8	9.4	32.2	9.8	62.6	22.8
	A-43	26.0	5.8	51.6	10.6	31.0	4.7	55.2	11.0
Penstemon eatonii	A-40	82.9	28.2	NA	NA	98.4	21.0	138.4	26.5
	A-45	90.2	7.7	NA	NA	93.2	17.0	124.4	17.5
	A-30	63.8	33.7	NA	NA	76.6	11.4	98.6	36.3
Purshia mexicana	A-24	38.9Bb	11.5	57.6	14.9	64.5Ab	21.9	77.0	32.5
	A-20	65.7Ba	6.7	73.3	8.3	89.7Aa	16.4	86.0	16.6
	A-2	47.8ab	7.3	73.8	10.4	60.5b	15.7	88.2	26.9
Stanleya pinnata	A-8	55.5	44.3	56.0B	59.3	89.0	27.0	190.5A	50.0

[z] Data within a column and species followed by the same lower case letter are similar at $P < 0.05$ using Fisher's Least Significant Difference. Capital letters indicate significance of data for the same parameter and species accession across sites. Data sets without letters were not significantly different.

Dalea searlsiae

Searl's prairie clover originated from seed collected at about 6000 feet at two sites in Kane County, Utah and Lincoln County, Nevada (Table 1). Plants from all accessions overwintered successfully and survived the summer without irrigation at both sites (Table 2). Plants that originated from seed collected in Kane County, Utah were larger and more vigorous at the North Logan site. Plants that originated from seed collected in Lincoln County, Nevada were larger at the Kaysville site. The extent of flowering on 9 June 2009 was greatest for plants of Ds-14 (Kane County, Utah).

Geranium viscosissimum

Plants of sticky geranium originated from two seed accessions collected at about 8000 to 9000 feet in Sanpete and Davis Counties in Utah (Table 1). Plants of both accessions overwintered successfully at both sites, but exhibited only about 50% survival over the summer without irrigation (Table 2). Plants from the Davis County accession were larger at the end of season at the North Logan site than were plants from the Sanpete County accession (Table 3), and they were larger than plants of the same accession grown at the Kaysville site.

Monardella odoratissima

Mountain beebalm is a high-elevation perennial in the Intermountain West. Our seed accessions came from Iron County at almost 9000 ft., and from Cache County at 7000 ft. (Table 1). Similar to Sticky geranium, plants overwintered successfully at both sites, but only about 50% survived the summer without irrigation (Table 2). No differences in end-of-season height or width were observed (Table 3).

Penstemon eatonii

Firecracker penstemon is a perennial with bright red flowers that grows at elevations ranging from 3000 to 11,000 ft. Our seed accessions originated from southern and central Utah at elevations ranging from 5200 to 8400 ft. (Table 1). All accessions overwintered successfully at both sites, but plants of the A-40 accession exhibited better summer survival at both sites without irrigation (Table 2). No end-of-season size differences were noted at either site (Table 3). We conclude that firecracker penstemon is broadly adapted for north-central Utah, regardless of seed source. A more drought-tolerant variety may be selected from our A-40 accession.

Table 4. Percent of flower buds in bloom as a visual estimate. Plants were planted spring 2008; data were collected on 9 June 2009. STD = standard deviation.

Species	Accession	Percent bloom[z]	STD
Astragalus filipes	LH (n=14)	96.4a	9.1
	NCO (n=9)	83.3a	28.0
Dalea ornata	10 (n=18)	17.2b	12.7
	LH (n=17)	49.7a	34.3
	23 (n=18)	48.9a	33.0
	17 (n=18)	35.6ab	27.3
Dalea searlsiae	8 (n=17)	42.4b	27.6
	17 (n=14)	34.3b	35.5
	14 (n=18)	63.9a	27.4

[z] Data in a column and species followed by the same letter are similar at $P < 0.05$ using Fisher's Least Significant Difference.

Purshia mexicana

Cliffrose is an attractive shrub species with honey-scented flowers that bloom in spring. We collected three accessions from southern, southeastern and southwestern Utah sites ranging from 6000 to almost 7000 ft. elevation (Table 1). Overwintering was not a problem for plants of these accessions at either trial site; however, survival without irrigation in summer varied between sites and among accessions (Table 2). Plants of accession A-20 from Grand County (about 6000 ft.) were larger and more vigorous at both trial sites than plants of the other accessions (Table 3).

Stanleya pinnata
Prince's plume is a western U.S. perennial with a lemon-yellow inflorescence that resemble feathers from a distance. We collected seed from four accessions in southwestern Utah and along the Colorado Plateau in Utah at elevations ranging from 3000 to 7000 ft. Only the A-8 accession from Iron County (5800 ft.) survived (Table 2) by the end of summer, and this accession grew larger at the Kaysville site than it did in North Logan (Table 3).

Future Plans
Further evaluation of flowering and other ornamental characteristics will be completed spring 2010. We will select one population or individual from each species from which to develop a named variety for ornamental purposes. Stock blocks are planned for increasing seed of each variety. Plant materials will be shared at the fall 2010 meeting of WERA 1013, Intermountain Regional Evaluation and Introduction of Native Plants. Published USU extension facts are available for five of the ten species; the other five will be published in 2010. *Dalea ornata*, *D. searlsiae* and *Astragalus filipes* will be planted in demonstration gardens across Utah.

Management Applications:
Growers who produce plants for both reclamation seed and ornamental markets will find information on plant species adaptability useful in determination of seed collection sites and potential markets for plant materials.

Products:
Demonstration gardens have been established at three sites within Utah: multiple gardens on the campus of Utah State University, one at the Kane County Extension office in Kanab and one at Tonaquint Gardens in St. George.

Living Circles. Interpretive panel for USU on-campus demonstration garden honoring Utah Native American traditional plant uses and including Great Basin native plants. Designed in collaboration with B. Middleton in the Environment & Society Dept., College of Natural Resources, Utah State University.

Water-Wise Starts with You. Interpretive panel for USU ornamental research and demonstration gardens. Designed in collaboration with B. Middleton in the Environment & Society Dept., College of Natural Resources, Utah State University.

Fact Sheets
Kratsch, Heidi A.; Hunter, G. 2009. Prince's plume in the landscape. USU Extension Publication HG/Native Plants/2009-05. http://extension.usu.edu/files/publications/publication/HG_Native_Plants_2009-05.pdf.

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Presentations:

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Bushman, B. Shaun; Johnson, Douglas A.; Bhattarai, Kishor. *Astragalus filipes* Population Structure and Diversity. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Bhattarai, Kishor; Bushman, Shaun; Johnson, Douglas; Carman, John. Estimation of Genetic Diversity in Wildland Collections *Dalea searlsiae* and *Dalea ornate* from the U.S. Intermountain West. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Johnson, Douglas. Plant materials available for Great Basin ecoregions. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Panel discussion.

Sriladda, C.; Kratsch, Heidi; Curtis, B.; Kjelgren, R. 2009. Vegetative propagation of *Shepherdia rotundifolia* (roundleaf buffaloberry) from softwood cuttings. HortScience. Abstract. 44: 1105.

Project Title: Establishment and Maintenance of Certified Generation 1 (G1) Seed, Propagation of Native Forbs, Develop Technology to Improve the Diversity of Introduced Grass Stands, Equipment and Strategies to Enhance the Post-Wildfire Establishment and Persistence of Great Basin Native Plants

Location: NRCS Aberdeen, ID Plant Materials Center

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Project Description:
The 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. The propagation of native forbs for evaluation and seed increase. Assist in development of technology to improve the diversity of introduced grass stands by evaluating methods to introduce native species into established plant communities. The development of equipment and strategies to enhance the post-wildfire establishment and persistence of Great Basin native plants.

<u>I. Seed Production</u>

Anatone Germplasm bluebunch wheatgrass
Currently 7.4 acres are in production. Estimated seed yield from 2009 seed crop is 280 pounds. Shipped 450 pounds of Generation 2 Certified seed to commercial growers in 2009.

Maple Grove Germplasm Lewis flax
A 0.6 acre seed field was established in May 2008 with stock seed provided by the FS Rocky Mountain Research Station. Estimated seed production from 2009 crop is 200 pounds.

Snake River Plains Germplasm fourwing saltbush
Estimated seed yield from 2009 crop is 10 pounds. No seed was requested by commercial growers in 2009.

Northern Cold Desert Germplasm winterfat
A hard windstorm in October detached seed prior to harvest resulting in no seed harvested in 2009. No seed was requested by commercial growers in 2009.

II. 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 into seed production plots at the PMC and remaining plants were to be provided 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 provided to cooperators. All plants that were successfully propagated in the PMC greenhouse were transplanted into seed production/observation plots 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.

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

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

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

The Rocky Mountain Research Station in Boise, Idaho cleaned the ERUM seed that was harvested from the plots. Some of the seed was utilized for the seeding trial planted near Aberdeen, Idaho in November 2009 for the study to improve the diversity of introduced grass stands. The other accessions will be processed and provided to cooperators for seeding trials as requested.

III. Develop Technology to Improve the Diversity of Introduced Grass Stands

In 2005, the PMC began providing assistance for this study by assisting Brigham Young University (BYU) Provo, Utah and the Agricultural Research Service (ARS) Burns, Oregon 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, Nevada on recently burned rangeland to compare the Truax drill to the Kemmerer drill, the 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. No trials were established in 2007. In 2008, seeding trials were planted near Elko, Nevada in cooperation with the University of Nevada Extension Service and near Aberdeen, Idaho (Grandview site) in cooperation with the ARS Sheep Experiment Station.

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

Grandview, ID
Broadcast Mix
12.90 acres

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

Grandview, ID
Drill Mix
12.90 acres

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

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

The objectives of this project are to: 1) examine seeding techniques for Wyoming big sagebrush; 2) test seeding technology for native species, particularly native forbs; 3) 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; 4) apply and examine the use of USGS proposed monitoring protocols for gauging seeding success for both the short and long term; and 5) 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. In 2007, the PMC made modifications to the Kemmerer drill by replacing the existing drop tubes with aluminum 3 inch diameter irrigation pipe to improve 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 species requiring deeper planting were drill seeded in alternating rows.

The PMC mixed the seed and rice hull mixtures and calibrated the drills prior to seeding. Wildfire sites near Mountain Home, Idaho and Burns, Oregon were seeded in fall 2007 and a wildfire site near Snowville, Utah was seeded in 2008. Due to lower than normal wildfire frequency in 2009, no suitable sites were found and no seeding occurred for this study in 2009.

Management Applications:

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.

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

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

Products:

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

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

Plant Guides are available for royal penstemon, hotrock penstemon and sharpleaf penstemon.

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

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Ogle, Dan; St. John, Loren. Conserving Ecosystems of the Intermountain West. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Project Title: Adapted Indian Ricegrass for the Great Basin

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

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Project Description:
Indian ricegrass [*Achnatherum hymenoides* (Roem. & Schult.) Barkworth] is a key species for wildlife habitat and grazing in the Great Basin. Current releases of Indian ricegrass are useful but we know of no germplasm derived specifically from and for 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 (Fig. 1). This material was established in common gardens in 2007 and data on plant traits taken in 2007 and 2008. The analysis showed that seed source location was strongly associated with variation in plant traits. In addition, plant traits were linked to numerous climatic and environmental variables. This information is being used to develop seed zones for Indian ricegrass in the Great Basin.

Collections of more than 100 sources of new germplasm in the Northern and Central Great Basin were completed in 2008. This germplasm will be the basis of additional genecology studies and to develop seed zones for the central and northern Great Basin.

Our objectives are:

1. Collect Indian Ricegrass from diverse ecological areas in the Great Basin in areas previously uncollected, especially in the central and northern Great Basin.

2. Based on the current collections representing the southern and eastern Great Basin, establish common garden studies and measure numerous plant factors associated with growth and development. Continue this research on new material collected from the central and northern Great Basin.
3. Analyze plant traits among Indian Ricegrass populations, select traits for principal component analysis and link plant traits to environmental variables.
4. Develop regression models and map seed transfer zones.
5. Make source identified plant material available for utilization through the Western Regional Plant Introduction Station seed repository and the National Plant Germplasm System.

In spring 2007, a diverse set of 115 Indian Ricegrass accessions from the USDA germplasm collection was planted in two common gardens at Central Ferry, WA, one under dryland and the other under light irrigation conditions, forming two growing environments. Each garden was randomized into five complete blocks with 575 plants each. This germplasm represented the southern and eastern Great Basin together with locations across the Colorado Plateau and into the Great Plains. Evaluation of key growth and developmental traits was completed in 2007 and 2008 on numerous growth and development traits on each plant.

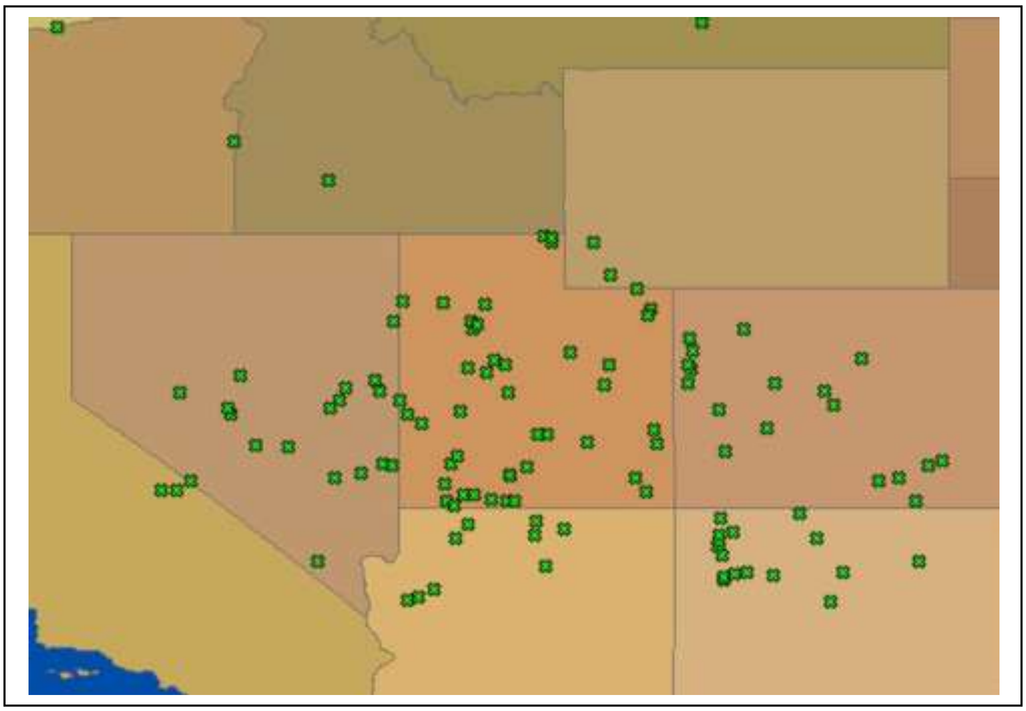

Figure 1. Collection locations for common garden studies at Central Ferry in 2007 and 2008.

For the 2007 analysis, collection location effects were all highly significant (Table 1). Thus, Indian ricegrass populations varied strongly depending on the seed source locations in the southern Basin, and extending into Colorado and the Great Plains. Although the environments (irrigated and non-irrigated) differed for many traits, the environment by location interaction was only significant for crown diameter (Table 1). This showed that irrigation caused differences in plant growth and development but the relative ranking of germplasm remained similar in both irrigation environments.

Table 1. Summary of plant traits and analyses of variance for Indian ricegrass in common gardens representing 120 seed source locations grown at Central Ferry, WA, in irrigated and dryland environments (2007).

Variable	Mean	CV	Environ	Location	Env x Loc
			---------------P-values---------------		
Full heading†	191	6.9	<0.01	<0.01	0.66
Initial blooming†	179	6.7	<0.01	<0.01	0.06
Maturity†	205	6.2	<0.01	<0.01	0.59
Leaf width (mm)	2.0	36.9	<0.01	<0.01	0.43
Leaf length (cm)	15.0	29.6	0.93	<0.01	0.93
Leaf length/width	8.9	45.2	<0.01	<0.01	0.64
Leaf length x width	29.6	56.2	0.12	<0.01	0.73
Panicles/plant	13	73.9	<0.01	<0.01	0.36
Seeds/panicle	50	41.9	0.60	<0.01	0.42
Culm length (cm)	25	21.5	0.35	<0.01	0.51
Panicle length (cm)	15	26.6	0.13	<0.01	0.67
Culm to inflor. length (cm)	1.8	28.7	0.96	<0.01	0.26
Habit (1 least-9 most upright)	5	21.3	0.31	<0.01	0.47
Leaf texture (1 coarse-9 fine)	5	24.6	<0.01	<0.01	0.18
Leaf abundance (1 low-9 high)	5	23.2	0.15	<0.01	0.22
Leaf roll (1 least-9 most)	4	37.1	0.03	<0.01	0.36
Crown dia. (cm^2)	26.5	57.0	<0.01	<0.01	<0.01
Dry weight (g)	23.4	36.1	<0.01	<0.01	0.33
Regrowth (g)	3.66	67.67	0.53	<0.01	0.39
Dry wt. less regrowth (g)	20.7	78.83	<0.01	<0.01	0.40

†Day of year

For 2008, the overall results were similar to 2007 in that seed source location was strongly significant for all plant variables measured (Table 2). There were far fewer significant effects associated with the irrigation treatment in 2008 than in 2007. As in 2007, interactions between garden environment and seed source location were usually not significant (Table 2). The data showed that Indian ricegrass populations differed at different seed source locations, suggesting that plant adaptation will vary depending on climatic/environmental factors.

A process was completed on all traits within years and environments to reduce the trait number for principal component analysis. This was done to reduce "noise" and improve the principal components as composite plants traits for regression modeling. Traits over years and environments that did not have significant interactions were averaged. If traits were strongly correlated (r>0.80) then only one of the traits was used for the principal component analysis. This process resulted in the traits in Table 3.

Table 2. Summary of plant variables and analyses of variance for Indian ricegrass in common gardens representing 120 seed source locations grown at Central Ferry, WA, in irrigated and dryland environments (2008).

Variable	Mean	CV	Environ	Location	Env x Loc
			-----------------	P-values	------------
Full heading†	148	1.60	0.98	<0.01	0.08
Initial blooming†	139	2.1	0.10	<0.01	0.63
Maturity date†	166	0.90	<0.01	<0.01	<0.01
Leaf width (mm)	2.0	35.4	0.93	<0.01	0.43
Leaf length (cm)	13.2	29.1	0.55	<0.01	0.22
Leaf length/width	9.57	40.2	0.85	<0.01	0.30
Leaf length x width	22.0	55.0	0.67	<0.01	0.51
Panicles/plant	105.6	59.3	0.20	<0.01	0.63
Seeds/panicle	44.9	42.4	0.31	<0.01	0.44
Culm length (cm)	27.3	22.5	0.95	<0.01	0.05
Panicle length (cm)	13.0	24.9	0.18	<0.01	0.72
Culm to inflor. length (cm)	2.21	27.0	0.27	<0.01	0.78
Habit (1 least-9 most upright)	6	21.1	0.17	<0.01	0.48
Leaf texture (1 coarse-9 fine)	6	21.0	0.97	<0.01	0.78
Leaf abundance (1 low-9 high)	4	32.3	0.04	<0.01	0.78
Leaf roll (1 least-9 most)	7	20.5	0.53	<0.01	0.59
Crown dia. (cm^2)	35.0	50.3	0.86	<0.01	0.39
Dry weight (g)	46.9	76.2	0.72	<0.01	0.54
Regrowth (g)	11.5	92.1	0.01	<0.01	0.01
Dry wt. less regrowth (g)	36.3	80.9	0.18	<0.01	0.29

†Day of year

Correlations between environmental variables and plant traits were often significant (Table 3). Thus links between genetic differences among seed source locations in common gardens and environmental factors were established. The strongest correlations were observed between seed per panicle and latitude in 2007 and 2008 (Table 3). The positive correlation showed that seed source locations in the north had generally more seed per panicle than those in the south part of the collection area. By convention, Western hemisphere longitude is increasingly negative from east to west. Thus the positive correlation of longitude with culm length and various leaf traits indicates a general increase in those traits from western to eastern locations. Elevation was also an important environmental factor related to seed source locations. Increased evelation was associated with plants that had finer texture, fewer seed per panicle and less dry weight in 2007 (the establishment year), more leaf roll, smaller leaves and smaller crowns (Table 3). There were fewer significant correlations with actual climatic factors associated with temperature and precipitation than the geographic variables latitude and elevation. This suggested that other environmental factors associated with the geographic variables but unknown were represented in the geographic variables.

Table 3. Linear correlation between traits selected for principal component analysis and environmental factors for Indian ricegrass (Central Ferry WA, 2007 and 2008) (n=112).

Trait†	Latitude	Longitude	Elevation	Mean Ann. Temp	Mean Ann. Precip.	Degree days>18C	Frost free days
Heading 0708	0.02	-0.01	0.02	0.02	-0.01	0.05	0.03
Leaf texture 07	-0.12	0.10	***0.31	**-0.26	0.02	*-0.20	***-0.31
Leaf texture 08	***-0.36	*0.22	**0.24	0.02	-0.07	0.06	-0.09
Leaf abundance 0708	0.08	-0.01	-0.13	0.03	-0.01	0.02	0.01
Culm length 07	*0.19	*0.21	-0.04	-0.15	***0.32	*-0.20	-0.12
Culm length 08	**0.30	-0.01	-0.09	-0.16	*0.21	*-0.21	-0.09
Head length 07	*0.20	0.01	-0.14	-0.05	0.09	-0.10	0.01
Head length 08	*0.23	0.08	-0.02	-0.17	*0.23	**-0.27	-0.09
Seed/panicle 07	***0.40	-0.09	**-0.25	-0.10	0.19	-0.13	0.00
Seeds/panicle 08	***0.41	-0.03	-0.09	**-0.27	**0.30	***-0.37	-0.16
Panicles/plant 0708	-0.09	0.12	0.08	0.01	0.11	-0.10	0.00
Leaf roll 0708	*-0.20	**0.25	**0.25	-0.11	-0.07	0.03	*-0.20
Leaf length/ width 07	-0.09	**0.28	0.06	-0.03	-0.01	0.00	-0.06
Leaf length/width 08	-0.06	**0.24	0.00	0.05	0.08	0.07	0.05
Leaf length x width 07	*0.21	0.01	***-0.34	0.17	0.05	0.11	*0.22
Leaf length x width 08	**0.30	-0.12	***-0.32	0.06	0.07	-0.01	0.16
Crown area 0708	*0.18	0.04	*-0.18	0.04	0.11	-0.03	0.10
Dry weight 07	0.02	0.04	**-0.27	**0.25	-0.05	0.17	*0.23
Dry weight 08	0.07	-0.03	-0.16	0.12	0.06	0.04	0.14

*,**,***Significant at P<0.05, P<0.01, and P<0.001, respectively

†Traits selected for principal component analysis had strong seed source location effects and were not redundant with other traits or over years; 07 and 08 refer to the years 2007 and 2008, and 0708 to the means for 2007 and 2008.

Principal component analysis on selected traits showed that 40% of the variation was explained in the first principal component, 12% in the second, and 8%, 7%, and 6 % in the third, forth, and fifth, respectively. Thus, a majority of the variation in selected plant traits (52%) was explained in the first two principal components. A preliminary regression model using principal component 1 and 2 environmental data at seed source locations was completed (Table 4).

The regression analysis based on environmental data at each seed source location and principal components 1 and 2 as composite plant traits both resulted in models with 12 coefficients (Table 4). The number of coefficients for each model was determined by choosing the model with the highest R-square and the lowest Akaike information criterion (AIC) using the SAS regression procedure.

The R-square values for the regression model developed with principal component 1 explained 41% of the variation and the model for principal component 2 explained 43% of the variation. This shows that a reasonably high fraction of the variation was accounted for in the model and successful mapping of seed zones will be possible. It also shows that considerable variation was not explained and that could be related to factors such as species plasticity, microclimate effects and soil variables that were not accounted for in the models.

Table 4. Regression equations for principal components 1 and 2 (prin 1 and 2) for Indian ricegrass based 112 seed source locations in the Great Basin and Colorado plateau. The R-square or model fit was 0.41 and 0.43 for prin 1 and prin 2, respectively.

Environmental variables	Regression Coefficients	Probability of > |t|	Standardized coefficients
	---------------------------------Prin 1-------------------------------		
Intercept	38.74216	0.0539	—
Elevation	-0.00206	0.1201	-0.30176
Ave T Oct	3.31618	<.0001	2.88734
Mean max T May	-3.028	0.0008	-2.96358
Mean max T Jun	2.72701	0.0052	2.74324
Mean max T Sep	-0.97572	0.0909	-0.95296
Mean min T Dec	2.29759	<.0001	2.37525
Precip Apr	0.1104	0.0065	0.3815
Precip Oct	-0.1381	0.0019	-0.42428
Ave T spring	5.34377	<.0001	4.83054
Degree days<0 C	0.03178	<.0001	2.71042
Degree days>5 C	-0.01778	0.0001	-3.98176
Frost free days	-0.21535	0.0021	-2.76037
	---------------------------------Prin 1-------------------------------		
Intercept	15.98532	0.1509	—
Ave Temp Jun	5.30587	<.0001	8.67508
Mean Max Temp Feb	1.54085	0.0004	3.21374
Mean Max Temp Ann	-3.76469	<.0001	-6.5975
Mean Min Temp Mar	-0.46622	0.1	-0.80626
Mean Min Temp Jun	-3.12991	<.0001	-5.25809
Precip Jun	-0.0465	0.0786	-0.35217
Precip Nov	0.06681	0.11	0.33941
Pricp Dec	-0.08121	0.0236	-0.45017
Precip Summer	-0.04736	0.017	-1.07013
Precip May to Sep	0.0416	0.0068	1.34157
Degree days<18 C	0.00449	0.0249	-2.09236
Evaporative demand	-0.01728	0.0046	-1.71314

Summary and Future Plans

The results show that there was genetic variation across the landscape in Indian ricegrass populations. Moreover, numerous plant traits were linked to basic climatic and environmental data. This is strong evidence that adaptation of Indian ricegrass varies in adaptation depending environment. In addition, principal components and regression modeling has been completed. These will be used to map seed zones across the source locations. For this initial Indian ricegrass study, objectives 1, 2, and 3 have been completed. The seed from the source locations is also available from the Western Regional Plant Introduction Station (Objective 5).

For the northern and central Great Basin objective 1 relating to germplasm collection has been completed (Fig. 2). Establishment has been delayed by the problem of breaking dormancy in freshly collected seeds. Germination monitoring is ongoing on Indian ricegrass collected from the northern and central Great Basin and gardens to determine when plants can be established in common gardens.

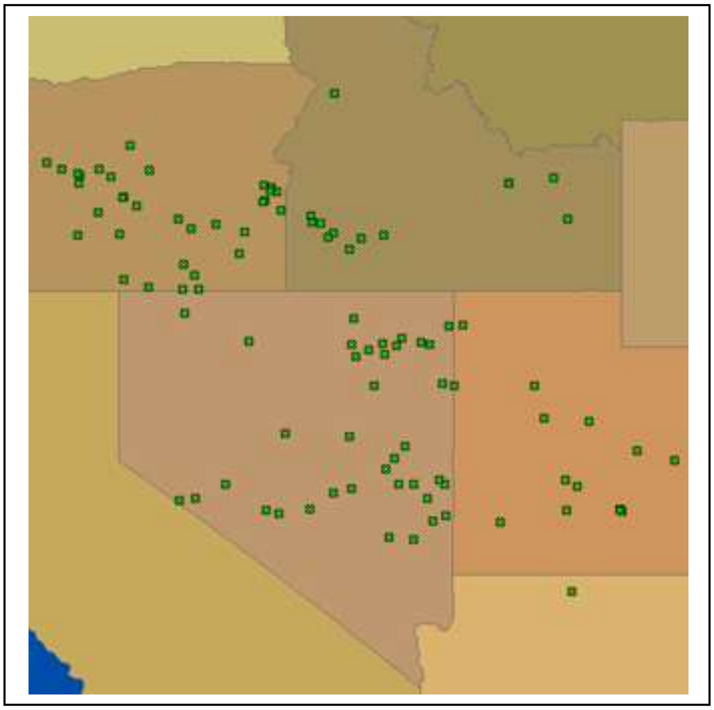

Figure 2. Seed collections of Indian ricegrass made in 2007 and 2008 for common studies of adaptation to Great Basin environments.

Management Applications and Seed Production Guidelines:
Seed zones are being developed for plant materials needed for revegetation and restoration in the Great Basin and adjacent areas.

Cooperation is ongoing with the BLM "Seeds of Success" program for collection, storage, conservation and distribution of native plant materials through the National Plant Germplasm System. This provides seed for distribution to users and 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:
Co-organized workshop: Restoring and Sustaining Western Landscapes: Interaction with Climate Change, sponsored by the Ecological Society of America in Albuquerque, NM.

Seed zones for revegetation in the Great Basin are being developed.

Native plant material needed for research and development is being distributed through the Western Regional Plant Introduction Station, Pullman WA.

Distribution of native seeds for research and development as part of the BLM, Seeds of Success program through the Western Regional Plant Introduction Station from 2005 through 2009.

Year	Seed packets distributed	Seed orders
2005	1	1
2006	23	3
2007	161	54
2008	438	129
2009	467	118
totals	1090	305

Publication:
Johnson, Richard C.; Erickson, V. J.; Mandel, N. L.; St Clair J. Bradley; Vance-Borland, K. W. Geographic variation and seed zones for mountain brome (*Bromus carinatus* Hook. & Arn.) from the Blue Mountains. (Revision submitted)

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Johnson, Richard C. Adaptation of key native species for the Intermountain West. Native Plant Summit, 2009 March 24; Boise, ID. Invited speaker.

Johnson, Richard C.; Hellier, Barbara and Cashman, Mike. Seed zones for Tapertip Onion and Indian Ricegrass. GBNPSIP Annual Meeting, March 31, 2009; Boise, ID.

St.Clair, J.B.; Johnson, R.C.; Shaw, N.L. 2009. Genetic diversity and genecology of bluebunch wheatgrass (*Pseudoroegneria spicata*). Great Basin Native Plant Selection and Increase Project Annual Meeting, 2009, March 31; Boise, ID.

Johnson, Richard C. Session panel member and speaker: Plant materials available for Great Basin ecoregions. Developing a Successful Native Plant Program Workshop, 2009 April 1; Ontario OR.

Johnson, Richard C. Plant conservation, gene banking, and genecology with climate change. Ecological Society of America: Restoring and Sustaining Western Landscapes: Interaction with Climate Change Workshop, 2009 August 2; Albuquerque, NM.

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

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

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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 have been conducted to determine genetic variation and seed transfer zones of *A. acuminatum* in the Great Basin. Genetic resource management strategies based on biological conservation principals are being developed and made available to land managers for field application. In addition, *ex-situ* gene bank conservation is being carried out at the Western Regional Plant Introduction Station, Pullman, WA. Gene bank conservation will provide readily available, source-identified genetic resources for research and increase and security back-up for *in-situ* source locations.

Objectives

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

Collections

In 2005, *A. acuminatum* bulbs were collected from 55 populations throughout eastern Oregon, southern Idaho and northeastern Nevada (Fig. 1) as described by Adair et al. (2006). 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.

<u>Common Gardens</u>

Bulbs were planted in the greenhouse and vernalized at 4°C. Plants were transplanted to the field in the spring of 2006. Common gardens were established at Pullman, WA (780 m elevation; 46° 43' 28.05" N and 117 08' 07.94"W) and Central Ferry, WA (206 m elevation; 46° 41' 52.78" N and 117° 39' 52.55" W). Four plants from each of the 55 collection sites were randomized in five complete blocks at both locations. Thus, there were 1,100 plants established at each site. Morphologic and phenotypic characterization data was collected in 2007.

All of the variables had significant location effects, so genetic differences in growth and development factors were present among different collection locations. Originally a set of 20 variables were measured. Table 1 shows a reduced set of variables or traits to use in principal component analysis. These traits met the criteria of being highly significant for seed source location and not redundant; that is, strongly correlated with each other (r>0.80). Except for flower color and days from flowering to seed maturity, the garden site by collection location interactions were not significant (Table 1).

Table 1. Summary of variables, analyses of variance, and variance components for Tapertip onion (*A. acuminatum)* collected in the Great Basin and measured in Central Ferry (CF) and Pullman (PU), WA common gardens in 2007.

	ANOVA location effects				Variance for locations		
A. acuminatum variables	Both sites	CF	PU	Site by Loc	Both sites	CF	PU
	----------------P-values†----------------				--------------%--------------		
Bolting date	0.001	0.000	0.001	0.109	52.8	57.9	57.9
Flower color	0.001	0.000	0.001	0.001	75.8	86.3	86.3
Flowers/umbel	0.001	0.001	0.001	0.986	17.5	9.4	9.4
Leaf length	0.001	0.001	0.001	0.190	23.2	22.0	22.0
Leaf length/width	0.003	0.000	0.221	0.357	87.6	77.2	96.5
Leaf width	0.001	0.009	0.001	0.901	20.2	12.6	12.6
Seeds/plant	0.001	0.001	0.001	0.494	20.1	18.9	18.9
Scape diameter	0.001	0.005	0.009	0.788	15.0	14.2	14.2
Scape length/dia.	0.001	0.001	0.001	0.688	22.2	21.7	21.7
Scape length	0.001	0.001	0.001	0.525	30.0	29.0	29.0
Days flower-maturity	0.011	0.001	0.001	0.009	12.8	20.2	20.9
Survival	0.001	0.001	0.001	0.041	31.2	34.0	34.0
Umbel diameter	0.001	0.001	0.001	0.312	20.3	21.7	21.7

In most cases the variation associated with seed source location was substantial (Table 1). For flower color and for leaf length/width, more than 75% of the variation was associated with locations for both garden sites combined and for the individual sites. More than 50% of the variation for bolting date was associated with location. Flowers/umbel at Central Ferry and Pullman was the variable with the lowest amount of location variation (Table 2), but the amount of location variation was relatively high and consistent with the low P-values for each plant trait (Table 1). These results, showing strong location effects, indicate a strong potential for differences in adaptation at different Great Basin environments.

There were numerous correlations between plant traits and selected climatic/environmental factors (Table 2). For example, bolting date was correlated with elevation, precipitation, frost free days and temperature. These data linked plant traits and environmental variables showed that regression modeling of the principal components as composite plant traits should produce useful seeds zones representing tapertip onion adaption.

Table 2. Linear correlation between selected variables measured in 2007 and collection location environmental factors averaged over sites (n=53).

Trait	Latitude	Elevation	Annual precip.	Frost free days	Ave. ann. temp.
Bolting date	-0.084	** 0.373	*0.336	***-0.514	***-0.523
Bolt to flower days	0.173	***-0.515	**-0.442	**0.469	**0.484
Flower color	*-0.308	*0.312	-0.008	-0.124	-0.053
Flowers/umbel	-0.180	*0.344	0.097	**-0.375	-0.230
Leaf erectness PU	0.189	-0.153	-0.104	-0.196	-0.079
Leaf length	-0.079	-0.029	-0.017	0.079	0.139
Leaf length to width CF	*0.317	*-0.340	-0.078	-0.029	0.038
Leaf number PU	**0.356	-0.011	**0.469	-0.104	*-0.277
Leaf width	*-0.313	*0.267	0.100	0.070	0.068
Seeds/plant	0.194	0.131	**0.427	**-0.379	*-0.325
Scape diameter	-0.252	*0.342	0.175	-0.167	-0.075
Scape length to diameter	0.159	*-0.335	*-0.313	0.107	0.073
Scape length	-0.055	-0.051	-0.215	-0.044	0.014
Flower to maturity days CF	-0.149	0.174	-0.036	-0.142	-0.089
Flower to maturity days PU	-0.134	0.073	-0.140	0.023	0.080
Survival	0.019	*0.320	*0.333	**-0.425	**-0.469
Umbel diameter PU	-0.196	0.196	-0.030	-0.052	-0.036
Umbel flowers to diameter	-0.039	0.268	0.157	**-0.488	*-0.300

*,**,***Significant at P<0.05, P<0.01 and P<0.001

Principal Components and Regression Models

Principal component analysis was used to simplify key taper-tip onion plant traits into principal components to be used as composite plant traits in modeling seed zones (Table 3). The first two principal components explained 64% of the variation, 41% for the first and 23% for the second. Additional components explained less than 10% of the variation. Thus the first two principal components explained almost two-thirds of the variation and had the most potential for regression modeling for seed zones.

Principal components 1 coefficients loaded positively for all traits, and most were relatively equal in strength (data not shown). The exceptions were bolting date, flower color, length/width and scape length/diameter, which had relatively low loading. Thus more flowers per umbel, longer and wider leaves, more seeds/plant, thicker and longer scapes, and wider umbels all were important for high principal component 1 scores. Principal component 2 interpretation was less obvious. It had high negative loadings for bolting date and flower color, but positive loadings for scape length/diameter, scape length and days from flowering to maturity. Correlations with principal components were significant for all plant traits except those with very small coefficients (data not shown).

Table 3. Tapertip onion regression models for principal components 1 and 2. Each model factor has one degree of freedom and the residual error had 43 and 42 degrees of freedom, respectively. The R-square values or model fit for principal component 1 and 2 were 0.52 and 0.58, respectively.

Factor	Regression coefficients	t Value	Pr > |t|	Standardized coefficients
	------------------------------Prin 1-------------------------			
Intercept	14.364	1.27	0.2100	0
Jan precip	0.3360	4.08	0.0002	2.639
Jun precip	0.1477	2.3	0.0265	0.4062
Oct precip	-0.3950	-4.67	<.0001	-1.252
Dec precip	-0.2292	-3.3	0.0019	-1.917
May min temp	-4.616	-4.17	0.0001	-2.890
Jul min temp	3.644	4.59	<.0001	3.109
First fall frost	-0.0714	-3.32	0.0018	-0.6231
Apr ave temp	4.734	3.42	0.0014	3.014
Jun ave temp	-3.850	-2.76	0.0085	-2.449
	------------------------------Prin 1-------------------------			
Intercept	94.749	3.54	0.0010	0
Longitude	0.5522	2.93	0.0053	0.4292
Jun precip	-0.1709	-5.03	<.0001	-0.6229
May max temp	1.627	2.42	0.0198	1.590
Mar max temp	0.9253	2.32	0.0253	0.9510
Aug min temp	1.362	3.01	0.0044	1.620
Apr ave temp	1.808	1.84	0.0724	1.525
Jun ave temp	-3.534	-3.64	0.0007	-2.981
Oct ave temp	-2.666	-3.04	0.0040	-1.842

Maps of principal components 1 and 2 (Prin 1 and Prin 2) showed the expected difference in apparent adaptation for tapertip onion (Fig. 1). The 70% confidence interval used for contour intervals, similar to isolines, was selected to give a conservative view of the interaction of environment with genetic variation in tapertip onion. Some geographic features were easily distinguished. For example the Snake River Plain mapped in reddish hues for Prin1 and greenish hues for Prin 2. For Prin 2 significant areas in the Snake River Plain shown in white were outside the model range and were not mapped. Prin 1 areas in the Snake River Plain and northern Nevada mapped to reddish-orange hues. Among other things, Prin 1 appeared to map to areas that roughly corresponded temperature and precipitation patterns. Prin 2 mapped the Snake River Plain and west into Oregon as darker green hues and into northeastern Nevada as lighter green hues. Orange hues predominated in north central Nevada. It appeared that Prin 2 was driven predominantly by temperature gradients (Fig. 1)

For both Prin 1 and Prin 2 the major groups consisted of reddish-orange hues and the other greenish hues. As a result, a preliminary seed zone map was constructed by overlaying high (reddish-orange) and low (green hues) for both Prin 1 and Prin 2 to give four basic seed zones (Fig. 2).

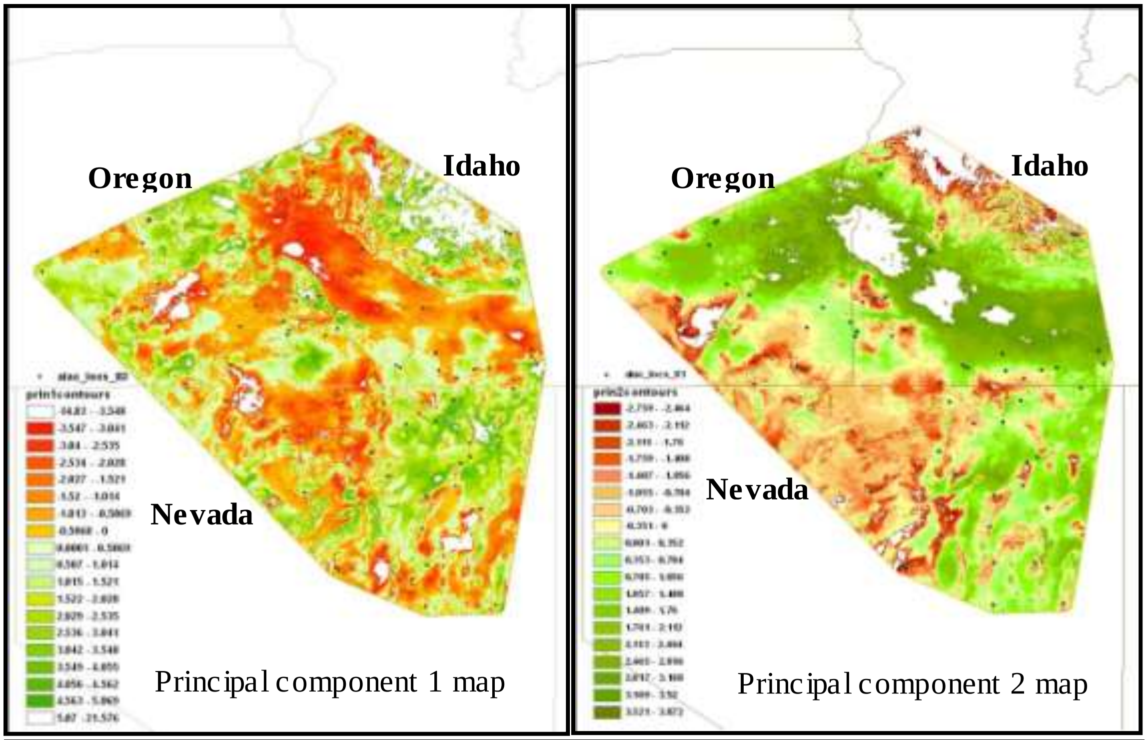

Fig. 1. Maps of principal components 1 and 2 across the field collection locations in the Great Basin showing different areas of expected adaptation for tapertip onion. The contour was the 70% confidence interval associated with regression error. The white areas represents areas outside the model range and were not mapped.

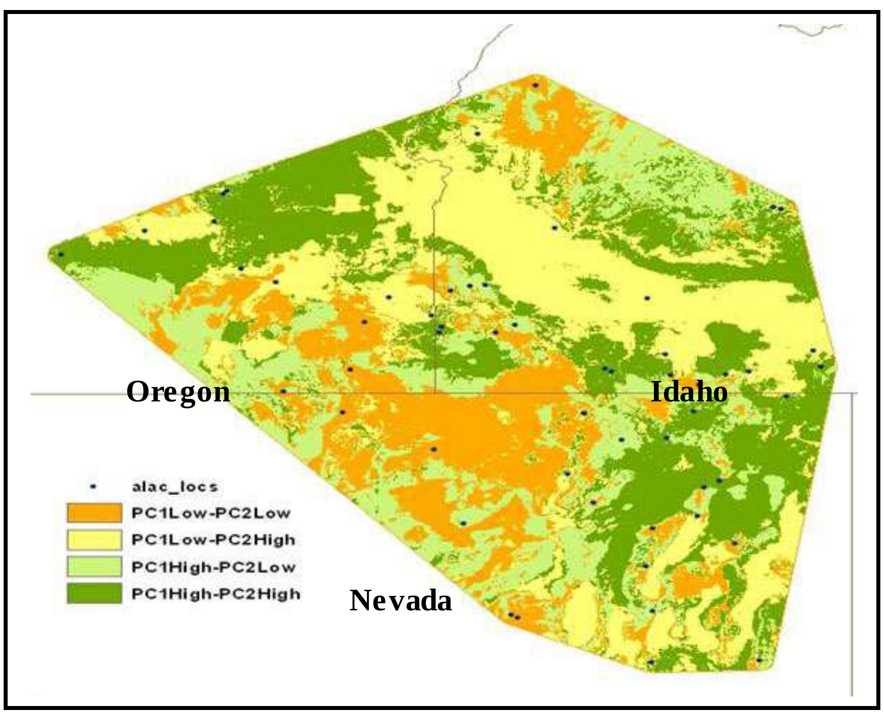

Fig. 2. Preliminary seed zones for tapertip onion across the Great Basin collection region. The map is an overlay of high and low groups for the principal component 1 and 2 maps (Fig. 1) giving a map with four seed zones.

The seed zone map showed a zone representing the Snake River Plain (yellow) and extending into areas in Oregon to the west and to Nevada to the south and east (Fig. 2). Areas mapped to orange were located north of the Snake River Plain and a substantial orange region was south of the Snake River Plain. Areas mapped with green hues represented the remaining seed zones.

Summary and Future Plans

These results have shown strong variation in *A. acuminatum* populations across the Great Basin and that specific plant traits are related to key environmental factors. Adaptation of *A. acuminatum* was associated with elevation, temperature and precipitation factors as shown in correlations (Table 2). Principal components were used to develop regression models that were mapped to show areas of apparent adaptation of tapertip onion across the landscape (Fig. 1). A preliminary seed zone map was developed. A manuscript for peer reviewed publication is being prepared that will summarize results and recommendations. The seed transfer zones will be used to select and propagate adapted material for restoration in the Great Basin.

Literature Cited

Adair, R.; Johnson, Richard C.; Hellier, Barbara; Kasier, W. 2006. Collecting Taper Tip Onion (*Allium acuminatum* Hook.) in the Great Basin using traditional and GIS methods. Native Plants Journal. 7: 141-148.

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

Project Location: USDA-ARS Western Regional Plant Introduction Station (WRPIS), Pullman, Washington; USDA Forest Service Rocky Mountain Research Station, Boise, Idaho; 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. It is found in a wide variety of habitats, and is a dominant species of many grasslands of the inland Northwest. The wide distribution across a diverse range of climates suggests that bluebunch wheatgrass is genetically variable, and much of that variation may be adaptive. Nevertheless, many restoration projects using bluebunch wheatgrass rely upon a few cultivars that have proven to be useful over a wide area (although with less experience in the Great Basin). Few studies have been done, however, to evaluate genetic variation in relation to climatic factors across the Great Basin or the greater range of the species in a large set of diverse populations, and to compare the mean and variation of cultivars with that of the species as a whole. Determining the extent to which adaptive genetic variation is related to climatic variation is needed to ensure that the proper germplasm is chosen for revegetation and restoration. Furthermore, comparisons of cultivars with the natural range of variation will address questions of the suitability of cultivars over larger areas.

Objectives

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

Progress

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 and Central Ferry, WA, and at the USFS Lucky Peak Nursery near Boise, ID. Data was collected on each of 17 traits of growth, phenology and morphology at each of the three contrasting test sites during years 2007 and 2008. Seed was collected from the common gardens in 2008 and germination tests were conducted in 2009 to evaluate population variation in germination rates. Preliminary analyses have been done to evaluate differences among test sites, years, populations and families within populations, as well as their interactions, and to look at the relationship between population variation and climatic variation at source locations. Preliminary maps of genetic variation across the landscape have been produced.

Preliminary Results

Differences among test sites and between years for traits of growth and phenology were generally large (Tables 1 and 2). Plants grown at the warmest and driest site, Central Ferry, were largest, whereas plants grown at the coolest, wettest site, Pullman, were smallest. Reproductive phenology was delayed at the coolest site, Pullman, as indicated by later dates of heading, anthesis and seed maturation. Plants were larger in 2007 compared to 2008, indicating that plants were better established during the second year. Reproductive phenology was later in 2008. Despite large differences among test sites and between years, correlations of population means between test sites were generally large ($r>0.70$) for the same traits measured at different sites. Correlations of population means between years were also generally large ($r>0.60$) for many traits. Thus, population performance was generally consistent between sites and between years.

Considerable variation was found between populations evaluated at each test site (Table 3). Most traits showed greater than 30% of the variation of individual plants could be attributed to differences among populations. Variation among families within populations was small.

Correlations of populations means with climates at the seed sources were moderate to relatively strong with many correlations greater than 0.30 (Table 4). Larger plants were generally from areas with greater precipitation and warmer winters but cooler summers, plants with later heading dates were from areas with later spring frosts and earlier fall frosts, plants with an upright form were from areas with less precipitation, plants with narrow leaves were from hotter and drier areas, and plants with longer awns were from cooler areas. These relationships make sense from an adaptation perspective. Large population differences consistently correlated with environmental variables in ways that make sense suggests adaptively significant genetic variation that should be considered when moving populations in restoration projects. Regressions between traits, including multivariate principle components, and climatic and geographic variables were done and the resulting models were used in GIS to produce maps of genetic variation in adaptive traits. The relationships and preliminary maps suggest that seed zones should be delineated mostly along gradients of temperature and aridity.

Table 1. Trait means for bluebunch wheatgrass measured at three test sites averaged over two years.

Trait	Test Site		
	Central Ferry	Lucky Peak	Pullman
Dry wt (g)	100	85	41
Crown width (cm)	9.5	7.5	8.4
Inflorescence no.	100	121	42
Heading date (Julian days)	133	136	143
Anthesis date (Julian days)	146	150	162
Maturity date (Julian days)	184	190	199
Germination rate (days to 50%)	5.0	6.1	4.8
Plant form (1-9 prostrate to upright)	6.1	6.3	6.5
Leaf form (height:width ratio)	41	39	33
Leaf pubescence (1-9 none to much)	3.9	4.5	4.0
Leaf color (1-9 yellow to dark green)	3.3	3.0	2.9
Awn length (1-9 none to long)	4.6	4.6	4.7

Table 2. Trait means in 2007 and 2008 averaged over all three test sites.

Trait	2007	2008
Dry wt (g)	42	109
Crown width (cm)	5.5	11.4
Inflorescence no.	28	148
Heading date (Julian days)	133	141
Anthesis date (Julian days)	148	157
Maturity date (Julian days)	189	192
Plant form (1-9 prostrate to upright)	6.3	6.3
Leaf form (height:width ratio)	38	38
Leaf pubescence (1-9 none to much)	4.8	3.5
Leaf color (1-9 yellow to dark green)	3.2	2.9
Awn length (1-9 none to long)	4.6	4.7

Table 3. Percent of total variation (populations, families within population, and residual) attributed to variation among populations for traits measured at each test site.

Trait (2007 data)	% Population Variation		
	Central Ferry	Lucky Peak	Pullman
Dry wt	48	21	37
Crown width	33	23	32
Inflorescence no.	46	36	34
Heading date (Julian days)	37	30	19
Anthesis date (Julian days)	22	44	27
Maturity date (Julian days)	17	18	10
Germination rate (days to 50%)	19	11	7
Plant form (1-9 prostrate to upright)	17	30	7
Leaf form (height:width ratio)	34	39	19
Leaf pubescence (1-9 none to much)	37	28	42
Leaf color (1-9 yellow to dark green)	33	35	12
Awn length	45	58	49

Table 4. Correlations between population means for individual plant traits and 30-yr climate normals of the seed sources (averaged across years and test sites).

Trait	Annual Precip	Aug Precip	Annual Temp	Aug Max Temp	Dec Min Temp	Frost Free Period	Latitude	Elevation
PC1	0.38	0.40	-0.06	-0.21	0.26	-0.05	0.35	-0.18
PC2	0.28	0.21	-0.38	-0.25	-0.36	-0.44	-0.41	0.49
PC3	-0.31	-0.34	0.39	0.50	0.18	0.22	0.08	-0.32
PC4	-0.07	-0.20	0.07	0.09	0.08	-0.22	-0.33	0.10
PC5	-0.16	-0.10	-0.05	-0.10	0.00	-0.06	0.07	0.12
Dry wt	0.35	0.33	0.04	-0.12	0.32	0.03	0.37	-0.26
Inflorescence no.	0.19	0.22	0.10	-0.05	0.34	0.10	0.43	-0.32
Plant form	-0.32	-0.31	0.05	0.17	-0.17	0.00	-0.31	0.14
Leaf color	0.27	0.22	-0.14	-0.24	0.11	-0.11	0.14	0.04
Heading date	0.10	0.07	-0.28	-0.19	-0.23	-0.36	-0.29	0.36
Leaf form	-0.44	-0.47	0.47	0.51	0.27	0.27	0.09	-0.37
Awn length	0.26	0.22	-0.23	-0.29	-0.02	-0.31	-0.19	0.21
Leaf pubescence	-0.33	-0.31	0.16	0.14	0.08	0.12	0.01	-0.01

Future Plans

In the next year we will look more closely at the relationship between climate and trait variation by considering additional climatic variables and the relationship among climatic variables. The maps will be refined and alternative seed zones will be evaluated by considering the amount of trait variation explained by different classifications. Performance of the commonly-used cultivars will be compared with the results from the range-wide analysis. Recommendations for seed transfer, seed zones and genetic conservation will be made. Results will be reported at meetings and in a peer-reviewed journal.

Management Applications:
Results from this study will be used to develop seed transfer guidelines and appropriate source material for revegetation and restoration in the Great Basin and adjacent areas. Results will also provide information on responses of bluebunch wheatgrass to climate change and appropriate management responses.

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

Presentations:
St.Clair, J.B.; Johnson, R.C.; Shaw, N.L. 2009. Genetic diversity and genecology of bluebunch wheatgrass (*Pseudoroegneria spicata*). Great Basin Native Plant Selection and Increase Project Annual Meeting, 2009, March 31; Boise, ID.

St.Clair, J.B. 2009. Genecology, restoration and adapting to climate change. Workshop on Restoring and Sustaining Western Landscapes: Interaction with Climate Change, 2009 Ecological Society of America Meeting, Albuquerque, NM.

St.Clair, J.B. 2009. Seed zone studies for native plants in the Pacific Northwest. Region 6 Native Plant, Invasive Plant and TES Plant Program Managers Meeting, USDA Forest Service, Pacific Northwest Region, Hood River, OR.

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). Common garden experiments, rhizobial inoculation experiments and toxic plant metabolite evaluations were done previously and presented in previous GBNPSIP reports. Exploratory molecular marker-based diversity and population structure were also reported previously from 81 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.

The exploratory analysis of the molecular data from these 81 accessions was conducted using Analysis of MOlecular VAriance (AMOVA), which indicated 73% of variation was apportioned within collections while 27% was apportioned among collections. This is important because it shows that this species has sufficient variation within any given population for selection or adaptation. Significant population structure was detected and two groups of populations were prominent in their distinction, one group from southern British Columbia and another group from central Nevada (Figure 1). Bayesian analysis conducted with the program STRUCTURE v2.1

was used to test population structure in the accessions. Groupings of 2 - 9 were tested, and the grouping where the log likelihood value-improvement tapered off was determined as the appropriate number of structured groups. A general increase in fit was found as the numbers of structures increased up to five (Figure 2), and increasing admixture among some populations was detected as the number of structures increased. Two distinct populations separated from the others early in structure testing, and remained separate and homogeneous thereafter. The first comprised six collections from British Columbia, and the second six collections from central Nevada. The remaining collections were roughly sorted geographically, with one group comprising collections from Idaho, northern and eastern Nevada, and Utah. However, the three latter groups all had many populations with admixed coancestry, suggesting that strong gene-flow barriers do not exist among these populations.

Estimates of within-population genetic diversity indicated that the highest genetic diversity among the *A. filipes* collections was found within the state of Oregon. Conversely, yet in line with population structure estimates, the lowest genetic diversity was found in British Columbia and central Nevada collections (Figure 3). Genetic diversity values were tested for significance by state boundary and by Level III ecoregion. Both tests were significant, but significance was greater for state boundaries (F=30.04 and P<0.0001) than for ecoregions (F=15.75 and P<0.0001). Thus, our data indicates a central meta-population in Oregon, with newer colonies spread out from there. This is consistent with the fact that the two strongly supported genetically differentiated groups (British Columbia and central Nevada) were on the extreme periphery of the known species distribution (Figure 4). A manuscript describing the population structure and genetic diversity has been submitted to a peer-reviewed journal.

Kishor Bhattarai (a Ph.D. student at Utah State University supported from funds on this project) conducted a series of greenhouse and field experiments with basalt milkvetch. These data were reported previously, and Kishor used these data for his Master's thesis, which he successfully defended in spring 2007. Manuscripts summarizing the study results were published in Rangeland Ecology and Management (Bhattarai and others 2008). Additionally Kishor extended his research to two other legumes: *Dalea ornata* and *Dalea searlsiae*, which were part of his Ph.D. dissertation. He will defend that in April 2010. Preliminary maps of the genetically differentiated groups for these two species are shown in Figures 5 and 6.

In consultation with those administering the Great Basin Native Plant Selection and 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. An article describing the release of NBR-1 Germplasm was published in Native Plants Journal. Efforts are underway to increase seed quantities of NBR-1 for commercial seed production.

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:
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, revegetating 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.

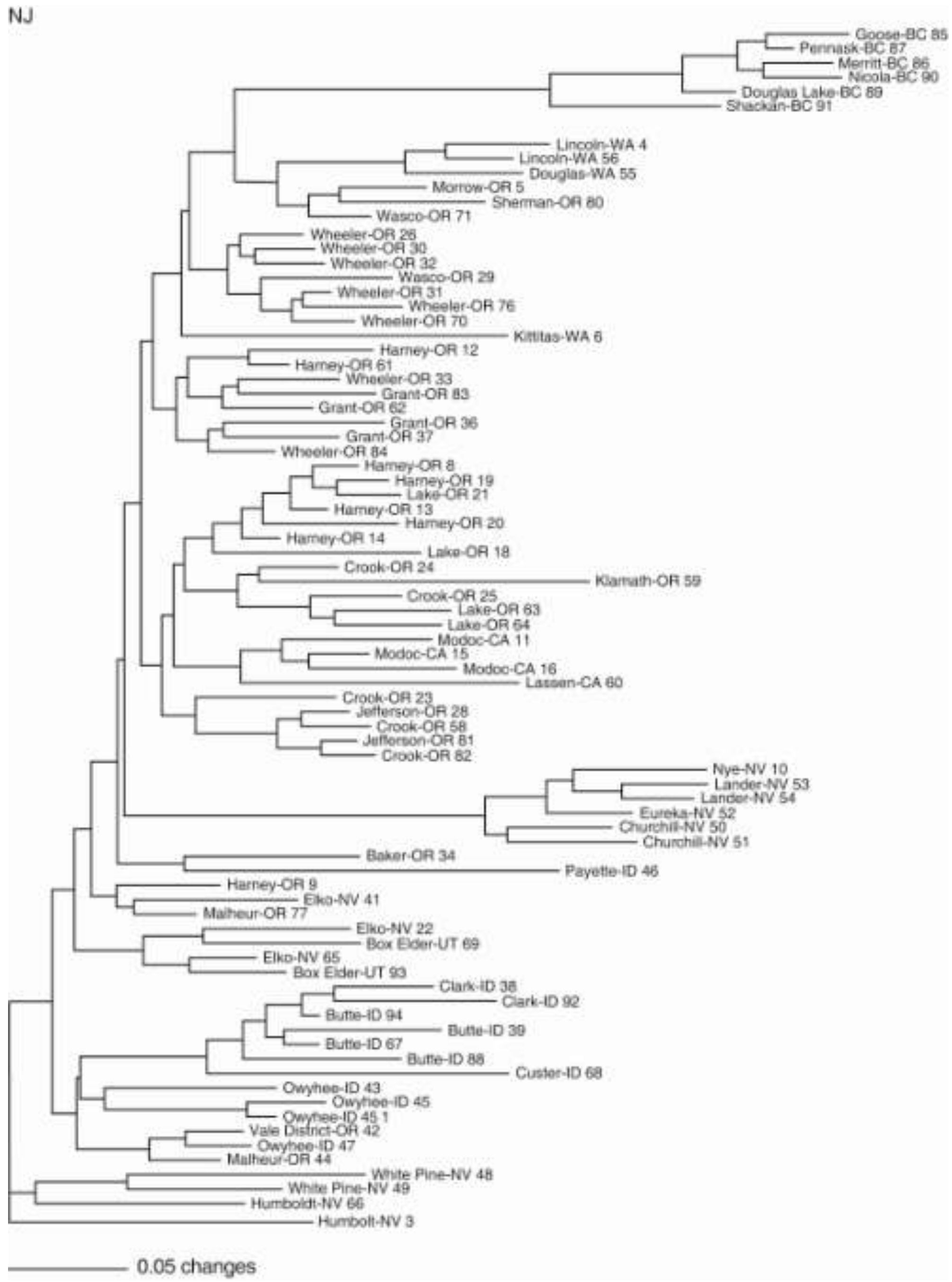

Figure 1. Neighbor-joining dendrogram of 81 basalt milkvetch accessions using analysis of molecular variance estimates of differences.

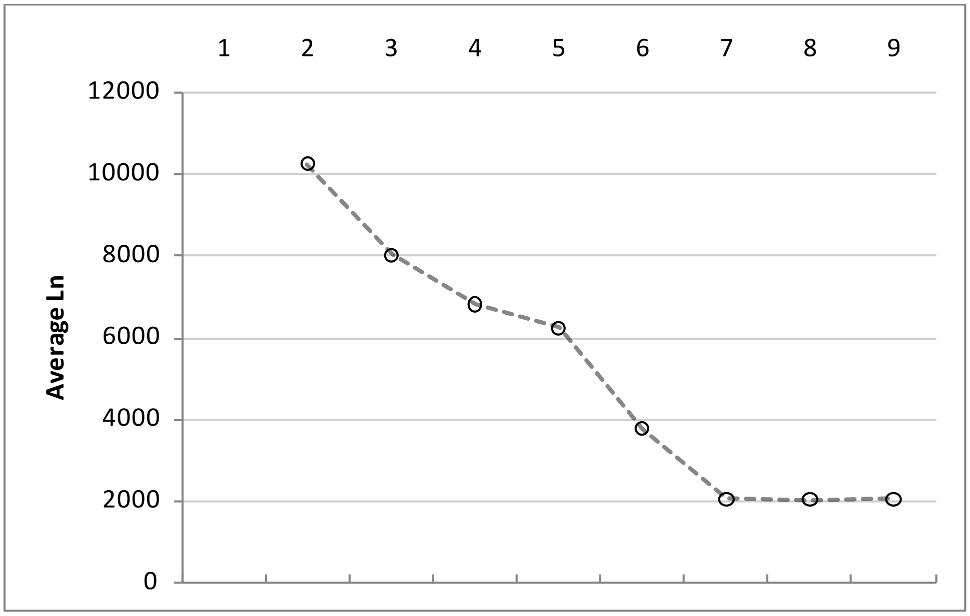

Figure 2. The difference in log likelihood estimates of testing 2 to 9 population structures using Bayesian clustering in the program STRUCTURE 2.2. The lower plateau of differences between structure tests suggest that no appreciable fit to the model is obtained by increasing the structures tested past six.

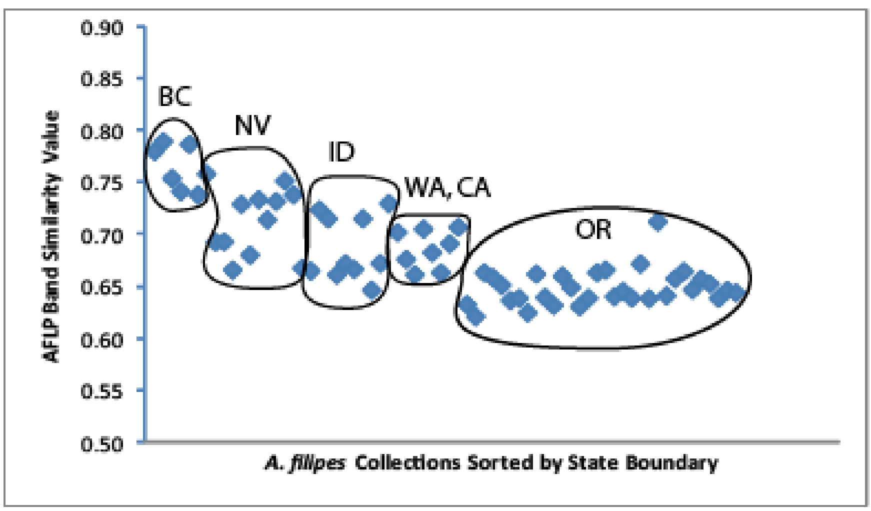

Figure 3. Average within-collection similarity values sorted by decreasing value within state/province boundary.

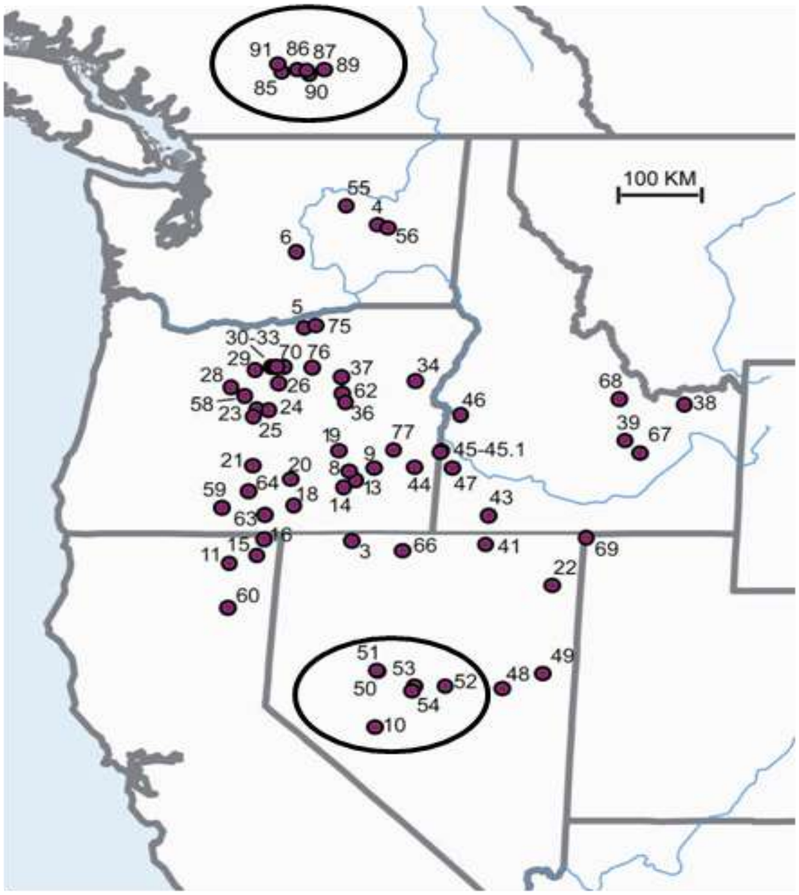

Figure 4. Collection-site map of *Astragalus filipes* with two strongly supported genetically differentiated groups.

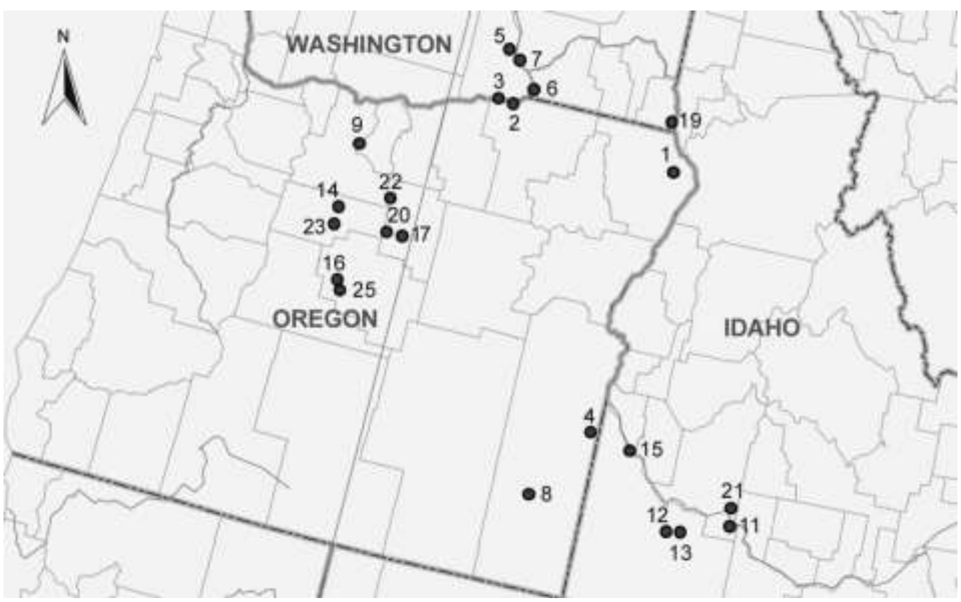

Figure 5. Collection-site map of *Dalea ornata*, with five collections in the Deschutes River Watershed (9, 14, 23, 16, 25) in central Oregon separating out as a genetically differentiated group.

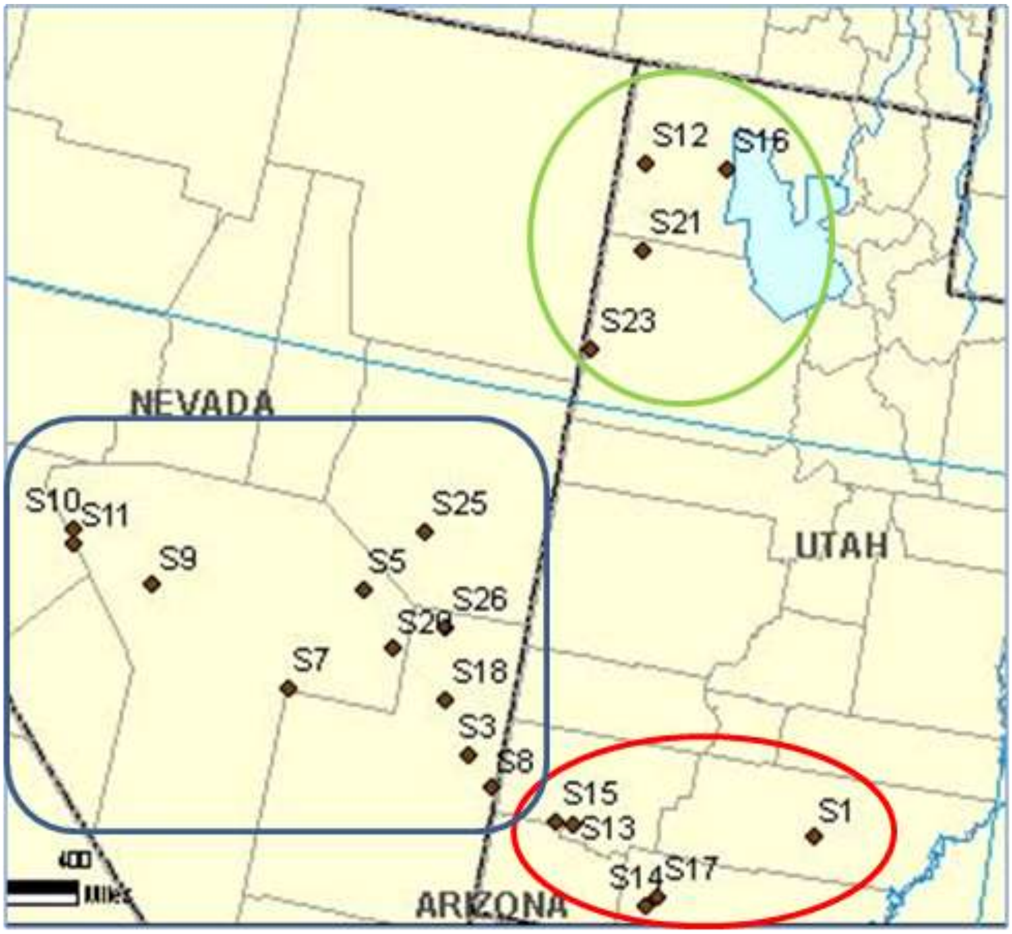

Figure 6. Collection-site map of *Dalea searlsiae*, with three genetically differentiated groups identified from preliminary analysis.

Publications:

Bushman B.S.; Bhattarai, K.; Johnson, D.A. 2009. Population structure of *Astragalus filipes* collections from the western U.S.A. and Canada. Botany (submitted).

Presentations:

Bushman, Shaun; Johnson, D.A. *Astragalus filipes* meta-populations and release of NBR-1 Germplasm. Great Basin Native Plant Selection and Increase Annual Meeting, 2009 March 31, 2009; Boise, ID.

Johnson, D.A. Collection and utilization of plant genetic resources for use on rangelands, pastures, and urban interfaces in the western U.S. Utah State University Department of Wildland Resources, Logan, UT.

Bushman, B. Shaun; Johnson, Douglas A.; Bhattarai, Kishor. *Astragalus filipes* Population Structure and Diversity. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Bhattarai, Kishor; Bushman, Shaun; Johnson, Douglas; Carman, John. Estimation of Genetic Diversity in Wildland Collections *Dalea searlsiae* and *Dalea ornata* from the U.S. Intermountain West. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Johnson, Douglas. Plant materials available for Great Basin ecoregions. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Panel discussion.

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

Project Location: Shrub Sciences Laboratory, Provo Utah

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

Objectives:

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

Project Status

Common garden study

Collection of seed and plant tissue began in autumn of 2009. A total of 93 seed sources were collected, largely by collaborators, in 11 western states (Fig. 1). In January 2010, seeds were planted in greenhouse containers. Ten families from each of 57 seed sources are being grown. The families will be replicated in each of the common gardens. Outplanting of seedlings will occur in late spring at three common garden sites (Table 1).

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

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

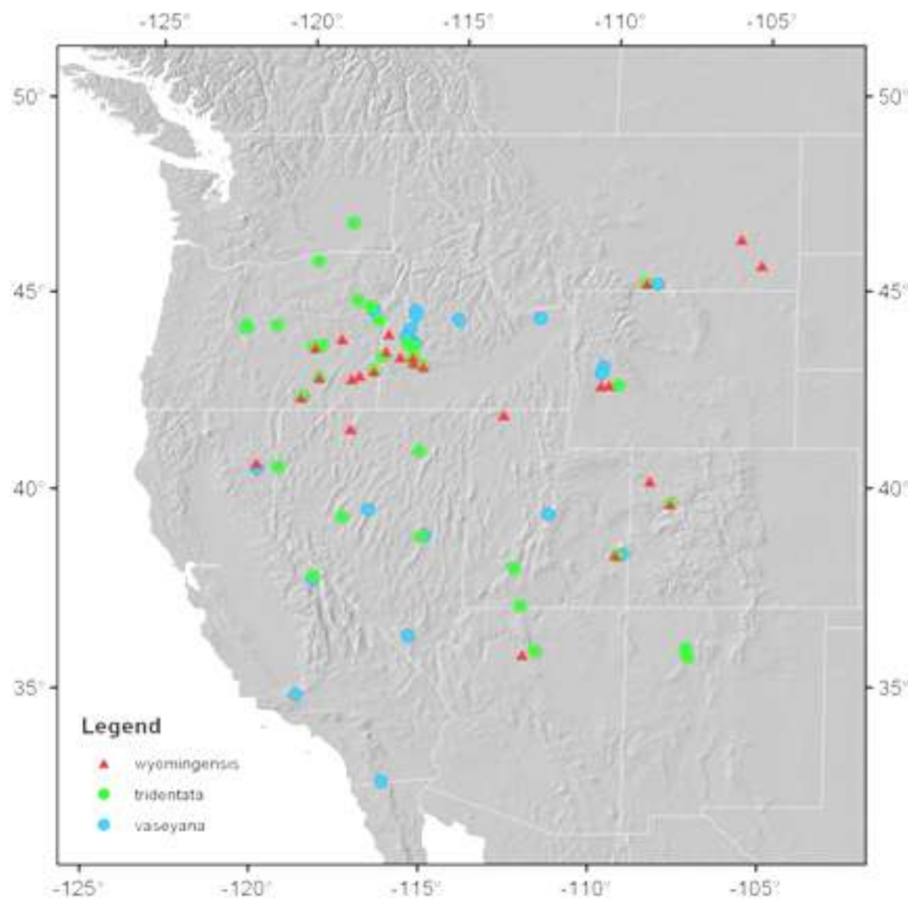

Fig. 1. The location of seed collection sites for *Artemisia tridentata*.
The symbols identify subspecies *wyomingenesis*, *tridentata* and *vaseyana*.

Molecular genetics

In September of 2009 leaf and bud tissue was collected from two big sagebrush specimens (subspecies *tridentata* and *vaseyana*) growing in Provo, Utah. Total RNA was extracted and the transcriptomes were sequenced for both subspecies using a Roche 454 FLX Genome Sequencer. The sequencing data is currently being compiled and annotated. This data includes approximately 300 million nucleotide bases of sequence for each of the subspecies and will be a data resource for downstream projects such as the development of molecular markers for population genetic and phylogenetics studies.

Future Plans

Common gardens

Beginning in 2011, after a year of establishment in the common gardens, the plants will be measured for growth and phenology traits. Monthly weather data will be collected at each common garden. Such data can be used in the development of genecological models for delineation of seed zones.

Molecular genetics

Molecular marker development from transcriptome sequencing will lead to a range-wide population genetic and phylogenetic assessment of big sagebrush. We also plan to sequence the transcriptome of subspecies *wyomingensis* for DNA sequence comparison. The final goal of this project is to discover associations between variation in transcriptome data collected from the common gardens with variation in adaptive traits.

Literature Cited

Freeman, D.C.; Turner, W.A.; McArthur, E.D.; Graham, J.H. 1991. Characterization of a narrow hybrid zone between two subspecies of big sagebrush (*Artemisia tridentata*: Asteraceae). American Journal of Botany. 78: 805-815.

McArthur, E.D.; Freeman, D.C.; Graham, J.H.; Wang, H.; Sanderson, S.C.; Monaco, T.A.; Smith, B.N. 1998. Narrow hybrid zone between two subspecies of big sagebrush (*Artemisia tridentata*: Asteraceae). VI. Respiration and water potential. Canadian Journal of Botany 76: 567-574.

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

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

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

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

Table 1. 2009 Utah Crop Improvement Association (UCIA) Great Basin Native Plant Selection and Increase Project Stock Seed Buyback Program. Forb and grass seed acquisition, distribution and field planting status for species germplasms planted in 2008 and 2009. Also listed are 2002-2007 plantings with activity in 2009.

Kind & Variety / Germplasm	Source	Lot / Origin	Seed acquisition and production status	Generation	lb Added to Inventory	date	lb distributed from Inventory	date	State distributed to	Field Status
					bulk		bulk			
2009										
Eriogonum umbellatum	Pooled ID, OR	ERUM2009	*1*2	G1	10.4	Fall 09	10.4	Fall 09	WA	Anticipate seeding spring 2010
Eriogonum umbellatum	Pooled ID, OR	ERUM2009	*1*2	G1	10.4	Fall 09	10.4	Fall 09	OR	Anticipate seeding spring 2010
Penstemon acuminatus	Pooled ID, OR	PEACSRP2009	*1*2	G0	12.3	Fall 09	12.3	Fall 09	NV	Seeded Fall09; failed, plowed out
Penstemon acuminatus	Pooled ID, OR, NV	PEACNBR	*1*2	G0	4.13	Fall 09	4.13	Fall 09	NV	Seeded Fall08, added 0.75 acres Fall 09
Poa secunda Mountain Home Germ.	Poa Sec 01-BSE-06	Lot# NBS-RR8MTH-1		G1	300	Summer 09	300	Fall 09	WA	Mostly seeded Fall 09
Elymus elymoides	Little Sahara site	Lot# CU-907, GBRI 29		G0	200	Summer 09	200	8/28/09	WA	Seeded Fall09
Linum lewisii	Maple Grove Germplasm	F-757, MGLF-1-08		G3	33	Spring 09	33	4/6/09	OR	Anticipate seeding spring 2010
2008										
Elymus elymoides	Little Sahara site	WC-628, 81, GBRI 18	*1*2	G0	2.5	10/10/08	2.5	10/10/08	ID	Plowed out
Eriogonum heracleoides	Pooled*	ERHE2	*1*2	G0	52.5	12/5/08	52.5	12/5/08	WA	2nd year seeding
Leymus cinereus	Pooled*	LECI	*1*2	G1	10.00	9/9/08	10.00	9/9/08	WA	2nd year sedding
Eriogonum umbellatum	Pooled*	ERUM	*1*2	G0	34.09	9/17/08	34.09	9/17/08	OR	Frost heave ruined stand
Penstemon deustus	Pooled*	PEDE	*1*2	G0/G1?	14.8	9/8/08	14.8	9/8/08	OR	Nothing came up
Dalea ornate	Pooled*	DAOR	*1*2	G0	1.14	9/10/08	1.14	9/10/08	WA	Failed, will retry
Astragalus filipes	Brothers	ASFI	*1*2	G1	8	9/28/08	8	9/28/08	WA	Good stand, 2nd year seeding
Lomatium triternatum	Pooled*	LOTR	*1*2	G0/G1?	9.05	9/24/08	9.05	9/24/08	ID	2nd year seeding
Agoseris heterophylla	Pioche	AGHE2	*1*2	G1	1.5	11/12/08	1.5	11/12/08	UT	Failed – plowed out
Balsamorhiza hookeri	Elko	BAHO	*1*2	G0	0.33	11/12/08	0.33	11/12/08	UT	2nd year seeding
Crepis acuminata	Warm Springs	CRAC	*1*2	G0	1.38	11/12/08	1.38	11/12/08	UT	Failed – plowed out
Crepis intermedia	Pequop Summit	CRIN4	*1*2	G0	5.74	11/12/08	5.74	11/12/08	UT	Failed – plowed out
Heliomeris multiflora var. *nevadensis*	Pioche	HEMUN	*1*2	G1	0.11	11/12/08	0.11	11/12/08	UT	Failed – plowed out
Lupinus prunophilus	Eureka	LUPR2	*1*2	G0	0.94	11/12/08	0.94	11/12/08	UT	Failed – plowed out
Penstemon pachyphyllus	Warm Springs	PEPA6	*1*2	G0	1.17	11/12/08	1.17	11/12/08	UT	Failed – plowed out
Sphaeralcea coccinea	Pooled*	SPCO	*1*2	G0	4.4	11/12/08	4.4	11/12/08	UT	Fair stand thickened Fall 09
Lomatium nudicaule	Pequop Summit	LONU2	*1*2	G0	0.96	11/12/08	0.96	11/12/08	UT	Failed – plowed out
Achnatherum thurberianum	Jordan Valley	ACTH7	*1*2	G0	1.133	11/12/08	1.133	11/12/08	UT	Added more rows Fall09
Penstemon cyaneus	Richfield	PECY3	*1*2	G0	0.51	11/12/08	0.51	11/12/08	UT	Failed – plowed out
Penstemon deustus	Huntington, OR	PEDE35	*1*2	G1	0.504	11/12/08	0.504	11/12/08	UT	Failed – plowed out
Eriogonum heracleoides	Adams ID	ERHE11	*1*2	G0	0.299	11/12/08	0.299	11/12/08	UT	Failed – plowed out
Achillea millefolium	Eagle ID	ACMI 01	*1*2	G0	0.125	11/12/08	0.125	11/12/08	UT	Poor stand, continue establishment next year
Lomatium dissectum	Godding ID	LODI 70 pooled	*1*2	G0	7.51	11/12/08	7.51	11/12/08	UT	Failed – plowed out
Penstemon acuminatus	SRPlain	PEAC pooled	*1*2	G0	2.55	11/12/08	2.55	11/12/08	UT	Failed – plowed out
Lupinus prunophilus	Eureka	LUPR2	*1*2	G0	0.94	11/6/08	0.94	11/6/08	NV	Failed – plowed out
Agoseris heterophylla	Orovada	AGHE2	*1*2	G2	6.61	11/6/08	6.61	11/6/08	NV	Failed – plowed out
Lomatium nudicaule	Pequop Summit	LONU2	*1*2	G0	0.68	11/6/08	0.68	11/6/08	NV	Replanted 1.5 acres 09
Heliomeris multiflora var. *nevadensis*	Pioche	HEMUN	*1*2	G1	0.22	11/6/08	0.22	11/6/08	NV	Added 3-4 acres Fall 09
Frasera albomarginata	Newcastle	FRAL5	*1*2	G0	0.124	11/6/08	0.124	11/6/08	NV	Failed – plowed out
Sphaeralcea coccinea	Pooled*	SPCO	*1*2	G0	1.57	11/6/08	1.57	11/6/08	NV	Failed – plowed out
Crepis intermedia	Pequop Summit	CRIN4	*1*2	G0	1.79	11/6/08	1.79	11/6/08	NV	Failed – plowed out
Eriogonum umbellatum	Pooled*	ERUM	*1*2	G0	0.61	11/6/08	0.61	11/6/08	NV	Failed – plowed out
Lomatium dissectum	Gooding ID	LODI 70 2005	*1*2	G0	6.04	11/6/08	6.04	11/6/08	NV	Failed – plowed out
Penstemon acuminatus	SRPlain	PEAC pooled	*1*2	G0	4.62	11/6/08	4.62	11/6/08	NV	Failed – plowed out
2002-2007										
Achillea millefolium	Eagle ID	Wild collected USFS			-				OR, WA, WY	Wide use in seed industry
Balsamorhiza hookeri	Wild Collected USFS	BAHO B1-02	*1*2	G0	-	Fall 02	0.31	Fall 02	CO	Small amounts of seed harvested
Balsamorhiza sagittata	Wild Collected USFS	BAS AU 32-02	*1*2	G0	1.62	4/15/04	1.19	4/16/04	UT	5th year immature stand
Linum lewisii	Maple Grove Germplasm	SG3-03-3 (APMC)	*1	G3	0.5	4/15/05	0.5	4/15/05	UT	Established
Lomatium dissectum	NBR Wild Collected USFS	Pooled	*1*2	G0	2	10/31/06	2	11/22/06	UT	3rd year immature stand
Penstemon acuminatus	Wild Collected USFS	PEAC2 B4-02	*1*2	G0	0.22	Fall 02	0.22	Fall 02	ID	Established
Penstemon cyaneus	PECY2 B6-02-CO	2006.0413	*1*3	G1	5	12/5/06	5	3/1/07	WY, ID	Seeded 2007
Penstemon deustus	Wild Collected USFS	PEDE B11-02	*1*2	G0	0.33	Fall 02	0.33	Fall 02	ID	Established, taken out 2009
Penstemon pachyphyllus	PEPA2 U6-99-OR	A5-4-P1	*3	G1	38.03	6/7/05	7.3	Fall 05	ID	3rd year immature stand
Penstemon palmerii 'Cedar'	Wild Collected UCIA	CPP KL-05-1, GBRI 16		F	133	10/24/05	46.54	2006-09	CO, ID, WY	Small scale use in seed industry
Penstemon speciosus	Wild Collected USFS	PENSPE1-BSE-03	*1*2	G0	-	4/15/04	-	4/16/04	UT	Plowed out, seed harvested 05-06
Sphaeralcea parvifolia	Wild Collected USFS	SPPA U14-02	*1*2	G0	0.33	Fall 02	0.33	Fall 02	CO	Taken out and reestablished
Poa secunda Mountain Home Germ.	Rainier Seed WA	557-215-31A	*3	G2	0.7	11/4/03	50.0	9/15/03	ID, UT, WA, WY	Wide use in seed industry
Poa secunda Mountain Home Germ.	Wild Collected USFS	Poa Sec01-BSE-06	*1	G0	6.5	9/10/06	6.5	9/11/06	WA	Seeded 4 acres 2006
				subtotal	942.9		724.9			

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

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

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

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

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

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

Notes:

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

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

Publication:
Young, S.A. Seed Provenance: Here to There and Back Again. Abstracts of the Conference of the Society for Ecological Restoration International, Perth, Western Australia, p. 202.

Presentations:
Young, S.A. AOSCA Pre-Variety Germplasm Program: Tamed or Untamed? Intermountain Native Plant Summit V, Boise, ID.

Youtie, Berta; Young, Stanford; Bouck, Michael. Seed Increase and the buy-back program. Great Basin Native Plant Selection and Increase Project Annual meeting. March 31, 2009; Boise, ID.

Young, S.A. Native Seed Certification and Wildland Seed Collection Permits. Workshop: Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR.

Young, S.A. Verification of germplasm source and status by seed certifying agencies as native plants are collected and cultivated. Workshop: Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

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

Project Location: Prineville, OR

Principal Investigator and Contact Information:

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Project Description:

Objectives

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

Methods

Native seed farms growing forbs for the GBNPSIP in the Columbia Basin and Treasure Valley were visited and fields were monitored. A few growers decided to take on another species or two for the 2010 season. Where seed stocks from the Great Basin were not immediately available, we spent the 2009 field season collecting seed to transfer to growers. We also collected seed for the GBNPSIP, ARS, USDA-FS and USDI BLM Seeds of Success programs.

Results

Five native seed growers from Oregon, Washington and Idaho were contracted to grow eight forb species (Table 1). Thirty seed lots from 11 species were collected by EOSS (Table 2) for GBNPSIP growers. Twenty-nine research collections from three species were made for ARS and USDA-FS scientists. Seed lot weights varied from less than a pound to over 20 pounds. A workshop, "Developing a Successful Native Plant Program" was held April 1 and 2, 2009 in Ontario, OR. Over 150 participants came from eight western states. Most were employed by agencies but a few were from private industry. The workshop highlighted partnerships and collaboration, available native plant materials, and success stories from Utah, Nevada, Idaho, Oregon and Washington. The workshop included a field demonstration on selecting and calibrating drills for seeding native seed mixes and a field tour of forb seed production research plots at the Oregon State University, Malheur Experiment Station.

Management Applications:

Increased communications and collaboration has led to better seed distribution to growers for seed development of new forb species that may be used in BLM seed buys and restoration projects in the future. The workshop will assist BLM and USFS Districts employees to increase efficiency in developing native seed selection and increase programs.

Products:

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

Species for Buy-Back	Code
Eriogonum heracleiodes	ERHE
Eriogonum umbellatum	ERUM
Dalea ornata	DAOR
Astragalus filipes	ASFI
Sphaeralcea grossulariifolia	SPGR
Chaenactis douglasii	CHDO
Machaeranthera canescens	MACA
Lomatium triternatum	LOTR

Table 2. Seed lots collected in the 2009 field season by Eastern Oregon Stewardship Services.

Species and Site No.	Site Details	Collection Date	No. Plants
DAOR1BY09	Hoodoo Ridge	6/16/09	1000
DAOR2BY08	Harper	6/25-26/09	1000s
DAOR3BY08	Twin Springs	6/30/09;7/1/09	1000s
ACTH1BY09	Hoodoo Ridge	6/16/09	60
ACTH2BY09	Negro Rock Rd	6/16/09	50
ACTH3BY09	Succor Creek	6/16/09	50
ACTH4BY09	Jordon Valley mp40	6/18/09	100
ACTH5BY09	Rome	6/18/09	50
ACTH6BY09	Frenchglen	6/18/09	50
ACTH7BY09	Right's Point	6/19/09	50
ACTH8BY09	Stinking Water	6/19/09	50
ACTH9BY09	Bonita Rd N of Harper	6/26/09	50
ACTH10BY09	Unity	6/20/09	60
ACTH11BY09	Picture Gorge	6/20/09	50
ACTH12BY09	Prineville	6/23/09	100
ACTH13BY09	JDFBNM Clarno	6/25/09	100
ACTH14BY09	Murderer's Creek	6/27/09	65
ACTH15BY09	Juniper Hills Post	6/27/09	75
ACTH16BY09	Lower Bridge Rd	7/02/09	60

Species and Site No.	Site Details	Collection Date	No. Plants
ACTH17BY09	Cove Palisades	7/02/09	200
ACTH18BY09	East of Burns	7/01/09	50
CHDO3BY08	Twin Springs	7/22/09	100
CHDO1BY09	N Castle Rock	7/24/09	1000
CHDO2BY08	Silver City Rd	7/28/09	300
ERUM1BY08	Pine Creek	8/8-9/09	1000
ERUM2BY08	Brothers	8/3-8/09	6000+
ERHE17BY08	PineCreek & StinkingWater	7/30/09	500
ERHE18BY08	Castle Rock	7/30-31/09	500
ERHE16BY08	Cow Creek	7/28-29/09	1000
LOTR4BY08	Castle Rock	7/31/09	100
LOTR59; LOTR3BY08	Frenchglen	7/8/09	50
LOTR1BY09	S Steens Rd	7/8/09	50
LOTR2BY08	Jordon Craters	6/17/09	60
LECI2BY09	Hoodoo Ridge	7/11/09	50
LECI1BY09	Harper	7/11/09	50
LECI3BY09	Hwy 95 Leslie Gulch	7/29/09	50
MACA03; MACA1BY08	Hwy 27	8/23-24/09	300
MACA1BBY09	Twin Springs	8/28; 10/2/09	100
MACA2BY09	Oxbow Rd Nyssa	10/2/09	75
MACA1ABY09	Rights Point	8/15-9/20/09	300
OECA1BY09	Harper	7/11/09	15
PEAC19	Denio Dunes	7/7/09	20
PEAC11	Keeney Pass	7/9-10/09	300
PEAC12	Twin Springs	7/10/09	200
PEDE 48; PEDE4BY08	Stinking Water Pass	8/9/09	500
PEDE1BY08	Frenchglen	7/8/09	20
PESP?	Leslie Gulch	7/29/09	85
PESP?	Frenchglen	7/8/09	20
PESP1BY08	Rock Creek	7/27/09	500
SPMU1BY09	Harper	7/11/09	25
SPMU2BY09	Rd to Hoodoo Ridge	7/11; 7/22/09	50
ARTR1BY09	Crooked River	11/19/09	15

Species and Site No.	Site Details	Collection Date	No. Plants
ARTR2BY09	Crooked River 2 upland	11/19/09	15
ARTR3BY09	Steens Mt Loop Rd	11/19/09	15
ARTR4BY09	Page Spring Campground	11/19/09	15
ARTR5BY09	N of Burns	11/20/09	15
ARTR6BY09	Glass Buttes	11/20/09	15
ARTR7BY09	Pilot Butte Bend	11/24/09	15
ARTR8BY09	Tumalo State Park	11/24/09	15

Presentations:
Youtie, Berta; Young, Stanford; Bouck, Michael. Seed Increase and the buy-back program. Great Basin Native Plant Selection and Increase Project Annual meeting. March 31, 2009; Boise, ID.

Youtie, Berta. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Moderator.

Youtie, Berta. Partnerships for developing regional native seed sources for use in restoration in central Oregon, USA. a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Project Title: Pollinator and Seed Predator Studies

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

Principal Investigator and Contact Information:

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

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

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

We have also been studying the tiny weevils and their relatives that infest these forb seeds, especially the legumes. This year we initiated collaboration with a nematologist, Dr. Edwin Lewis at UC Davis, to explore if some of the predatory nematodes can be used to control these seed predators during their resting stages in the soil. If so, this biocontrol will be a far more bee-safe means of weevil control for growers than the use of systemic insecticides. It is also cost competitive and can be delivered through irrigation.

Anticipating that seed from some of these perennial forb species will be used for post-fire restoration, we are evaluating susceptibilities and fates of wild bee communities to wildfire in the sage-steppe and juniper woodlands. Inasmuch as bees are necessary for pollination of most of these forbs, bee communities must persist in or recolonize burns if seeded forbs are to reproduce.

Nesting habits will likely predict a bee species' risk with fire, which will be evaluated through lab experiments and sampling of faunas in natural burns throughout the Intermountain West.

Status Report

Many ground-nesting wild bees are present and populous in the years after wildfires where the pre-existing flora was in good shape. The wet winter of 2009, plus a new and capable student, allowed me to redouble sampling for bee communities (actually floral guilds) in pairs of burned and neighboring unburned plots across a 15-year chronosequence of wildfires in sagebrush steppe and juniper woodlands in 5 states of the northern Great Basin and Columbia Plateau. We now have efficient and effective protocols for: 1) net sampling bees at target flowering forbs that allows us to compare sites on a bees/plant basis for taxonomic diversity, nesting habits and abundance, 2) standardized pan sampling of bees while we are net collecting, useful in harsh burns where nothing may be flowering, 3) characterizing densities of shrubs and prevalent wildflowers using measured distances to third nearest neighbors along the pan-trap transect and calculating densities using Morisita's ordered distance method, and 4) simple binomial diversity measures for genera in flower at each site.

To date, we have now sampled bees and flora in 27 site pairs in a chronosequence representing a span of 1-15 years since the last large fire (>1000 acres). We have focused on three species of *Balsamorhiza,* but also some *Lomatium*, globemallows, *A. filipes*, and *Penstemon*. In all, we have collected, curated and are in the final throes of identifying 1267 native bees from net-collecting, and perhaps 600 more from our pan traps. At just three species of *Balsamorhiza*, we have 908 individuals representing 54 species of native bees. Most all are ground-nesters and non-social. We are preparing maps for fires and samples in ArcGIS. Our impression is that forb communities are more plentiful and slightly more diverse in most of the fires than the control sites, but this awaits analytical confirmation.

Some of these bee species, esp. at *Lomatium* and *Sphaeralcea*, are near impossible to identify to species, even with our lab's expertise and reference collection of ½ million bees. We have therefore taken advantage of an offer from the "The Barcode of Life Data Systems" (BOLD), an online workbench that aids collection, management, analysis and use of DNA barcodes, processed through the Canadian Centre for DNA Barcoding at the University of Guelph. Of the 150 bee specimens sent, DNA sequences of the COI gene for 103 (of 155) bees have been successfully amplified, sequenced and taxonomically associated. It turns out that the prevalent bees at wild *L. dissectum* appear to be a single species, not two sibling species as suggested by the monograph of the subgenus. Our identifications of difficult but prevalent species of bees at globemallows have been confirmed as well.

What are the fates of bee faunas in crested wheatgrass? We have also begun collaborating with Tom Monaco at Logan to study the fates of bee communities fifty years after a one-time conversion of sage-steppe plant communities to monocultures of exotic crested wheatgrass. We have sampled by pan-trapping in and out of 12 of the 30 potential paired sites whose plant communities have been carefully quantified by Dr. Monaco, using our protocols developed for sampling post-fire bee communities. The sites are far from pristine, but the native bee faunas are no more depauperate in than outside of the crested wheatgrass plantings, mostly we think because the controls are in themselves in sorry vegetative condition with very sparse bloom.

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, several of which are being multiplied at this lab for distribution to growers in the near future. It should be noted that the host specificity of these bees does not preclude them from hybridizing their hosts, so some standard isolation distance (e.g. 160') will be needed between fields of *Balsamorhiza* if hybrid seed is unwelcome.

Likewise, growers that do not scout for seed beetles risk losing a well-pollinated crop (or risk losing their pollinators if sprayed during bloom). We discovered and reported a massive outbreak of seed weevils in the genus *Apion* at one commercial seed field of *Dalea ornata*, with densities of 10 or more adult weevils per raceme. That grower has now hired scouting expertise to prevent such outbreaks in the future. Our preliminary lab experiments with entomopathogenic nematodes show that these biocontrol agents accept growers' field soils and can successfully attack several of the seed weevil species in the lab, but we need more individuals for proper quantitative assays.

Products:
Species of three *Osmia* bee species and one *Hoplitis* that effectively pollinate *Hedysarum* and *Astragalus* continue to be increased at the Logan labs for eventual distribution to seed growers. With our guidance, one of these, *O. sanrafaelae*, continues to be successfully increased at Wind River Farm in Wyoming for pollination of sweetvetch (now 2600 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, James H. In press. Specialist *Osmia* bees forage indiscriminately among hybridizing *Balsamorhiza* floral hosts. Oecologia.

Presentations:
Cane, James H.; Miller, Stephanie; Weber, Melissa. Contrasting self-fertilities of a biscuitroot and three globemallows, and prospects for their pollination. Great Basin Native Plant Selection and Increase Annual Meeting, 2009 March 31, 2009; Boise, ID.

Hammon, Bob; Cane, James H. Plant materials pest update. Great Basin Native Plant Selection and Increase Annual Meeting, 2009 March 31, 2009; Boise, ID.

Cane, James H. 2009. Do specialist bees better discriminate among their hybridizing *Balsamorhiza* floral hosts? Botany and Mycology Meeting, 2009 July 25-29; Snowbird, Utah

Watrous, Kristal M.; Cane, James H. 2009. Breeding biology and pollinator assessment of threadstem milkvetch, *Astragalus filipes*. Botany and Mycology Meeting, 2009 July 25-29; Snowbird, Utah. Poster.

Cane, James H. 2009. Pollinators and climate change. Ecological Society of America Annual Meeting: Restoring and Sustaining Western Landscapes: Interaction with Climate Change, 2009 August 2-7; Albuquerque, NM.

Cane, James H. 2009. Pollinators for restoration seed production. 10th Biennial Conference on Research on the Colorado Plateau, 2009 October 5-8; Flagstaff, AZ.
"Pollination, pollinators, and promise for forb seed farming and sustainable rehabilitation"

Love, Byron; Cane, James H. 2009. Response of bee pollinators to wildfire in sagebrush steppe. Restoring the West Conference, 2009 October 27-28; Utah State University, Logan, UT. Poster.

Project Title: Insect Pests of Native Plant Seed Production

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

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Project Description:
The objective of this project is to identify insects that are potential or actual pests of production fields and collection sites for seed associated with the GBNPSIP. Insects are collected at production or collection sites and transported to the diagnostic lab at the Tri River Area Extension Office in Grand Junction, CO for identification.

Several previously unreported insects were found impacting GBNPSIP plants in 2009. Complete reports for each insect, with identification and management information are posted at http://wci.colostate.edu/seed_production.shtml.

<u>Mountain Brome, *Bromus marginatus*</u>
The aphid *Diuraphis mexicana* is a perennial pest of mountain brome seed production fields at the Upper Colorado Environmental Plant Center (UCEPC) near Meeker, CO. This insect requires annual applications of insecticide to prevent impact to seed production. The Meeker, CO site hosts the only known population of this aphid, although it has been previously reported from Washington, New Mexico and Mexico. It appears to have distinct preferences for some *D. marginatus* genetic lines over others. The current infestations are in 'Garnet', but not a Teton National Park source identified accession. Research on *Diuraphis* spp. aphids is being conducted in cooperation with Dr. Gary Puterka, USDA/ARS, Stillwater, OK.

A holocyclic (sexual) population of Russian wheat aphid (RWA), *Diuraphis noxia*, was identified in a seed production block of 'Routt National Forest' mountain brome near Hotchkiss, CO in the spring of 2009. *D. noxia* is known as an occasional pest of many species of cool season grasses grown for seed, especially during field establishment. Identification of a sexual generation for RWA is significant because it is only the second time this has been observed in the 20+ years the species has been established in the United States. This discovery, coupled with the initial find of a holocyclic RWA population in Montezuma County, CO in 2008 in wheatgrasses, gives an explanation for the appearance of genetic diversity in the species in the mid 2000s. Biotype development in RWA allowed it to overcome resistance bred into wheat varieties planted on millions of acres of farmland in the Western United States.

Blue Wildrye, *Elymus glaucus*

A recently described flea beetle, *Chaetocnema subconvexa* White, was found doing extensive damage to a seed production block at UCEPC. Damage was from larval feeding and was extensive enough to justify removal of the block and replanting in a different field. This flea beetle is widespread in wheat in northwestern Colorado and can be expected to attack several wheatgrasses and/or wildryes in northern seed production areas.

Diuraphis frequens is another leaf-rolling aphid that is now known to be present in native stands of *E. glaucus* from many sites in the Rocky Mountains, Great Basin and Colorado Plateau. It has the potential to attack seed production monocultures of blue wildrye and possibly other *Elymus* species, although it has not been found in seed production fields yet.

Blue Grama, *Bouteloua gracilis*, and Galleta, *Hilaria jamesii*

Adults of the checkered melon leaf beetle, *Paranapiacaba tricincta*, were found in abundance in Montezuma County, CO seed production fields of blue grama and galleta in late August. According to the printed literature, adults are typically found feeding on leaves of many species of broadleaf plants, especially cucurbits, but we observed them feeding on blue grama and galleta pollen. The biology of the larval stage of this insect is unknown, but we suspect it will be found feeding on the roots of these species because adults were present at a density of more than five per sweep with a 15 inch sweep net.

Grain itch mites, Acari:Pyemotidae:*Pyemotes* spp., were identified as the causal agent in a dermatitis that occurs after handling of ‘Alma’ blue grama seed produced in Montezuma County, CO. The dermatitis occurs after handling seed in the springtime, after winter storage, but not in the field or during harvest or cleaning. The mites appear to be confined to ‘Alma’ and not in ‘Hachita’ or ‘Lovington’ blue gramas grown on the same farm. We are currently working on identification of this mite to species, and investigation of its field biology and management.

Buckwheats, *Eriogonum* spp.

Larvae of several species of lycaenid butterflies in the genera *Euphilotes* and *Plebejus*, are well known as foliar feeders on several species of *Eriogonum*. *Euphilotes* is currently going through taxonomic revisions, with one new species from western Colorado, *E. stanfordorum*, and a new subspecies described in 2009. These butterflies have not been seen in damaging numbers in seed production or collection sites, but there is potential for damage when seed production monocultures are established. Given that many *Euphilotes* species and subspecies are rare and/or of limited distribution, their presence is a consideration when choosing *Eriogonum* as a reclamation species in a seed mix. *Eriogonum* species that are recorded host plants for rare *Euphilotes* are *E. umbellatum*, *E. ovalifolium*, *E. racemosum* and *E. corymbosum*. Research on *Euphilotes* is being conducted in association with Dr. Paul Opler, Colorado State University.

Several species of aphids in the genus *Braggia* were collected from *E. racemosum* and *E. corymbosum* in Colorado during the past five years. Two new species were described in 2009 from Washington, and several other species are of limited distribution. *Braggia* has not been seen impacting seed production or collection sites, but an occasional heavily infected *Eriogonum* plant in natural settings indicates that the aphid has potential to become an issue in seed production monocultures.

Penstemon

We received two samples of an ebony bug, Hemiptera:Corimelaenidae:*Corimelaena* spp., in 2009. One was from Colorado and the other from Texas. We had received a sample from a GBNPSIP collection of *P. deustus* near Idaho City, ID in 2008. These bugs pierce the plant epidermis and suck fluids from flowers, leaves, stems and seed pods. The Texas specimens, possibly *C. pulicaria* Gemar, were collected from mature open seed pods where they were apparently overwintering. The impact of these true bugs on *Penstemon* seed production is unknown, but they are widely distributed and present in many native stands and seed production blocks of many *Penstemon* species.

Fourwing Salt Bush, *Atriplex canescens*

A little known ortheziid mealybug, *Orthezia annae* Cockrell, was collected from fourwing saltbush in a native setting near Grand Junction, CO. The infestation was significant enough to kill many of the infested plants. The literature on this insect is very limited (one citation from 1926), but does state that it is known from Colorado, Arizona, New Mexico and California. It should be watched for wherever *A. canescens* is grown for seed since it has potential to kill established plants.

The Irregular Wax Scale, *Ceroplastes irregularis* Cockerell, has been observed on several occasions in western Colorado attacking fourwing salt bush. Heavy infestations can kill mature plants. The scale is covered entirely with a thick cream-colored wax and usually masses in colonies on branches and crowns of several species of *Atriplex*. It is reported from the desert areas of southern California, Arizona and New Mexico in the literature. It may be present in the Great Basin and seed growers and collectors should watch for it.

Mountain Mahogany, *Cercocarpus montanus*

A leaf galling psylid, *Cacopsylla maculata* Crawford, was observed doing significant damage in a mountain mahogany seed production block near Hotchkiss, CO. The curled leaves were very evident although the impact on seed yield is unknown. In conducting literature research on this insect, we discovered that there are several other little known psyllids recorded from *Cercocarpus* in the western US. Any of them could become a pest of seed production in some situations.

Management Applications and Seed Production Guidelines:

The database of herbicides, fungicides and insecticides labeled for seed production uses was updated in 2009. It is posted at http://wci.colostate.edu/shtml/SeedProductionPesticides.shtml.

Publications:

Pike, K.S.; Graf, G.; Foottit, R.G.; Maw, H.E.L.; Starý, P.; Hammon, Robert; Miller, D.G. 2009. New species of *Braggia* (Hemiptera:Aphididae) on buckwheat in western North America. Canadian Entomologist. 141: 561–581.

Western Colorado Insects Native Plant Seed Production [Homepage of Colorado State University Extension], [Online]. Available: http://wci.colostate.edu/seed_production.shtml [2010, February 8, 2010].

Presentations:

Hammon, Bob; Cane, James H. Plant materials pest update. Great Basin Native Plant Selection and Increase Annual Meeting, 2009 March 31, 2009; Boise, ID.

Hammon, Robert. 2009. Managing some unique pests of mountain brome and blue wild rye. 10th Biennial Conference of Research on the Colorado Plateau. 2009 October 7; Flagstaff, AZ. Abstract: http://sbsc.wr.usgs.gov/cprs/news_info/meetings/biennial/2009/index.asp

Puterka, G.J; Burd J.; Hammon, Robert W.; Peairs, F.B.; Randolph, T.; Cooper, W.R. 2009. Sexual reproduction in the Russian wheat aphid (*Diuraphis noxia*) and its role in creating biotypes. Entomological Society of America Annual Meeting, 2009, December 16; Indianapolis IN. Poster.

Project Title: *Allium acuminatum* Seed Production: First Look at Cultural Parameters

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

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

Methods

It takes 3-4 years for *A. acuminatum* plants grown from seed to flower. The average bulb diameter of plants that age is 4-5 mm (Dave Skinner, personal communication). For this trial, dormant mature bulbs with a diameter of 7-15 mm were used. The trial was planted in October 2008 in Pullman, WA in randomized complete blocks with four replications. The treatments were 1) mechanical planting with 1 inch between bulb spacing, 2) mechanical planting with 2 inches between bulb spacing, 3) hand planting with 1 inch between bulb spacing, and 4) hand planting with 2 inches between bulb spacing. Each plot had 60 bulbs planted at a depth of 1 inch. The plots were rototilled prior to planting but no pre-plant herbicide or fertilizer was applied. A single-row Hage belt cone planter was used for the mechanically planted plots. No irrigation was applied to the trial during the growing season. Emergence was taken April 16, 2009. Flowers/umbel counts were taken for 25 randomly selected plants per plot on June 11,

2009. When half or more of the capsules were open on individual umbels and all plants in a plot had mature seed, whole umbels from 25 individual plants were harvested by hand for each plot. Harvest dates were July 14 and 15, 2009. In August 2009 the bulbs from all plots were dug and stored in the Western Regional Plant Introduction drying shed until September 2009 when they were moved to a temperature and humidity-controlled chamber. Bulbs were stored at 14°C and 40% RH until early October 2009 when they were cleaned, counted, sized and repackaged for planting. During repackaging, bulbs were discarded if they 1) showed signs of disease or herbivory, 2) were soft and rubbery, or if they were 3) hard and desiccated. Seed from each plant was cleaned, counted and weighed separately. Only fully filled seed was included in the counts. Light or partially filled seed was discarded.

Results and Discussion

Tables 1 and 2 summarize emergence, flower production, seed harvested per plant, seed weights and bulb production for the trial. There were no statistical differences found among any of the treatments for the production of flowers/umbel, seed harvested/plant or seed weights. Thus, mechanical planting was successful as an efficient planting technique. Also, when using mature bulbs for seed production, bulbs can be spaced as close as 1 inch without compromising yield.

Seed production per plant was lower than expected. During harvest shattered seed was observed on the ground. *A. acuminatum* seed in lower flowers ripens before those in the upper flowers and is easily dislodged from open capsules during harvest. In many harvested umbels there were some green capsules. Even though the seed in these capsules looked fully filled, they did not dry down to produce high quality seed. Because of these factors, timing seed collection to maximize harvest will be critical for *A. acuminatum* production.

There were no statistical differences found among treatments for total bulb production, bulbs < 7 mm in diameter and the number of discarded bulbs. There were statistical differences between spacing treatments for the number of 7-15 mm diameter bulbs produced. The number of 7-15 mm diameter bulbs was highest for the mechanically planted, 1 inch spacing treatment, and lowest for the hand planted, 1 inch treatment with the mechanical 2 inch and hand 2 inch treatments intermediate (Table 2). We had difficulty getting a consistent 1 inch spacing using the Hage belt cone planter. The bulbs tended to bunch in the cone making bulb spacing greater than 1 inch in some cases. This potentially wider average spacing could have caused the increased number of bulbs produced in the mechanically planted 1 inch bulb spacing treatment.

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

Table 1. Summary of emergence, flowers/umbel, seed harvest/plant and 100 seed weight data collected from *Allium acuminatum* seed production trial planted in Pullman, WA. (There were no treatment differences observed at P<0.05)

Planting method	Between bulb spacing	Percent emergence	Avg. flowers/umbel	Avg. seed/plant	Avg. 100 seed wt. (g)
Hand	1 inch	91.6	30.8	31.1	0.19
Hand	2 inch	95.0	28.9	37.2	0.21
Mechanical	1 inch	93.3	29.4	39.0	0.19
Mechanical	2 inch	94.2	30.8	34.4	0.20

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

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

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

Future Plans

The trial was replanted in October 2009 using the same number of bulbs/plot, experimental design and planter. Flowers/umbel, seed harvest/plant, seed weights and bulb production/plot data will be collected in 2010. Data from the two years will be compiled and reported. Production protocols will be developed from the compiled data.

Presentation:

Hellier, Barbara; Johnson, R.C. Mechanically planting *Allium acuminatum* bulbs for seed production. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2009 March 31, Boise, ID.

Johnson, Richard C.; Hellier, Barbara and Cashman, Mike. Seed zones for Tapertip Onion and Indian Ricegrass. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2009 March 31, Boise, ID.

Project Title: Emergence of Native Plant Seeds in Response to Seed Pelleting, Planting Depth, Scarification and Soil Anti-crusting Treatment

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

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Project Description:
Seed of native plants is needed to restore rangelands of the Intermountain West. Reliable commercial seed production is desirable to provide the quantity of seed needed for restoration efforts. Establishment of native seed crops has been difficult because fall planted seed is susceptible to bird damage, soil crusting and soil erosion. Fall planting is important for many species, because seed of many species requires a period of cold to break dormancy (vernalization). Planting of native seed has resulted in poor stands in some years at the Malheur Experiment Station. This trial tested seed pelleting, planting depth and soil conditioner treatment for emergence of five important species that are native to Malheur county and surrounding areas.

<u>Materials and Methods</u>
Seed of the five native species was either pelleted or used raw. Pelleting was done by Seed Dynamics Inc. (Salinas, CA). The pelleted and raw seed of each species (including the scarified

and non-scarified *Lupinus argenteus*) was planted in single rows on 30-inch beds in a field of Owyhee silt loam on November 19, 2008. Each plot consisted of one row 5 feet long with 100 counted seeds planted in each plot. The pelleted and raw seed was planted at three depths: on the soil surface, ⅛ inch depth, and ¼ inch depth. The pelleted and raw seed planted at each depth was further submitted to three soil anti-crusting treatments: untreated check, WaterMaxx II (Aquatrols, Inc., Salt Lake City, UT) at 2 quarts per acre, and Soil Binder (Simplot Soil Builders, Boise, ID) at 2 quarts per acre. The anti-crusting treatments were applied to the soil surface after planting using a backpack sprayer with 8004 nozzles at 30 PSI and applying 30 gallons of water per acre in a band 4 inches wide directly over the seed. One half of the *Lupinus argenteus* seed was scarified by immersion in concentrated sulfuric acid for six minutes and the other half was left without scarification. Both *L. argenteus* lots were subjected to all of the pelleting, planting depth and anti-crusting treatments. Emerged seeds in each plot were counted four times: March 31, April 7, May 1, and May 10, 2009.

Results and Discussion

Seed emergence was poor. The fall planting suffered from heavy soil crusting. Bird damage might also have reduced emergence and could be a factor in why emergence was poor for the seed planted on the surface. *Penstemon deustus* (hotrock or scabland penstemon) did not emerge so it was not considered in the statistical analyses.

Seed pelleting

Seed pelleting did not result in a statistically significant improvement in the emergence of any of the species planted, but did decrease *Lupinus argenteus* establishment (Table 1).

Planting depth

Planting the seed on the soil surface was detrimental to establishment (Tables 1 and 2).

Lupinus argenteus (silvery lupine)

Seed scarification resulted in a decrease in emergence compared to the non-scarified seed (Table 1). For the non-scarified seed, the highest emergence was obtained with the non-pelleted seed planted at either the ⅛ inch depth and treated with Soil Binder, or planted at the ¼ inch depth with no soil treatment. Seed pelleting reduced emergence.

Achnatherum thurberianum (Thurber's needlegrass)

The highest emergence was obtained with the combination of seed planted at ¼ inch depth and the soil treated with Soil Binder (Figure 1, Table 2). Seed pelleting did not affect emergence.

Sphaeralcea grossulariifolia (gooseberryleaf globemallow)

Emergence was poor and there were no statistically significant differences between treatments.

Penstemon acuminatus (sharpleaf or sandhill penstemon)

The ⅛ inch or the ¼ inch depth with or without soil treatment were among the treatments with the highest emergence (Table 2). Seed pelleting did not affect emergence.

Table 1. Seed emergence of *Lupinus argenteus* (silvery lupine) by May 10, 2009 in response to seed scarification, seed pelleting, planting depth, and soil treatment. Malheur Experiment Station, Ontario, OR.

Seed pelleting	Planting depth	Soil treatment	Scarified	Non-scarified	Average
	inches		------ % emergence ------		
none	0	none	0.00	2.33	1.17
		WaterMaxx	1.00	1.33	1.17
		Soil Binder	0.00	0.00	0.00
		average	0.33	1.22	0.78
	⅛	none	1.67	3.00	2.34
		WaterMaxx	3.00	5.00	4.00
		Soil Binder	3.00	15.33	9.17
		average	2.56	7.78	5.17
	¼	none	1.67	13.00	7.34
		WaterMaxx	4.33	11.67	8.00
		Soil Binder	9.33	2.00	5.67
		average	5.11	8.89	7.00
average			6.26	7.52	6.89
pelleted	0	none	0.00	0.00	0.00
		WaterMaxx	0.00	0.00	0.00
		Soil Binder	0.00	0.33	0.17
		average	0.00	0.11	0.06
	⅛	none	0.00	1.67	0.84
		WaterMaxx	0.33	2.67	1.50
		Soil Binder	0.33	2.67	1.50
		average	0.22	2.34	1.28
	¼	none	0.67	1.33	1.00
		WaterMaxx	2.00	2.67	2.34
		Soil Binder	0.00	2.33	1.17
		average	0.89	2.11	1.50
average			0.37	1.52	0.94
		none	0.67	3.56	2.11
		WaterMaxx	1.78	3.89	2.83
		Soil Binder	2.11	3.78	2.94
		average	1.52	3.74	2.63
average	0		0.17	0.67	0.42
	⅛		1.39	5.06	3.22
	¼		3.00	5.50	4.25
		average	1.52	3.74	2.63
LSD (0.05)					
Planting depth				2.47	
Seed scarification				0.94	
Scar. X depth				NS	
Scar. X anti-crusting soil trt.				NS	
Scar. X pelleting				1.09	
Scar. X depth X anti-crusting				2.31	
Scar. X depth X anti-crusting X pelleting				3.26	

Table 2. Seedling emergence by May 10, 2009 for 4 native plant species in response to seed pelleting, planting depth, and anti-crusting soil treatment. Malheur Experiment Station, Ontario, OR.

Seed pelleting	Planting depth	Soil treatment	*Lupinus argenteus* non-scarified	*Achnatherum thurberianum*	*Sphaeralcea grossulariifolia*	*Penstemon acuminatus*	Avg.
	inches		--------------------- % emergence ---------------------				
none	0	none	2.33	0.00	0.00	1.67	1.00
		WaterMaxx	1.33	0.00	0.00	0.00	0.33
		Soil Binder	0.00	0.00	0.00	0.00	0.00
		average	1.22	0.00	0.00	0.56	0.44
	⅛	none	3.00	3.00	0.00	3.67	2.42
		WaterMaxx	5.00	7.00	0.00	5.67	4.42
		Soil Binder	15.33	6.67	0.00	8.33	7.58
		average	7.78	5.56	0.00	5.89	4.81
	¼	none	13.00	1.00	0.00	3.67	4.42
		WaterMaxx	11.67	0.00	2.33	8.00	5.50
		Soil Binder	2.00	12.33	0.00	0.33	3.67
		average	8.89	4.44	0.78	4.00	4.53
average			5.96	3.33	0.26	3.48	
pelleted	0	none	0.00	0.33	0.00	0.67	0.25
		WaterMaxx	0.00	0.00	0.33	1.00	0.33
		Soil Binder	0.33	5.33	0.00	0.67	1.58
		average	0.11	1.89	0.11	0.78	0.72
	⅛	none	1.67	3.33	0.33	8.00	3.33
		WaterMaxx	2.67	4.67	0.00	6.33	3.42
		Soil Binder	2.67	6.67	0.33	4.33	3.50
		average	2.34	4.89	0.22	6.22	3.42
	¼	none	1.33	0.67	2.00	4.00	2.00
		WaterMaxx	2.67	0.00	0.00	8.33	2.75
		Soil Binder	2.33	9.33	0.00	8.00	4.92
		average	2.11	3.33	0.67	6.78	3.22
average			1.52	3.37	0.33	4.59	2.45
		none	3.56	1.39	0.39	3.61	2.24
		WaterMaxx	3.89	1.94	0.44	4.89	2.79
		Soil Binder	3.78	6.72	0.06	3.61	3.54
		average	3.74	3.35	0.30	4.04	2.86
average	0		0.67	0.94	0.06	0.67	0.58
	⅛		5.06	5.22	0.11	6.06	4.11
	¼		5.50	3.89	0.72	5.39	3.88
		average	3.74	3.35	0.30	4.04	2.86
LSD (0.05)							
Depth					NS		
Species					1.20		
Species X depth					2.08		
Species X soil treatment					2.08		
Species X pelleting					1.70		
Species X depth X soil treatment					3.61		
Species X depth X soil treat. X pellet					5.10		

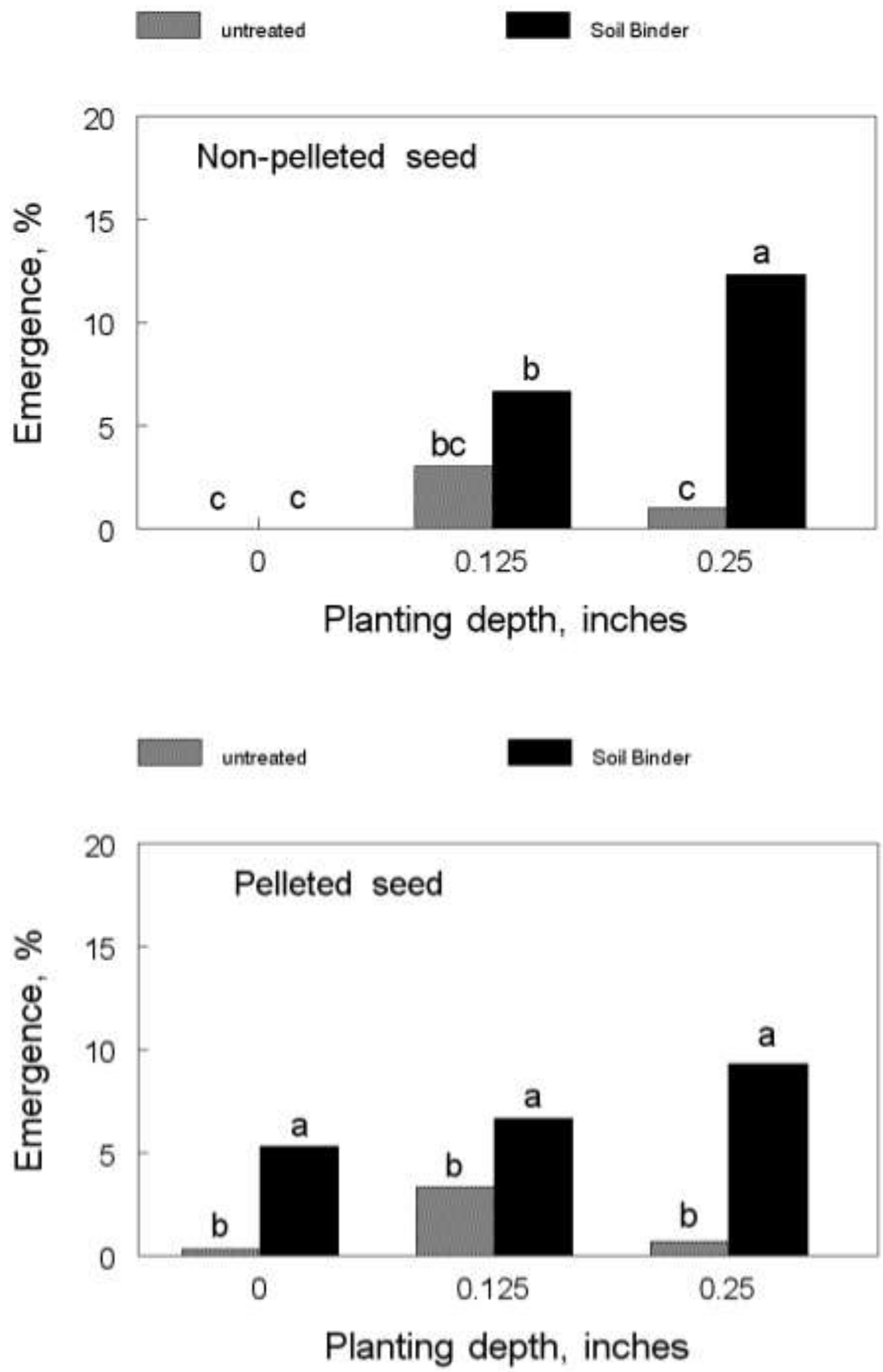

Figure 1. Emergence of *Achnatherum thurberianum* in response to planting depth and treatment with Soil Binder as an anti crusting for non-pelleted and pelleted seed. Malheur Experiment Station, Oregon State University, Ontario, OR.

Presentations:

Shock, Clinton C.; Feibert, Erik; Saunders, Lamont; Shaw, Nancy. Do these plants need water? Great Basin Native Plant Selection and Increase Project Annual Meeting. March 31, 2009; Boise, ID.

Shock, Clinton C.; Feibert, Erik; Saunders, Lamont; Shaw, Nancy. Where did all the weeds go? Great Basin Native Plant Selection and Increase Project Annual Meeting. March 31, 2009; Boise, ID.

Shock, Clinton C.; Feibert, Erik; Ishida, Joey. Native forb research: Irrigation and weed control. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Field demonstrations.

Shock, Clinton C.; Shock, Cedric A.; Plummer, Sam. Mid-Snake River watershed vegetation database. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Shock, Clinton C.; Feibert, Erik B.G.; Saunders, Lamont D.; Shaw, Nancy L.; Mohan, S. Krishna; Sampangi, Ram K. Desert Parsley (*Lomatium* spp.) seed production challenges. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Shock, Clinton C.; Feibert, Erik B.G.; Saunders, Lamont D.; Shaw, Nancy L.; Mohan, S. Krishna; Sampangi, Ram K. Irrigation and mechanization for seed production of Sulfur-flower Buckwheat, a native forb. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Shock, Clinton C.; Feibert, Erik B.G.; Saunders, Lamont D.; Shaw, Nancy L.; Mohan, S. Krishna; Sampangi, Ram K. Sharpleaf and Sagebrush Penstemon seed yield response to irrigation. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

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

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

Materials and Methods
Continued difficulty working with seedlings in the greenhouse resulted in trials focusing on herbicide tolerance of established plants in field trials. Plantings of *Astragalus filipes*, *Dalea ornata* and *Dalea searlsiae* were established by Doug Johnson of the USDA-FRRL in 2005 by transplanting growing plants from cone-tainers into the field with 0.5 meter between plants. Both fields were mixtures of different collections that had been evaluated for various traits. Because there were not enough plants to have borders between plots, treatments were applied with a shielded sprayer to prevent any contamination of adjacent plots during treatment application. Treatments were applied at 20 gpa and 30 psi.

Astragalus filipes

Because *Astragalus filipes* plants had been utilized in 2008 to evaluate herbicide tolerance, treatments in 2009 were applied perpendicular to the previous treatments and arranged in a way that would decrease plot variability. Herbicide plots were two plant rows wide and 21 plants long (1 by 11 m, 42 plants per plot). Treatments were applied on May 15. Injury was evaluated on May 26 and June 25. The number of flowering plants was also recorded on May 26. Plant biomass was harvested July 23.

Dalea ornata and *Dalea searlsiae*

Dalea plots were treated on May 21, 2009. *Dalea ornata* and *searlsiae* were not treated with herbicides previously. Herbicide plots were two plant rows wide and 11 plants long (1 by 6 m, 22 plants per plot). To account for herbicide influence on plant growth, plant height and width were measured prior to treatment on May 19 and again on June 18 and 22 for *Dalaea searlsiae* and *Dalea ornata*, respectively. Height and width were also used to calculate plant volume. Plants not emerged at the time of herbicide application were removed from the analysis.

Results

Astragalus filipes

Postemergence herbicide treatments caused varying levels of damage to *Astragalus filipes* (Table 1). Transline was most injurious at both evaluation dates. Injury with Buctril and Raptor was initially high but declined by the last evaluation date. Injury from 2,4-DB was minimal. Average plant weight was reduced by Buctril and Transline compared to the untreated plots and all other herbicide treatments. However, Transline and Paramount reduced the number of flowering plants per plot compared to the untreated plot and all herbicide treatments reduced flowering plant numbers compared to 2,4-DB. It appears that 2,4-DB may hold promise for use in controlling weeds in *Astragalus filipes*. However, seed yield and viability were not evaluated and must be tested to certify that candidate herbicides do not have a negative impact on seed production.

Table 1. Effect of herbicide treatments on plant injury and average plant height, and average plant width of established *Astragalus filipes*.

		Plant response*			
		Injury			
Herbicide†	Rate	May 26	June 25	Flowering	Ave. weight
	lb ae/A	———%——–		plants/plot	—g/plant–-
Untreated	--	-	-	5.8 ab	15.2 a
Buctril	0.25	41 b	28 b	2.8 bc	9.6 b
2,4-DB	0.25	13 d	6 c	10.0 a	19.1 a
Transline	0.124	59 a	64 a	0.0 d	8.8 b
Paramount + MSO	0.248	23 cd	21 bc	1.3 cd	17.8 a
Raptor + MSO	0.078	39 bc	20 bc	2.5 bc	16.9 a

*Injury was measured by visual evaluations. Flowering was measured May 26 and biomass was harvested on July 23. Flowering data was log transformed for analysis but raw data means are shown. Data within columns followed by the same letter are not significantly different at P=0.05.

†Buctril and Raptor rates are in lb ai/A. MSO is methylated seed oil applied at 1.0% v/v. All treatments were applied in 20 gpa spray volume.

Dalea ornata

In 2008 *Dalea ornata* exhibited little injury from postemergence herbicide applications. However, the applications were made before there was significant plant growth. In 2009, when treatments were applied to actively growing plants, several herbicides caused significant injury to *Dalea ornata* (Table 2). Goal and Chateau caused severe tissue burn 5 days after treatment (DAT) but recovered considerably by 35 DAT. Injury from Transline was high initially and remained high, while injury from Milestone was moderately high 5 DAT and increased significantly by 35 DAT. Only Milestone significantly reduced vegetative biomass compared to the untreated plot. However, Buctril, Transline and Milestone caused significant declines in seedhead biomass compared to the untreated plot. Seedheads were virtually eliminated by treatment with Milestone. Increases in plant height and/or width and plant volume were decreased by Goal, Chateau, Transline, Raptor and Milestone and plant width was reduced by Paramount compared to the untreated control. Increases in plant height, width and volume were similar to the control plots for plants treated with Prowl H_2O, Outlook, Sencor, Buctril and 2,4-DB. This data suggests that Prowl H_2O, Outlook, Sencor and 2,4-DB may have potential for postemergence use in *Dalea ornata*. The other herbicides tested may have potential if applied prior to *Dalea ornata* breaking dormancy as was observed in 2008. Further testing will be required to determine herbicide effects on seed production and viability.

Table 2. Effect of herbicide treatments applied May 21 on plant injury, biomass and average changes in plant height, width and volume of established *Dalea ornata*.*

		Injury		Biomass		Change in growth		
Herbicide†	Rate	5 DAT	35 DAT	Veg.	Seedhead	Height	Width	Volume
	lb ai/A	———%———		——g/plot——		cm	cm	cm^2
Untreated	--	-	-	520	243 a	27	44	2043
Prowl H_2O	0.71	10	1	545	203 ab	27	45	2099
Outlook	0.84	6	4	616	189 ab	27	43	2071
Goal	0.25	64	26	513	218 a	178	28	1039
Chateau + NIS	0.064	56	18	479	203 ab	21	35	1434
Sencor + NIS	0.5	21	5	572	140 ab	30	47	2313
Buctril	0.25	13	14	337	126 b	26	37	1692
2,4-DB	0.25	23	10	393	150 ab	27	43	2038
Transline	0.124	41	44	416	32 c	22	33	1503
Paramount + MSO	0.248	25	10	704	191 ab	25	36	1711
Raptor + MSO	0.078	38	18	446	185 ab	16	24	936
Milestone	0.047	35	63	258	2 d	18	28	1091
LSD (0.05)	-	13	12	212	-	5	8	481

*Injury was measured by visual evaluations. Plant height, width, and volume are the increase of individual plants between May 19 and June 22, 2009. For seedhead biomass mean separations are based on log transformed data with raw data shown. Means within a column followed by the same letter are not significantly different at P=0.05.

†2,4-DB, Transline, Paramount and Milestone rates are in lb ae/A. NIS is non-ionic surfactant applied at 0.25% v/v. MSO is methylated seed oil applied at 1.0% v/v. All treatments were applied in 20 gpa spray volume.

Dalea searlsiae

Trends in the injury to *Dalea searlsiae* (Table 3) were similar to those observed on *Dalea ornata* (Table 2). Injury was severe with Goal and Chateau early, but declined with time. Transline injury was severe and persistent, while injury from Paramount and Raptor were moderately high initially and also declined with time. Prowl H_2O, Buctril and 2,4-DB caused little injury. Even though injury trends were similar to those observed in *Dalea ornata*, resulting vegetative and seedhead biomass were not significantly different among treatments. Despite the variability in the data there is a nearly significant (P=0.06) reduction in seedhead biomass caused by Transline. Goal, Chateau and Raptor all reduced the average increases in plant height, diameter and volume compared to the untreated plots. Plots treated with 2,4-DB had among the highest plant growth and were significantly greater than plots treated with Sencor and Transline in addition to Goal, Chateau and Raptor. Part of the increases in growth in plots treated with 2,4-DB may be attributed to minimal herbicide injury to the *Dalea* and slight suppression of field bindweed re-growth between cultivations. Several herbicides including 2,4-DB may have potential for use in *Dalea searlsiae* seed production and additional trials should further document treatment effects on seed production and viability.

Table 3. Effect of herbicide treatments applied May 21 on plant injury, biomass and average changes in plant height, width and volume of established *Dalea searlsiae*.*

		Injury		Biomass		Change in growth		
Herbicide†	Rate	5 DAT	35 DAT	Veg.	Seedhead	Height	Width	Volume
	lb ai/A	———%———		—g/plot—		cm	cm	cm^2
Untreated	--	-	-	423	99	23	35	1394
Prowl H_2O	0.71	9	8	401	102	23	34	1425
Goal	0.25	65	16	489	146	17	22	805
Chateau + NIS	0.064	58	21	403	97	17	25	848
Sencor + NIS	0.5	28	19	404	102	22	33	1330
Buctril	0.25	13	6	508	110	23	37	1583
2,4-DB	0.25	16	5	518	110	27	41	1734
Transline	0.124	33	44	410	32	19	28	1190
Paramount + MSO	0.248	25	16	472	80	24	34	1442
Raptor + MSO	0.078	36	15	547	89	14	24	791
LSD (0.05)	-	16	22	NS	NS	4.6	7.4	366

*Injury was measured by visual evaluations. Plant height, width and volume are the increase of individual plants between May 19 and June 18, 2009.

†2,4-DB, Transline and Paramount rates are in lb ae/A. NIS is non-ionic surfactant applied at 0.25% v/v. MSO is methylated seed oil applied at 1.0% v/v. All treatments were applied in 20 gpa spray volume.

Direction for 2010

Efforts in 2010 will focus on expanding experiments on forb tolerance to herbicides. Utilizing established plants, if available, and also seeking to work with seedlings if germination can be improved.

Management Applications:

The data from this year of research continue to identify herbicides that could potentially be used for weed management in forb seed production. Information is still lacking on herbicides that could be used to establish forb seed fields. This is critical as weed competition is often most detrimental during crop establishment. Additional data is needed to confirm this year's findings and document herbicide impacts on seed production and viability.

Presentations:

Ransom, Corey; Edvarchuk, Kim. Identification of herbicides for use in native forb seed production. Great Basin Native Plant Selection and Increase Project Annual meeting. March 31, 2009; Boise, ID.

Project Title: Tolerance of Native Perennial Forbs Grown for Seed Production to Rates and Mixtures of Postemergence Herbicides

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

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Project Description:

The plant species planted in this trial are native to Malheur County and surrounding areas. These species are judged by the BLM and US Forest Service to be important rangeland restoration species for wildlife and other beneficial characteristics. 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 results reported here deal with postemergence herbicide rates and mixtures.

This work seeks to discover product rates and mixtures 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 a recommendation for the application of any of these herbicides. *Pesticide labels should always be* *consulted before any pesticide use. Considerable efforts may be required to register these herbicides for use for native forb seed production.*

Materials and Methods

In the fall of 2006 *Eriogonum umbellatum, Penstemon acuminatus, P. deustus* and *P. speciosus* were each planted in areas 10 ft wide and 220 ft long (Table 1). The seeds were planted in four rows, 30 inches apart. The field previously had been disked, ground hogged and marked in rows 30 inches apart. Planting depths were similar to those used in the irrigation trial (Shock et al. 2007) and appropriate to each species. Prior to planting, one drip tape was inserted every 5 feet equidistant between where pairs of rows were to be planted at a 12-inch depth as previously described (Shock et al. 2007). The drip tape was supplied with irrigation water using filtration and other common drip-irrigation practices (Shock 2006). Drip irrigations were applied every two weeks starting on April 10 and ending on May 29 (total of four irrigations). Each irrigation applied 1 inch of water.

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

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

General Considerations

The focus of the evaluations was forb tolerance to the herbicides, not weed control. Therefore, weeds were counted and 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, Owyhee Co., ID	2004
Penstemon acuminatus	Sharpleaf or sand-dune penstemon	Bliss Dam, Elmore Co., ID	2004
Penstemon deustus	Scabland or hot-rock penstemon	Blacks Cr. Rd., Elmore Co., ID	2003
Penstemon speciosus	Royal or sagebrush penstemon	Leslie Gulch, Malheur Co., OR	2003

Results and Discussion

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

Symptoms of herbicide injury were not observed in any of the plants in 2008 or 2009. Foliar injury would not be expected since all herbicides tested (except Select®) were soil active and were applied early. There were no significant differences in seed yield between the herbicide treatments and the untreated check for *Eriogonum umbellatum*, *Penstemon acuminatus* and *P. speciosus* in 2008 (Shock et al. 2009). In 2009 the seed yields of *Eriogonum umbellatum* were higher than those in 2008 and seed production continued to be unaffected by herbicide rate or mixture (Table 2).

Table 2. Yield of *Eriogonum umbellatum* in response to postemergence herbicides applied on March 12, 2008 and March 20, 2009, Malheur Experiment Station, Oregon State University, Ontario, OR. All herbicides except Select are soil active.

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

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

Summary

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

Acknowledgements
This project was partially funded by the Great Basin Native Plant Selection and Increase Project and expenditures by Oregon State University.

Literature Cited

Shock, Clinton C. 2006. Drip irrigation: an introduction. Sustainable Agriculture Techniques, Oregon State University Extension Service. EM8782-E, revised October 2006.

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Shock, Clinton C.; Feibert Erik B.G.; Shaw, Nancy. 2009. Native perennial forb tolerance to rates and mixtures of postemergence herbicides. Oregon State University Agricultural Experiment Station, Special Report. 1094: 177-179.

Presentations:

Shock, Clinton C.; Feibert, Erik; Saunders, Lamont; Shaw, Nancy. Do these plants need water? Great Basin Native Plant Selection and Increase Project Annual Meeting. March 31, 2009; Boise, ID.

Shock, Clinton C.; Feibert, Erik; Saunders, Lamont; Shaw, Nancy. Where did all the weeds go? Great Basin Native Plant Selection and Increase Project Annual Meeting. March 31, 2009; Boise, ID.

Shock, Clinton C.; Feibert, Erik; Ishida, Joey. Native forb research: Irrigation and weed control. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Field demonstrations.

Shock, Clinton C.; Shock, Cedric A.; Plummer, Sam. Mid-Snake River watershed vegetation database. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Shock, Clinton C.; Feibert, Erik B.G.; Saunders, Lamont D.; Shaw, Nancy L.; Mohan, S. Krishna; Sampangi, Ram K. Desert Parsley (*Lomatium* spp.) seed production challenges. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Shock, Clinton C.; Feibert, Erik B.G.; Saunders, Lamont D.; Shaw, Nancy L.; Mohan, S. Krishna; Sampangi, Ram K. Irrigation and mechanization for seed production of Sulfur-flower Buckwheat, a native forb. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Shock, Clinton C.; Feibert, Erik B.G.; Saunders, Lamont D.; Shaw, Nancy L.; Mohan, S. Krishna; Sampangi, Ram K. Sharpleaf and Sagebrush Penstemon seed yield response to irrigation. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Project Title: Native Perennial Forb Tolerance to Four Years of Repeated Annual Applications of Postemergence Herbicides

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

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Project Description:

The plant species planted in this trial are native to Malheur County and surrounding areas. These species are judged by the BLM and US Forest Service to be important rangeland restoration species for wildlife and other beneficial characteristics. Seed of native forbs 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 often not competitive with these weeds in a seed production setting. 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 field trials reported here tested the tolerance of seven native forb species to conventional postemergence herbicides over four successive years. During the last two years (2008 and 2009) the application dates were earlier than the first two years.
This work seeks to discover products that could eventually be registered for use in 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 a recommendation for the application of any of these herbicides. *Pesticide labels should always be consulted before any pesticide use. Considerable efforts may be required to register these herbicides for use for native forb seed production.*

Materials and Methods

Plant Establishment

Seed of seven Great Basin forb species (Table 1) received in October 2005 was planted November 1, 2005. The field had been disked, ground hogged and marked 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. 2007a) and varied by species. The crop preceding forbs was wheat. Prior to planting, one drip tape was inserted 12 inches deep every 5 feet, equidistant between where pairs of rows were planted. The drip tape was supplied with irrigation water using filtration and other common drip-irrigation practices (Shock 2006).

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, Owyhee Co., ID	2004
Penstemon acuminatus	Sharpleaf or sand-dune penstemon	Bliss Dam, Elmore Co., ID	2004
Penstemon deustus	Scabland or hot-rock penstemon	Blacks Cr. Rd., Elmore Co., ID	2003
Penstemon speciosus	Royal or sagebrush penstemon	Leslie Gulch, Malheur Co., OR	2003
Lomatium dissectum	Fernleaf biscuitroot	Mann Creek, Washington Co., ID	2003
Lomatium triternatum	Nineleaf biscuitroot or nineleaf desert parsley	Hwy 395, Lake Co., OR	2004
Lomatium grayi	Gray's biscuitroot or Gray's lomatium	Weiser R. Rd., Washington Co., ID	2004

2006 Postemergence Treatments

The lower 200 ft of the field was staked out to make 5-ft-wide plots perpendicular to the forb rows, crossing all seven species. Eight treatments including the untreated check were replicated four times in a randomized complete block design (Table 2). 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 with significant plant injury (Shock et al. 2007b).

In 2006 the trial was irrigated very little 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.

Table 2. Yield of two native forbs in response to postemergence herbicides applied on March 20, 2009, Malheur Experiment Station, Oregon State University, Ontario, OR. This was the third consecutive year these forbs received the same herbicide treatments.

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

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

2007 Postemergence Treatments

The same treatments as in 2006 were applied again to the same plots on April 24, 2007. The application specifications of 2006 were used in 2007. Plant injury was rated visually on May 1, May 11, May 25 and June 12 (Shock et al. 2008).

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

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

2008 Postemergence Treatments

The same treatments as in 2006 were applied again to the same plots on March 13, 2008 (Shock et al. 2009). The same application specifications as in 2006 were used again in 2008, but the application date was 72 and 42 days earlier than 2006 and 2007, respectively.

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

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

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

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

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

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

2008 Postemergence Treatments
Symptoms of herbicide injury were not observed on any of the plants in 2008 (Shock et al. 2009). All treatments were applied earlier in 2008 (March 12) than in 2006 (May 24) or 2007 (April 24) (Shock et al. 2007b and 2008). The earlier application in 2008 occurred before many of the forb species broke dormancy, with the exception of the *Lomatiums*. The *Lomatiums* were observed breaking dormancy around February 29. In 2007, the treatments were applied when all the forbs were actively growing and herbicide damage was associated with the foliar-active herbicides. The timing of future applications should be based on the mode of action of each herbicide: early applications for the soil-active herbicides (before weeds emerge) and later applications for the foliar-active herbicides (after weeds emerge). Later applications of the foliar-active herbicides might have resulted in foliar damage to the forbs as was observed in 2007.

Although the seed yields were based on very small harvest areas, seed yields were substantial for the five species with prolific flowering in 2008. There was no significant difference in seed yield between the reapplied herbicide treatments and the check for *Eriogonum umbellatum, Penstemon acuminatus, P. deustus* and *P. speciosus* in 2008. For *Lomatium triternatum,* seed yield was reduced for the Buctril® treatment, despite the early application timing. The *Lomatium* spp. break dormancy early in the growing season, and *L. triternatum* could have been susceptible at the March 13 application date. Buctril that had been applied later in 2007 also reduced seed yield of *L. triternatum* that year.

2009 Postemergence Treatments
Following the March 20 application, no symptoms of herbicide injury were observed in 2009. Root rot caused severe damage to plant stands of *Penstemon acuminatus* and *Penstemon speciosus*. *Penstemon deustus, Lomatium triternatum* and *Eriogonum umbellatum* produced very little seed in 2009. *Lomatium dissectum* and *Lomatium grayi* produced seed in 2009 and there were no significant difference in forb seed yield between any of the applied herbicide treatments and the check (Table 2).

<u>Summary</u>
All the herbicides tested showed promise for seed production of most of the native species tested in these trials. Phytotoxic symptoms were observed in 2006 and 2007, but symptoms were not observed in 2008 and 2009 with earlier applications.

All seven species tested were tolerant to Prowl® and Outlook® applied as postemergence treatments at the rate, timing and soils used in these trials. All species were also tolerant to postemergence applications of Select® at the rate, timing and soils used in these trials. Prowl and Outlook are broad-spectrum, soil-active herbicides that 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 native species. Further tests are warranted to describe the range of safety for these herbicides and whether or not they have any undesirable interactions.

<u>Literature Cited</u>
Shock, Clinton C. 2006. Drip irrigation: an introduction. Sustainable Agriculture Techniques, Oregon State University Extension Service. EM8782-E, revised October 2006.

Shock, Clinton C.; Feibert, Erik B.G.; Saunders, Lamont D.; Shaw, Nancy; DeBolt, Ann. 2007a. 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.

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

Shock, Clinton C.; Ishida, Joey; Feibert, Erik B.G. 2008. Native wildflowers grown for seed production show tolerance to conventional postemergence herbicides. Oregon State University Agricultural Experiment Station, Special Report. 1087: 197-203.

Shock, Clinton C.; Ishida, Joey; Feibert, Erik B.G.; Shaw, Nancy. 2009. Native perennial forb tolerance to repeated annual applications of postemergence herbicides. Oregon State University Agricultural Experiment Station, Special Report. 1094: 180-184.

Presentations:
Shock, Clinton C.; Feibert, Erik; Saunders, Lamont; Shaw, Nancy. Do these plants need water? Great Basin Native Plant Selection and Increase Project Annual Meeting. March 31, 2009; Boise, ID.

Shock, Clinton C.; Feibert, Erik; Saunders, Lamont; Shaw, Nancy. Where did all the weeds go? Great Basin Native Plant Selection and Increase Project Annual Meeting. March 31, 2009; Boise, ID.

Shock, Clinton C.; Feibert, Erik; Ishida, Joey. Native forb research: Irrigation and weed control. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Field demonstrations.

Shock, Clinton C.; Shock, Cedric A.; Plummer, Sam. Mid-Snake River watershed vegetation database. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Shock, Clinton C.; Feibert, Erik B.G.; Saunders, Lamont D.; Shaw, Nancy L.; Mohan, S. Krishna; Sampangi, Ram K. Desert Parsley (*Lomatium* spp.) seed production challenges. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Shock, Clinton C.; Feibert, Erik B.G.; Saunders, Lamont D.; Shaw, Nancy L.; Mohan, S. Krishna; Sampangi, Ram K. Irrigation and mechanization for seed production of Sulfur-flower Buckwheat, a native forb. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Shock, Clinton C.; Feibert, Erik B.G.; Saunders, Lamont D.; Shaw, Nancy L.; Mohan, S. Krishna; Sampangi, Ram K. Sharpleaf and Sagebrush Penstemon seed yield response to irrigation. Developing a Successful Native Plant Program. April 1-2, 2009; Ontario, OR. Poster.

Project Title: Characterization of Seed Germination Requirements for Improved Direct-seeding Success in a Changing Climate

Project Location: University of Idaho, Moscow, Idaho

Principal Investigator and Contact Information:

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Project Description:

The objectives of this study are to increase our understanding of the germination requirements of two common native plants found in the Great Basin. Once germination is better understood, that information will be used to a) assess the early competitive ability of those species and b) identify potential management outcomes (such as pelletizing seed for field application) which would improve restoration success. Funding was received in March 2009. A graduate student, Emily Overton, was recruited to conduct this work, starting in August 2009. She has been working on a literature review and will be beginning controlled-environment studies with *Artemisia tridentata* in spring 2010. Olga Kildisheva, a Master's student, will be working with the *Sphaeralcea munroana* component of this project.

Products:

We are currently working on optimizing a seed treatment protocol and container seedling production protocol for *Sphaeralcea munroana*.

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

Presentations:

Davis, Anthony S.; Herriman, Kayla R.; Dumroese, R. Kasten. Container production of Wyoming big sagebrush for Great Basin restoration: greenhouse and field effects. Great Basin Native Plant Selection and Increase Project Annual meeting. March 31, 2009; Boise, ID.

Publications:

Herriman, KR. 2009. Wyoming big sagebrush: efforts towards development of target plants for restoration. Moscow, ID: University of Idaho. 70 p. Thesis.
http://www.treesearch.fs.fed.us/pubs/33481

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

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

Principal Investigators and Contact Information:

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

Management Applications: How can land managers, seed producers or others use the results?

Products:
Seed Moisture
The relative humidity that a seed equilibrates with can be measured and used to determine if the seed's moisture condition is good for preserving seed viability in storage. Traditionally this was done by oven drying methods and, when possible, electronic meters that were calibrated with oven moisture content measurements on clean seeds. 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. Seed workers will be

easily and accurately able to assess seed moisture in any stage of handling the seed in order to preserve its viability.

Prechill Requirements were explored for *Achnatherum hymenoides*, *Penstemon acuminatus, P. deustus* and *P. speciosus*. Chilling for up to 60 days produced little or no germination. Therefore, dormancy is clearly very deep in all these species and likely variable among seeds within a single seed lot. In the coming year, longer chilling periods will be tried, and in conjunction with scarification, artificial aging and repeated cycles of warn and cold temperatures. Use of these species for restoration might be limited until workable dormancy breaking procedures are determined.

Seed storage

Wyoming big sagebrush seed lots stored in sealed 6mil poly bags or foil laminated bags were tested for germination after 29 months of storage. These bags are moisture proof and will maintain the initial ERH for the seeds. The results are summarized in Figure 1. The highest viabilities were maintained using -20^{o}C, 30% ERH and foil laminate bags. Little loss of viability was observed when storing seeds under these conditions. Cleaning the seeds to high purity also appears to be beneficial to preserving viability in sealed moisture proof bags. Only at the driest and coldest treatment was a useful amount of germination preserved in low purity seed lots.

Wyoming big sagebrush seed usually dies after a few years when using conventional warehouse storage methods, but this study appears to be indicating that the seed of this species, after drying to an ERH of 30%, might store long term in moisture proof containers at -20^{o}C. As this species is being reduced in range and abundance by wildfires of the recent decades, long term seed storage could be a solution for preserving seeds for post fire restoration and genetic preservation. Many seed sources could be stored in a relatively small freezer space if cleaned to high purities.

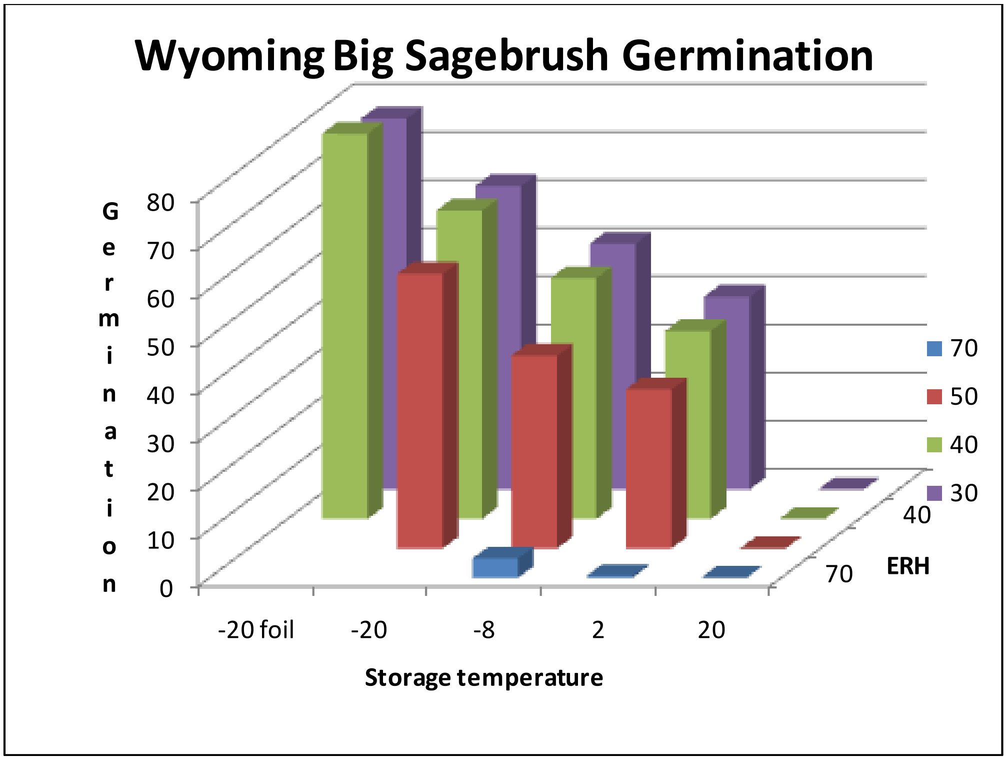

Figure 1. Average germination for five lots of Wyoming big sagebrush seed after 29 months of storage at 17 ERH (equilibrium relative humidity)-temperature combinations in 6mil poly bags or foil laminate bags.

Presentations:

A report on Wyoming big sagebrush seed storage 15 month data was given at the Western Forest and Conservation Nursery Association meeting in Moscow ID July 14 – 16, 2009.

Karrfalt, Bob. Developing Seed Technologies. Great Basin Native Plant Selection and Increase Project Annual Meeting. March 31, 2009; Boise, ID.

Karrfalt, Bob. Using Equilibrium Relative Humidity (ERH) as a Guide in Storing Native Plant Seeds. Developing a Successful Native Plant Program Workshop, April 1-2, 2009; Ontario, OR. Poster.

Karrfalt, Bob; Shaw, Nancy. Long term storage for Wyoming big sagebrush. Developing a Successful Native Plant Program Workshop, April 1-2, 2009; Ontario, OR. Poster.

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

Project Location: Department of Biology, Boise State University, Boise, ID

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Project Description:
One of the objectives of the proposal was to investigate the effect of plant growth regulators on embryo growth and germination of *L. dissectum* seeds. The hormone treatments tested did not replace the requirement for cold stratification nor did they promote embryo growth under cold conditions. On the contrary, application of gibberellic acid at 3 mM reduced embryo growth under cold conditions and increased the cold period required for germination (Scholten and others 2009).

A second major goal of the grant was to compare the stratification requirements of different seed populations. We studied eight different populations, four populations of *L. dissectum* var. *dissectum* and four populations of *L. dissectum* var. *multifidum*. Seeds of var. *dissectum* were collected from moist sites in the Willamette Valley, Oregon, while those of var. *multifidum* were from semiarid environments in eastern Oregon and southwest Idaho. Overall, *L. dissectum* var. *dissectum* seeds had longer cold stratification requirements than those of *L. dissectum var. multifidum* (Scholten and others 2009). At present, it is not clear whether these differences reflect genetic differences between the populations and/or differences in environmental conditions during seed development. Independent of the factors involved, the shorter stratification requirements for seeds from the drier sites may provide an ecological advantage. Seeds of variety *multifidum* were from sites where the growing season is relatively short due to the dry summer conditions. For these seeds, the shorter stratification results in early germination, which extends the growth period allowing the seedlings to photosynthesize and accumulate reserves until the dry summer.

In addition, to investigate the cold stratification requirements of different seeds populations, we have analyzed possible variations in stratification requirements between seeds collected at one location in different years. This analysis was conducted with var. *multifidum* seeds collected in 2005 and 2007 at Harper, OR. In both the greenhouse and field experiments, the 2005 seeds required more hours of stratification than the 2007 seeds (Fig. 1). Seeds were collected from the same population; consequently, it is unlikely that the differences were attributed to genetic variability among the seeds. Also from the time of harvest to the initiation of the experiments, the seeds were in storage for approximately the same period, suggesting that differences in the degree of dormancy cannot be attributed to disparity in the age of the seeds. The difference in stratification requirements may reflect differences in environmental conditions during seed development, which can alter the degree of seed dormancy. Precipitation data from weather stations within a 50 km distance from the collection site (Vale-OR 43º 59' N, 117º 15 W; West Fall-OR 43º 59' N, 117º 47' W and Owyhee Dam-OR 43º 39' N, 117º 15' W) indicates that at the time of seed development, May and June, the precipitation was higher in 2005 than in 2007, 78.2 ± 25 and 27.2 ± 10 mm, respectively (Oregon Climate Service). In species from various families, water deficits during seed development result in less dormant seeds. Perhaps, this phenomenon also occurs in *L. dissectum*. Under this scenario, the seeds that developed during the spring of 2007 would require less stratification than those that developed during the moister spring of 2005, which would account for the results observed.

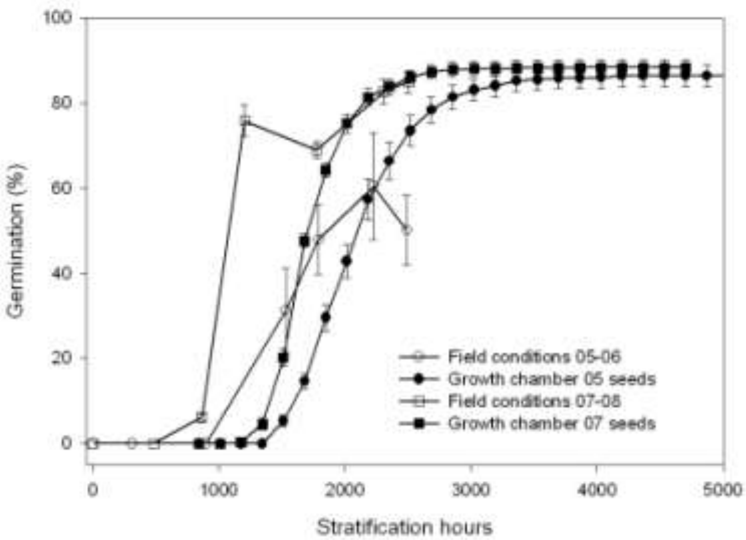

Figure 1. Relationship between stratification hours and germination under field and growth chamber conditions. (○) Field conditions 05-06; (●) growth chamber 05 seeds; (□) field conditions 07-08; (■) growth chamber 07 seeds. The stratification hours under field conditions were estimated from hourly measurements of soil temperature assuming that stratification occurred at temperatures between 0 and 10 °C. Mean ± s.e. of ten replications with 50 to 60 seeds per replication.

In addition to the experiments described above, we are currently conducting two related studies. One is aimed at characterizing changes in the physiology of the embryo during cold stratification and the second is intended to analyze the degree of genetic differences among and within the eight populations studied. For the first project, we have investigated the desiccation tolerance of embryos after various lengths of cold stratification. Our results indicate that at late stages of embryo growth within the seeds the embryos lose their desiccation tolerance (Fig. 2). We are presently investigating the extent to which the surviving seeds enter secondary dormancy. For the second project, we have placed in stratification seeds from 30 different plants from each of the eight populations. The seedlings will be used to study genetic diversity by allozyme electrophoresis as described in the proposal.

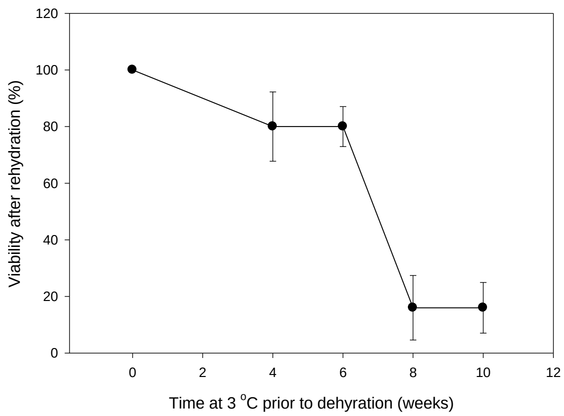

Figure 2. Effect of dehydration on seeds exposed to cold stratification at 3 °C for various times. After cold stratification for the indicated periods, seeds were dehydrated to 8% water content and kept at room temperature for eight weeks. The seeds were then rewatered and viability determined by the tetrazolium test. Values represent mean ± s.d. of five replications with ten seeds per replication.

Publication:

Scholten, Melissa; Donahue, J.; Shaw, Nancy L.; Serpe, Marcelo D. 2009 Environmental regulation of dormancy loss in *Lomatium dissectum* (Apiaceae) seeds. Annals of Botany. 103: 1091-1101.

Presentation:

Serpe, Marcelo D. 2009. Factors affecting *Lomatium dissectum* seed germination and seedling establishment. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2009, March 31; Boise, ID.

Project Title: Modeling Seedling Root Growth of Great Basin Species

Project Location: Brigham Young University, Provo, UT

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

<u>Objectives</u>

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

<u>Growth Chamber Study</u>

We are measuring seedling root depths over time for six forbs, five perennial grasses and two cheatgrass collections (Table 1) in relation to constant temperatures in a walk-in growth chamber. The experiment is organized in a randomized block design of four blocks and two soils in a walk-in growth chamber. Black plexiglass holders have been constructed to hold 65 (5 replicates x 13 collections) clear plastic root tubes 2.9-cm diameter by 20-cm long. Each block contains two plexiglass holders, one with tubes filled with sand and the other with tubes filled with Borvant gravelly loam soil passed through a 0.6 cm screen. The holders keep the tubes slanted at at a 45° angle and exclude light from roots. For each of six constant temperature runs (5, 10, 15, 20, 25 and 30° C), three seeds of a collection are sown 0.5 cm below the soil surface against the lower side of a planting tube. Prior to sowing, *Astragalus utahensis* seeds were scarified in sulfuric acid for 15 minutes followed by stratification at 1.5° C for two weeks with *Elymus elymoides* seeds. Tubes are checked six days per week and the depth of the deepest root is recorded. Time to germination is recorded in petri dishes filled with 25 seeds of each collection and placed on racks below the root experiment in the incubation chamber. Soil temperatures are measured by thermocouples placed in one root tube per soil per block and attached to a Campbell Scientific, Inc. CR10X micrologger. Temperatures are read each minute with average hourly temperatures recorded. At the end of each temperature run, one tube of each collection per block is harvested and dry weight of root biomass recorded. The entire experiment will also be conducted at three diurnal temperatures based on cold, cool and warm soil temperatures recorded in the field. We will compare actual with root depths predicted from thermal accumulation models.

Table 1. Plant materials tested in root study.

	Scientific name	**Common name**	**Cultivar**	**Source**	**Collection date**
Forbs	*Achillea millefolium*	Eagle yarrow	Eagle	Eastern WA	2003
	Achillea millefolium	White yarrow	White-VNS	Granite Seed	2003
	Agoseris heterophylla	Annual agoseris		USFS Shrub lab	2007
	Astragalus utahensis	Utah milkvetch		USFS Shrub lab	2002
	Linum perenne	Blue flax	Appar	UDWR	2003
	Lupinus arbustus	Longspur lupine		Wells, NV; UDWR	2004
Perennial grasses	*Agropyron cristatum x A. desertorum*	Crested wheatgrass	Hycrest	UDWR	2003
	Agropyron desertorum	Crested wheatgrass	Nordan	Granite Seed	2003
	Elymus elymoides	Squirreltail	Sanpete	UDWR	2003
	Elymus wawaiensis	Snake River wheatgrass		WA; Granite Seed	2003
	Pseudoroegneria spicata ssp. *spicata*	Bluebunch wheatgrass	Anatone	Granite Seed	2003
Weedy grasses	*Bromus tectorum*	Cheatgrass		Rush Valley, UT	2005
	Bromus tectorum	Cheatgrass		Skull Valley, UT	2005/2006

Field Experiment

The same experiment as described above is being conducted at two locations in Utah 1) on the Brigham Young University campus, and 2) on the east side of the Onaqui Mountains in a Utah juniper/Wyoming big sagebrush plant community where the juniper trees have been shredded. In the field experiment, tubes are watered after initial sowing in the fall and then are not watered thereafter. Emergence and root depth are recorded 1-3 times per week at the BYU campus and monthly at the Onaqui site. Thermocouples and gypsum blocks are placed in each block in the field outside root tubes, but inside soil or sand surrounding tubes. These sensors are read every minute and hourly averages are recorded with Campbell Scientific, Inc. CR10X microloggers.

Modeling

We will model time to root depth as a function of degree days for each temperature, as we have done for time to a germination percentage (Roundy et al. 2007, Rawlins 2009). We will then compare predicted and actual time to a root depth based on soil temperatures from our diurnally-fluctuating growth chamber and field experiments. We will also input soil temperatures and soil water potentials from a number of SageSTEP and other field sites to predict root growth and seedling survival under a range of field conditions.

Project Status:

Growth Chamber Experiment

We have conducted 5 of the 6 constant temperature runs and are currently running the remaining constant temperature, 10 ° C. That temperature is an important one because we have found that time to a root depth decreases most between 5 and 15 ° C, with much less variation in heat accumulation for different temperatures > 15 ° C (Figures 1 and 2). Although roots grew slowly at 5 ° C, most grass collections did not require more degree days at that temperature to reach 15 cm depth than higher temperatures (Figures 1 and 2). Forb roots grew best at 15-20 ° C, while grass roots grew well at 15 to 30 ° C (Figures 1 and 2). Forb roots were sensitive to increasing temperatures and required more degree days at temperatures above 20 ° C to reach 15-cm root depth. Grass roots were generally less sensitive to temperature and had generally similar degree day requirements to reach 15-cm root depth at all temperatures. This suggests that the forbs are most likely to establish during early spring, while grasses are able to establish under early spring or late spring temperatures, as long as soil moisture is available.

Grasses were more robust and less variable in growth and survival than the forbs. Because many of the forbs grew slowly or died, we show data for the ones that did grow well in Figures 1 and 2. Figure 3 shows the number of root tubes out of 20 with actively-growing plants and indicates that the forbs did not grow well at warmer temperatures, while most of the grasses did. That forbs in some tubes grew much better than others indicates potential for plant selection programs to develop more robust seedlings of these forbs.

As expected, cheatgrass roots grew the fastest at cool temperatures. However, the crested wheatgrasses and Anatone bluebunch wheatgrass definitely grew well enough to compete with cheatgrass (Figures 1 and 2). The importance of faster root growth to establishment is suggested by comparing the heat accumulation requirement of the forbs and that of the grasses. Forbs are known to not establish as well as grasses in rangeland revegetation projects. Blue flax, one of the most successfully-seeded forbs requires about 400-900 degree days to reach 15 cm root depth, while Anatone bluebunch wheatgrass requires 250-400 (Figure 2). SageSTEP data from four Great Basin pinyon-juniper locations for two years were used to calculate wet degree days in spring 2008 and 2009. Degree day accumulations when the soil is wet ranged from around

300 in early spring (March and April) to around 700 in late spring (May and June). As long as soil moisture is available from March into June, robust plants of both forbs and grasses should establish because they will have around 1000 wet degree hours for root growth. However, if soil moisture becomes unavailable by May in a dry year, even robust forbs might not establish because they may have insufficient wet degree hours to grow their roots and keep them below the soil drying front. The details of just how many wet degree hours are available under different field conditions in relation to how many are needed for successful establishment will become better understood with specific modeling exercises and field validation tests.

What appears to be a major concern for successful establishment of forbs is the lack of robust plants (Figure 3). Occurrence of some vigorous forb plants indicates potential for plant improvement. Such plant improvement work could potentially increase forb establishment success.

Field Experiments

We have also conducted two field experiments but had some problems with frost-heaving of root tubes. We hope to have solved that problem and have installed the field experiments again in fall 2009 for the two sites. We will record data from them in spring 2010.

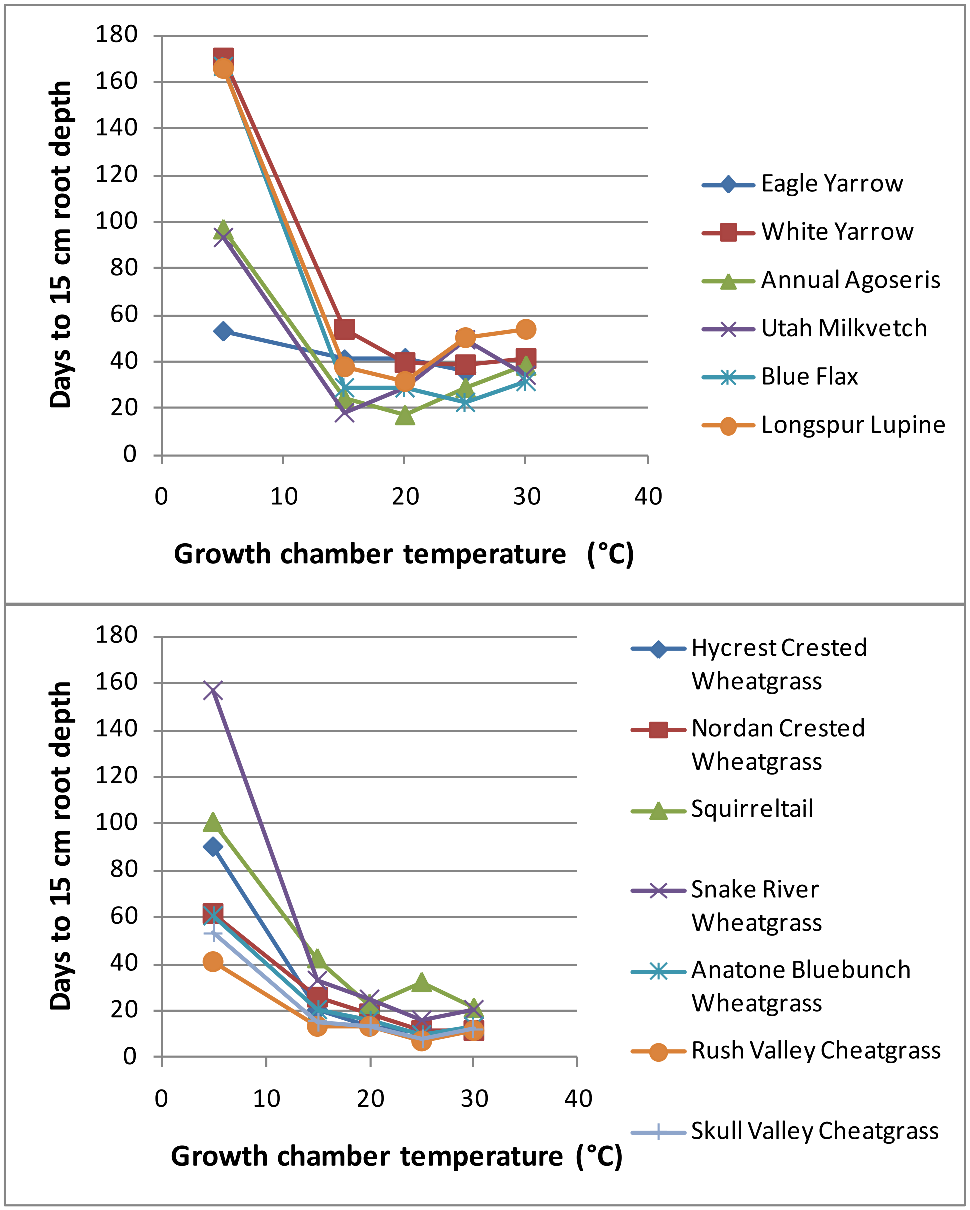

Figure 1. Days for seedling roots of forbs (above) and grasses (below) to reach 15 cm depth for a constant temperature in the growth chamber.

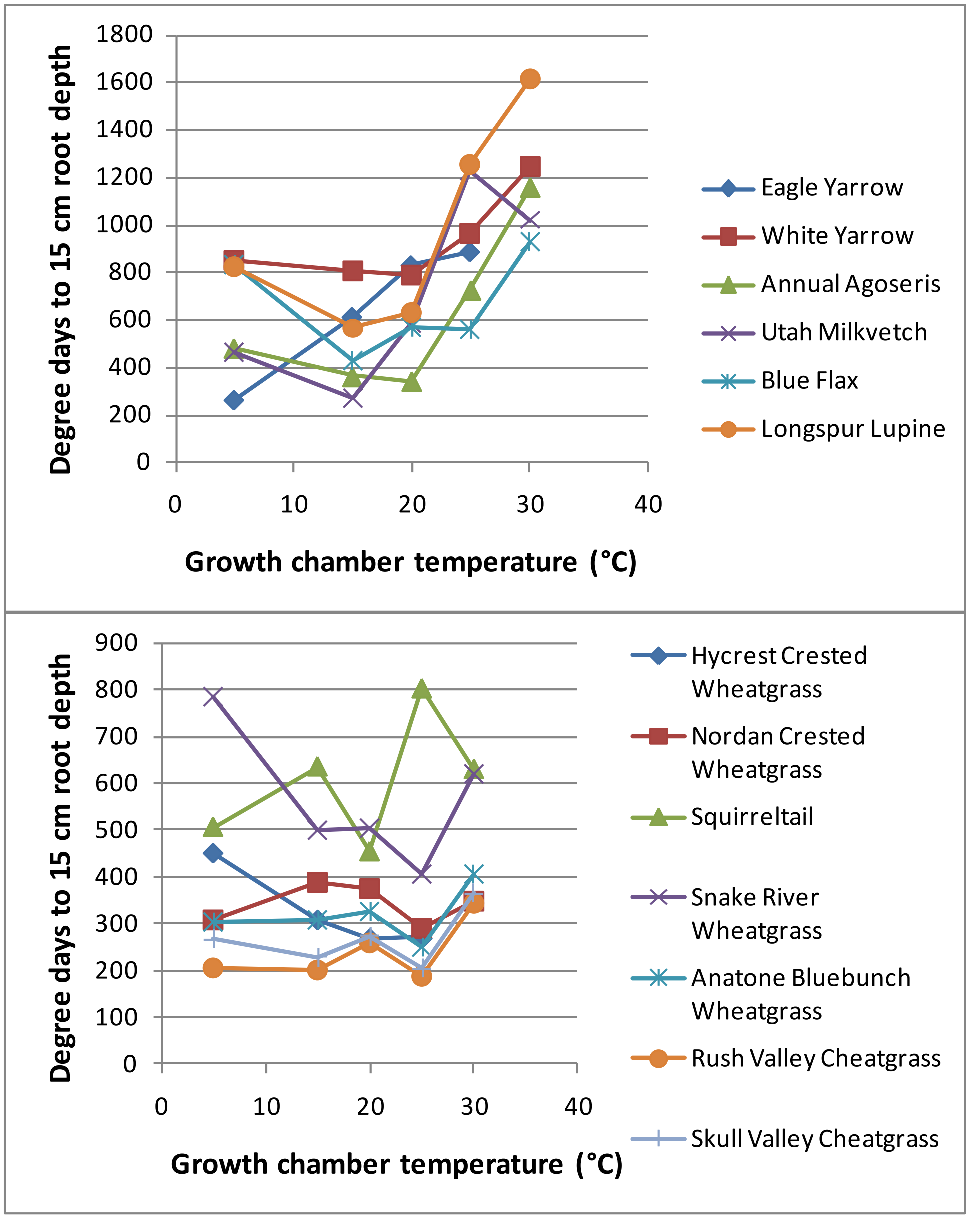

Figure 2. Degree days for seedling roots of forbs (above) and grasses (below) to reach 15 cm depth for a constant temperature in the growth chamber.

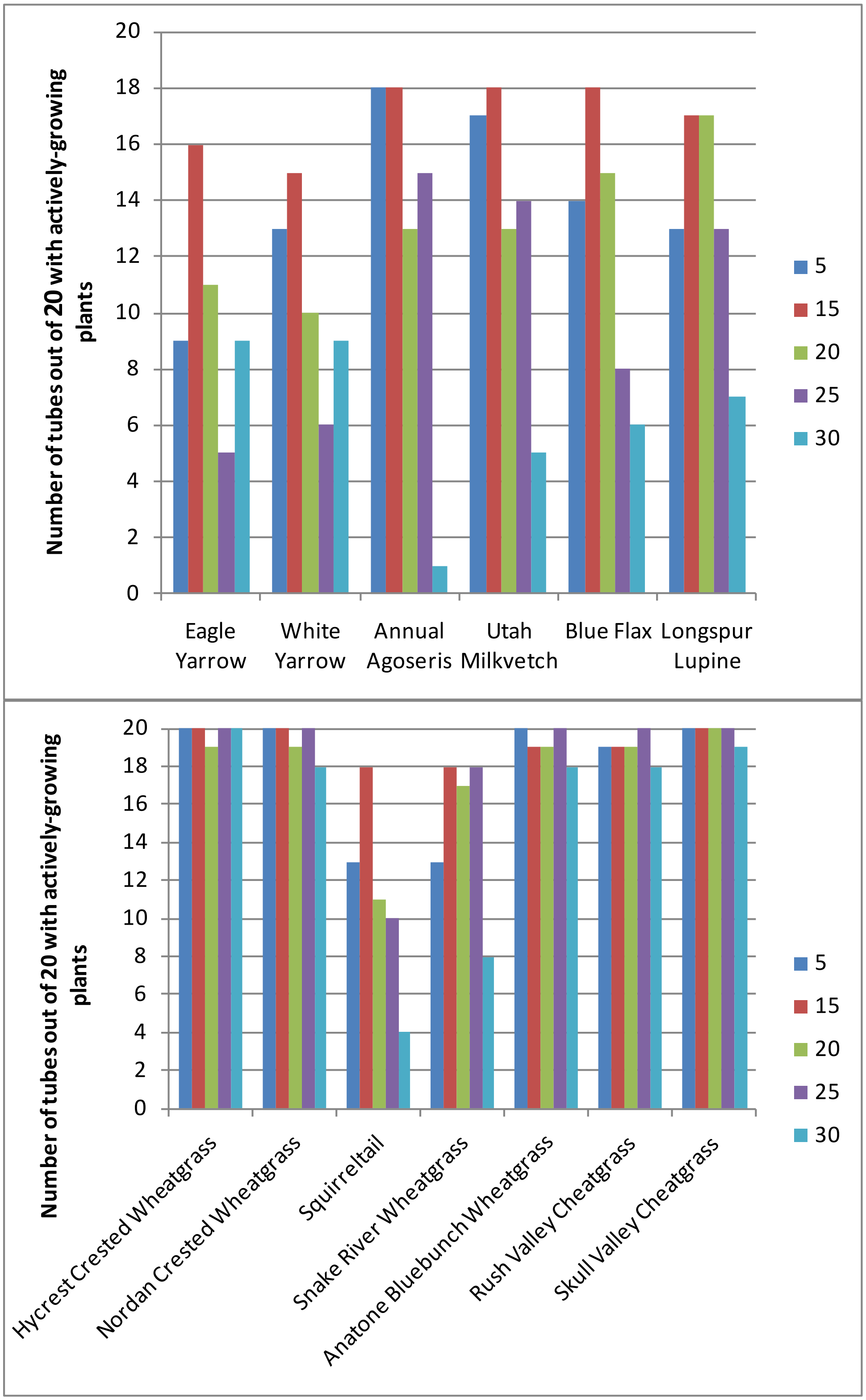

Figure 3. Number of root tubes out of 20 with actively-growing plants for forbs (above) and grasses (below) in relation to different growth chamber temperatures.

Future Work

We will finish the 10 ° C constant temperature experiment and conduct the three diurnal temperature experiments in the growth chamber. We will begin developing heat accumulation models for each collection and record data from the two field experiments. We will begin comparing predicted and actual root depths based on measured soil temperatures and water potentials at the field sites.

Literature Cited

Meyer, S. E.; Allen, P. S. 2009. Predicting seed dormancy loss and germination timing for *Bromus tectorum* in a semi-arid environment using hydrothermal time models. Seed Science Research. 19: 225-239.

Rawlins, J. K. 2009. Wet thermal accumulation modeling of germination of western U.S. rangeland species. MS Thesis, Brigham Young University, Provo, UT. 48 p.

Roundy, Bruce A.; Hardegree, Stuart P.; Chambers, J. C.; Whittaker A. 2007. Prediction of cheatgrass field germination using wet thermal accumulation. Rangeland Ecology and Management. 60: 613-623.

Management Applications:

We hope to eventually predict potential seedling survival of revegetation and weed species for the Great Basin using the thermal models we are developing. This will allow us to rate different plant materials for potential establishment on different soils, regions, and yearly weather conditions. An additional side benefit of this research is to indicate which species may warrant plant improvement work to improve establishment characteristics.

Publications:

Hulet, A. 2009. Diversification of crested wheatgrass stands in Utah. Provo, UT: Brigham Young University. 43 p. Thesis. http://www.treesearch.fs.fed.us/pubs/33480

Johnson, RL. 2008. Impacts of habitat alterations and predispersal seed predation on the reproductive success of Great Basin forbs. Provo, UT: Brigham Young University. 114 p. Dissertation. http://www.treesearch.fs.fed.us/pubs/33483

Rawlins, JK. 2009. Wet thermal accumulation modeling of germination of western U.S. rangeland species. Provo, UT: Brigham Young University. 61 p. Thesis. http://www.treesearch.fs.fed.us/pubs/33478

Project Title: Investigations of Seed and Seedling Ecology and Competitive Ability of Native Annual Forbs of the Western Great Basin

Project Location: Exotic and Invasive Weeds Research Unit, Agricultural Research Service, USDA, Reno, NV

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Project Description:
Investigation of (1) the potential for Great Basin native annual forbs to effectively compete with cheatgrass and (2) the relative establishment success of native perennial grasses in native annual forbs vs. in cheatgrass. The ultimate goal of this work is to determine whether it would be useful to include native annuals in postfire rehabilitation seed mixes.

Germination Phenology of Great Basin Native Annual Forbs

Species Selection and Objectives
Great Basin native annual species with the ability to germinate in the fall would be more likely to occupy a niche similar to that of cheatgrass. Species that germinate in the fall, with cheatgrass, are able to accumulate biomass and establish roots that might provide a competitive advantage relative to spring germinators. Thus for this study, native annual species that I observed to be part of the post-disturbance flora in Wyoming sagebrush (*Artemisia tridentata* var.*wyomingensis*) plant communities in western Nevada and that produced seed in 2007 and/or 2008 were selected. These species included *Amsinckia menziesii* var. *intermedia* (Boraginaceae), *Amsinckia tesselata* (Boraginaceae), *Blepharipappus scaber* (Asteraceae), *Descurainia pinnata* (Brassicaceae), *Eriastrum sparsiflorum* (Polemoniaceae), *Lappula occidentalis* (Boraginaceae), *Mentzelia veatchiana* (Loasaceae), and *Plagiobothrys tenellus* (Boraginaceae)

To my knowledge, none of these species have been formally assessed for germination requirements to date. With the goal of identifying species that may have a germination phenology similar to that of cheatgrass, I screened these eight species to determine whether they exhibit dormancy, and if so, whether it is broken by dry after-ripening, as would be expected for obligate and facultative winter annuals, or if it is broken by cold stratification, as would be expected for spring annuals.

Methods
Ripe seeds were collected as shown in Table 1 and stored at room temperature until experiments commenced. All lots from an individual site were mixtures of seeds from at least 20, usually more, maternal plants. All seed lots were assessed for viability using a tetrazolium test. For each species, four samples of 50 seeds were soaked in deionized water overnight. Next, seeds were pierced and soaked overnight in a solution of 1% 2,3,5-triphenyl tetrazolium chloride. Last, embryos were assessed for staining.

Next, seeds were checked for dormancy and light responsiveness using a 4-week germination test in Petri dishes. For each species, four replicate dishes of 25 seeds each were placed in fluorescent light, and four in the dark (wrapped in aluminum foil) in a Percival growth chamber under a constant 20 ºC. The seeds were placed on a moistened blue germination blotter. Tap water was added to the blotters as needed to maintain moisture during the experiment. Germinated seeds were counted and removed from the dishes weekly. Seeds were considered germinated if the radicle was visible. Seeds in the dark treatment were checked under a green "safe" light (Baskin and Baskin 2001).

Seeds were also tested for responsiveness to dry after-ripening and cold stratification. The dry after-ripening treatment consisted of subjecting four replicates of 25 seeds per species to storage in sealed glass jars in a 40ºC incubator for four weeks. At the end of each week, six seeds per dish were checked for dormancy by placing them on wet filter paper in a 20ºC incubator for one week. For the cold stratification treatment, four replicates of 25 seeds each were placed in Petri dishes with wet filter paper at 2ºC for up to eight weeks and checked for germination weekly by moving six seeds to a new dish in the 20ºC incubator for one week. Eight weeks was used as the stratification period because seeds from these low elevation sites in the western Great Basin do not experience long periods under snow, or months below freezing temperatures. Viability testing was done on these seed lots during March of 2009. Germination experiments were conducted from 20 July 2008 to 30 August 2008.

There is an exception to the above for *M. veatchiana*, two *Amsinckia* species and *B. scaber*, which were collected (Table 1) and tested for viability (December 2008) and germination (12 March 2009 through 3 April 2009) at a later date than the other species. For these species, each dish contained 50 seeds, and 10 seeds were taken out of after-ripening and cold stratification treatments per dish each week. More seeds were used in this experiment because more were available from these seed lots than from the lots used in the earlier experiment. For the *D. pinnata* in the cold stratification treatment, the experiment was terminated after three weeks due to accidental loss of seed dishes.

At the end of the experiment, germination percentage was calculated using the number of viable seeds as follows:

germination percentage = (# germinated seeds/# viable seeds) * 100 Eq. 1

Percent of viable seeds germinating per dish was rank transformed and used as the response variable in a GLM analysis (PROC GLM, SAS 9.0). Species were analyzed separately and treatment was the predictor in each analysis. Treatments were compared by species using least square means with a Bonferroni adjustment.

Germination rate data were calculated as the percent of germinants per dish per week, adjusted using viability numbers. Rather than looking at an index of rate (for example, calculated as time to 50% germination per dish, which does not take dishes with no germinants into account) I analyzed this data using germination curves.

Results

All germination percentages represent the percent of viable seed germinating based on the tetrazolium tests. Error estimates reported represent one standard deviation.

Because the light and dark constant temperature treatments were intended to be a dormancy check as well as a test for light responsiveness, germination percentage under the light treatment is assumed to indicate the level of dormancy at the time of germination testing (i.e. either after some months of dry storage or under fresh conditions). The exception to this is when germination is significantly higher under the dark treatment, in which case germination in the dark is used as the baseline. Therefore, the results of the stratification and after-ripening treatments are compared to these baseline levels of dormancy.

Amsinckia menziesii var. *intermedia*

This species showed moderate levels of dormancy after nine months of dry storage. Percentage of viable seeds germinating in the light treatment was 40.0±11.2% (Fig. 1). There was a strong light response (light vs. dark Bonferroni $P<0.05$) – only 1.7±3.3% germinated in the dark. *A. menziesii* var. *intermedia* did not respond to stratification (light vs. stratification Bonferroni

P>0.05) and after-ripening appeared to induce dormancy – germination percentage dropped to 13.9±7.5% in this treatment (light vs. after-ripening Bonferroni $P<0.05$; Fig. 1).

Only in the light treatment did germination continue to increase dramatically after the first week. Germination percentage in this treatment went from 8.3±8.0% after one week to 40.0±11.2% after 4 weeks (Fig. 2).

Amsinckia tesselata
This species was also somewhat dormant after nine months of dry storage. Percent of seeds germinating in the light treatment was 40.9±15.3% (Fig. 1). As with *A. menziesii* var. *intermedia*, there was a strong light response (light vs. dark Bonferroni $P<0.05$) – only 1.6±1.1% of the seeds germinated in the dark. There was no significant response to stratification (light vs. stratification Bonferroni $P>0.05$); however the mean was higher -- 67.5±20.0% of viable seeds germinated after chilling. The after-ripening treatment had no significant effect (light vs. after-ripening Bonferroni $P>0.05$; Fig. 1).

As with *A. menziesii* var. *intermedia*, it was only in the light treatment that germination continued to increase dramatically after the first week. Germination percentage in this treatment went from 9.4±5.1% after one week to 39.1±13.8% after four weeks (Fig. 2).

Blepharipappus scaber
This species was highly dormant after nine months of dry storage – there was no germination in either light or dark treatments. Eight weeks of cold stratification broke dormancy for a small (20.1±4.4) but significant (light vs. stratification Bonferroni $P<0.05$) percent of the seeds. None of the treatments applied allowed for more than 20% of viable seeds to germinate (Fig. 1).

For this species, germination did not increase from week one through week four in any treatment (Fig. 2).

Descurainia pinnata
This species had very low dormancy levels after 12 months of dry storage. Surprisingly, germination was higher in the dark (98.2±3.7%) than the light treatment (62.5±24.0%; dark vs. light Bonferroni $P<0.05$; Fig. 1). Neither the stratification (dark vs. stratification Bonferroni $P>0.05$) nor after-ripening (dark vs. after-ripening Bonferroni $P>0.05$) had a significant effect on dormancy levels relative to the dark treatment (Fig. 1).

Germination in week one was relatively high for two of the four treatments, the dark and stratification. In the other two treatments, germination increased substantially after the first week. For the light treatment, it went from 19.7±18.7% in week one to 62.5±24.1% in week four. In the after-ripening treatment, it went from 22.0±5.8% in week one to 94.9±8.0% in week four (Fig. 2).

Eriastrum sparsiflorum
This species was relatively dormant after 12 months of dry storage (23.1±2.5% germination in light; Fig. 1). It showed a strong response to the stratification treatment, with 100% of seeds germinating (light vs. stratification Bonferroni $P<0.05$). The after-ripening treatment did not

have a significant effect relative to the light treatment (light vs. after-ripening Bonferroni $P>0.05$; Fig. 1).

In this species, germination was below 25% in all treatments in week one, and only increased in the stratification treatment from 25±0% in week one to 100±0% in week four (Fig. 2).

Lappula occidentalis
This species was nondormant under every treatment regime and germination did not differ among regimes (GLM $F=3.08$, $P=0.0682$) (Table 2). After 12 months of dry storage, germination in the light treatment was 98.2±2.8%. Stratification and after-ripening neither increased nor decreased dormancy levels (Fig. 1).

Although all treatments achieved high germination percentages by week four, only the light treatment had high germination in week one. In the other treatments, germination was low in week one, but increased to high levels in week four (for example, in the stratification treatment, germination in week one was 21.3±5.6%, in week four it had increased to 88.5±8.5% (Fig. 2).

Mentzelia veatchiana
This species had very high levels of dormancy after nine months of storage. Germination in light and dark treatments did not differ (Bonferroni $P>0.05$); germination in light was 0%, in dark, 2.9±5.9%. After-ripening had no effect on dormancy, but stratification broke dormancy in a significant percent of the seeds (55.9±28.5%; light vs. stratification Bonferroni $P<0.05$).

Germination percentage in this species did not increase substantially over time in any treatment; the increase was greatest in the cold stratification treatment, where germination was 47.1±20.8% in week one and increased to 62.0±28.2% in week four (Fig. 2).

Plagiobothrys tenellus
Dormancy levels were relatively high after 12 months of dry storage. Germination percentage was 6.6±5.6% in the light treatment and did not differ significantly in the dark treatment (Bonferroni $P>0.05$). Both stratification and after-ripening increased germination percentage, with stratification resulting in 98.0±4.0% germination, significantly higher (Bonferroni $P<0.05$) than the 48.2±3.6% resulting from after-ripening (Fig. 1).

In *P. tenellus*, germination did not increase substantially after week one in the light or dark treatments. In the cold stratification treatment, germination increased from 26.3±0% in week one to 100±6.6% in week four. A smaller increase was seen over the same period in the after-ripening treatment (Fig. 2).

<u>Conclusion</u>
Winter annuals (facultative and obligate) would be expected to have no requirement for cold stratification (Baskin and Baskin, 2001). Species that clearly meet this criterion under the conditions of this lab study are *D. pinnata* and *L. occidentalis*. Species that had their highest germination after cold stratification would be expected to be spring germinators. This included *B. scaber, E. sparsiflorum, M. veatchiana* and *P. tenellus*.

Both of the potential fall germinators, *D. pinnata* and *L. occidentalis*, germinated to high percentages after a single week under at least one treatment; *D. pinnata* germinated to 75.2±9.5% in the dark and *L. occidentalis* germinated to 98.6±3.7% in the light.

Germination requirements are obviously not the only consideration for selecting species for restoration potential or potential competition with cheatgrass. Both *D. pinnata* and *L. occidentalis* occur in disturbed sites but neither has been observed to occur at high densities with cheatgrass. Such a pattern is difficult to interpret, however, as stands of these species might be excluding cheatgrass, or these species might be experiencing seed limitation in cheatgrass-dominated sites.

The species that do seem to co-occur with cheatgrass, *A. menziesii* var. *intermedia*, *A. tesselata*, and *M. veatcheana*, did not respond as winter annuals. However, seedlings of *A. menziesii* var. *intermedia* and *A. tesselata* have been observed in the fall, so either our after-ripening treatments did not meet the requirements of this species, or fall-germinating seeds were not dispersed in the current, but in the previous year. It is also not known whether these species can behave as winter annuals in some years and spring annuals in others, depending on the conditions of the year in which they were produced, or on other factors.

Other species that achieved high germination percentages by the fourth week appeared to be continuing to lose dormancy over time – this was most striking in the case of *E. sparsiflorum* in the cold stratification treatment, *D. pinnata* in the after-ripening treatment, *L. occidentalis* in all treatments except light and *P. tenellus* in the cold stratification treatment. The behavior of these species in the field would be expected to differ; our dry after-ripening treatment, intended to mimic warm summer temperatures, lasted only four weeks, a much shorter time than seeds would experience in the western Great Basin. Likewise, the cold stratification treatment, lasting eight weeks, is shorter than the winter that these species would experience. Therefore, comparing laboratory results to results from the field will be essential as field results can often be effectively predicted by lab experiments (e.g. Meyer and Kitchen 1992) but sometimes show marked differences (e.g. Hendrix 1984).

One species was not induced to germinate at greater than 50% by any of the treatments we applied -- *B. scaber* will require further study. One possible explanation is that this species, as well as the other species that did not achieve 100% germination of viable seeds under any treatment, may have a high fraction of seed populations that exhibit cue-nonresponsive dormancy in order to ensure high levels of seed carryover among years (e.g. Meyer and others 2005; Jones 2009).

Table 1. Locality, date of collection, storage prior to start of experiments and viability for each species studied.

Species	**Locality**	**Month**	**Storage time**	***Viability***
Amsinckia menziesii var. *intermedia*	Keystone Canyon, Washoe County, NV	June 2008	9 mo.	*89.9±5.4*
Amsinckia tesselata	Keystone Canyon, Washoe County, NV	June 2008	9 mo.	*94.0±4.7*
Blepharipappus scaber	Keystone Canyon, Washoe County, NV	June 2008	9 mo.	*77.0±8.7*
Descurainia pinnata	White River Valley, White Pine County, NV	June 2007	12 mo.	*90.2±2.4*
Eriastrum sparsiflorum	White River Valley, White Pine County, NV	June 2007	9 mo.	*99.0±2.0*
Lappula occidentalis	White River Valley, White Pine County, NV	June 2007	12 mo.	*92.9±2.6*
Mentzelia veatchiana	Keystone Canyon, Washoe County, NV	June 2008	9 mo.	*50.5±11.7*
Plagiobothrys tenellus	Balls Canyon, Sierra County, CA	June 2007	9 mo.	*95.2±3.5*

Table 2. Results of GLM of treatment effects on germination percentage after 4 weeks. All results based on Type III SS. Bonferroni-adjusted differences among treatments appear in Figure 1 and in the Results section text.

Species	**Source**	**MS**	**F**	**P**
Amsinckia menziesii var. *intermedia*	Treatment	2539.77	37.88	<0.0001
Amsinckia tesselata	Treatment	2910.31	21.17	<0.0001
Blepharipappus scaber	Treatment	1463.06	147.85	<0.0001
Descurainia pinnata	Treatment	747.56	4.95	<0.0183
Eriastrum sparsiflorum	Treatment	4949.08	57.05	<0.0001
Lappula occidentalis	Treatment	234.77	3.08	0.0682
Mentzelia veatchiana	Treatment	4550.89	32.37	<0.0001
Plagiobothrys tenellus	Treatment	5605.35	50.16	<0.0001

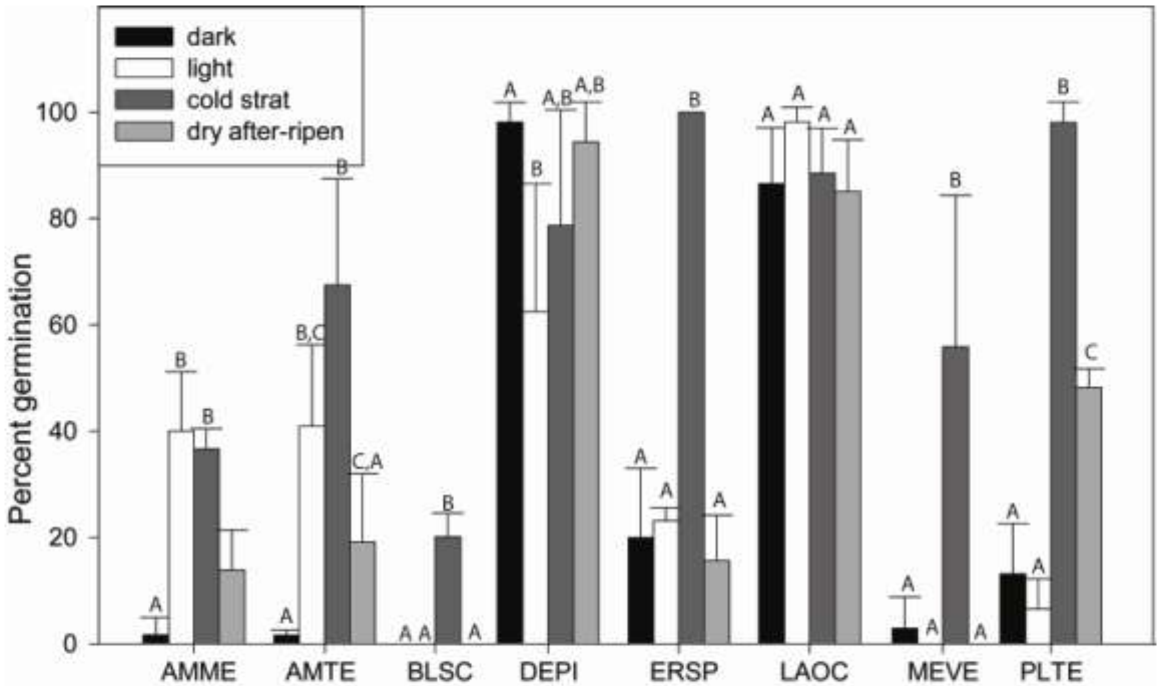

Figure 1. Percent germination, adjusted using viability data to represent percent of viable seed germinating under each of four treatments, light constant temperature, dark constant temperature, cold stratification, and hot, dry after-ripening. Error bars represent one standard deviation. Letters represent differences among LS means, using a Bonferroni adjustment for multiple comparisons. All comparisons among treatments were done by species. AMME = *Amsinckia menziesii* var. *intermedia*, AMTE = *Amsinckia tesselata*, BLSC = *Blepharipappus scaber*, DEPI = *Descurainia pinnata*, ERSP = *Eriastrum sparsiflorum*, LAOC = *Lappula occidentalis*, MEVE = *Mentzelia veatchiana*, PLTE = *Plagiobothrys tenellus*.

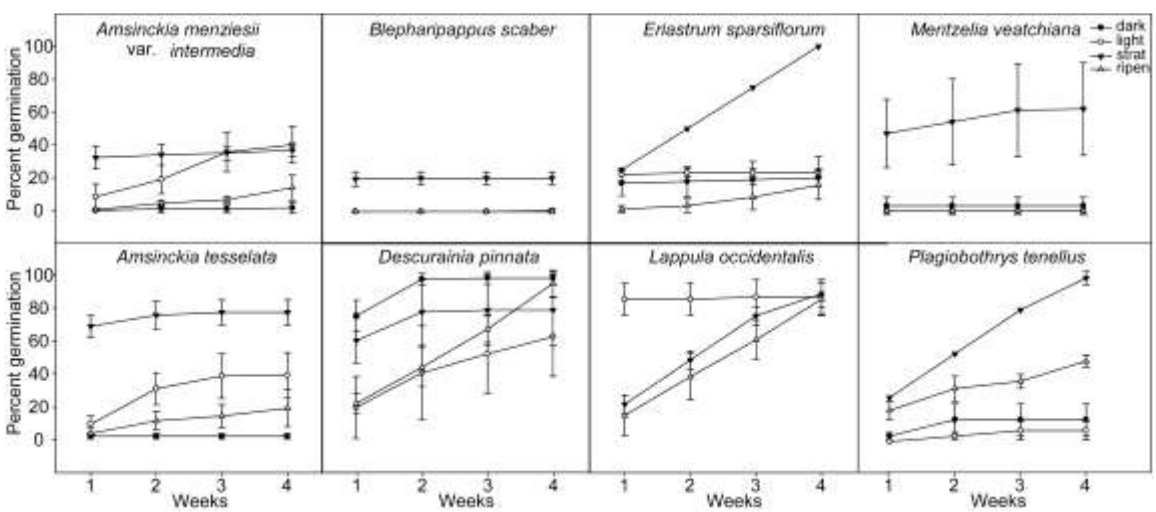

Figure 2. Germination rate curves, by species and treatment. Symbols represent mean cumulative germination percentages, error bars are 1 S.D. All values adjusted using viability data. Strat = stratification, ripen = dry after-ripening, light and dark are the original dormancy test conditions as explained in the methods.

Literature Cited

Baskin, C.C.; Baskin, J.M. 2001. Seeds: ecology, biogeography, and evolution of dormancy and germination. San Diego: Academic Press.

Hendrix, S.D. 1984. Variation in seed weight and its effects on germination in *Pastinaca sativa* L. (Umbelliferae) American Journal of Botany. 71: 795-802.

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Meyer, S.E.; Kitchen, S.G. 1992. Cyclic seed dormancy in the short-lived perennial *Penstemon palmeri*. Journal of Ecology. 80: 115-122.

Meyer, S.E.; Quinney, D; Weaver, J. 2005. A life history study of the Snake River Plains endemic *Lepidium papilliferum* (Brassicaceae). Western North American Naturalist. 65: 11–23.

Management Applications:
Perennial species must be able to persist in Intermountain West rangelands in order for these ecosystems to remain productive and healthy, both as functioning range systems and as functioning native communities. This research focuses on the potential for using native annual forbs to increase establishment of early successional native perennial species in *B. tectorum* invaded rangelands. Identification of any species that negatively impact *B. tectorum* fulfills a management need by identifying potential tools for reducing *B. tectorum* dominance on disturbed rangelands. The results of this research will lead into future work focusing on the facilitative effects of early seral grass and forb species on the successful restoration of later successional species, such as shrubs and longer-lived perennial grasses and forbs, into disturbed communities.

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

Contributed to the allocation of additional funds to EIWRU for research on the establishment of native plants in cheatgrass, red brome and medusahead-threatened sites.

Publication:
Forbis, T.A. In Press. Germination phenology of some Great Basin native annual forbs. Plant Species Biology.

Presentations:
Forbis, Tara A. Germination phenology of some Great Basin native annual forbs. Botanical Society of America Annual Meeting, Snowbird, UT. Poster.

Forbis, Tara A.; Meyers, Susan E. 2010. Germination phenology of some Great Basin native annual forbs. Society for Range Management Annual Meeting, Denver, CO. Poster.

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

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

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Project Description:
Objectives of this research include:
1. Determine the effect of crested wheatgrass (*Aropyron desertorum*) control methods on wheatgrass density and cover.
2. Determine the effect of crested wheatgrass control methods and revegetation on establishment of seeded species.

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

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

Within the main plots in each block, the following methods of control (mechanical and chemical) and revegetated vs. non-revegetated strategies are being compared:
1. Untreated crested wheatgrass plots receiving no chemical or mechanical treatment, but divided into unseeded and seeded sub-plots.
2. Partially controlled crested wheatgrass plots split into 3-way disked or herbicide-treated plots, divided into unseeded and seeded sub-plots.
3. Completely controlled crested wheatgrass plots split into combined 3-way disked and herbicide-treated plots or combined spring and fall herbicide-treated plots, divided into unseeded and seeded sub-plots.

Treatment Implementation

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

2009 Preliminary Results

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

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

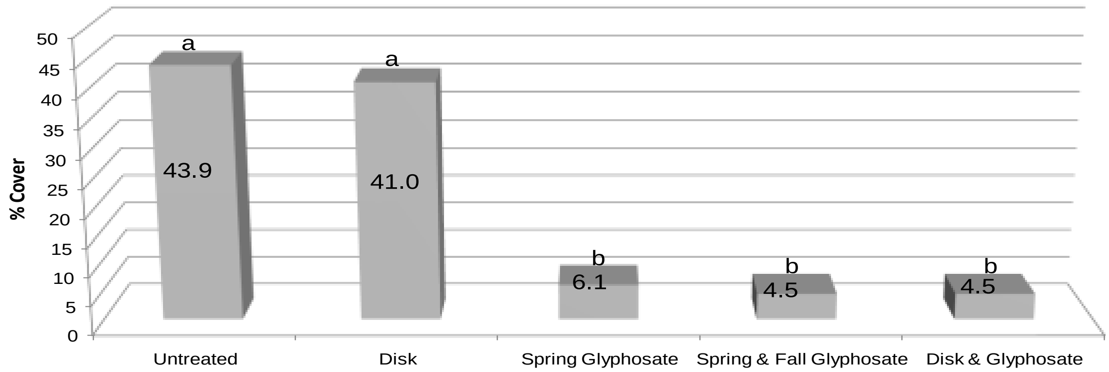
Data analysis for germination and establishment of seeded species is currently in progress, but preliminary observations show the following: (1) four of the six seeded native grass species established, including basin wildrye, bluebunch wheatgrass, bottlebrush squirreltail and Indian ricegrass; (2) each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

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

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

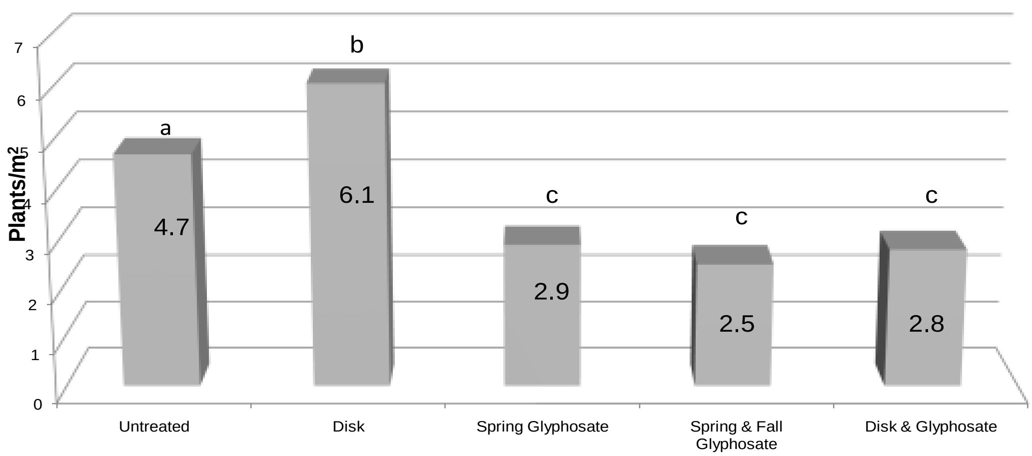
[1] From Granite Seed Co.
[2] From BFI Native Seeds
[3] From Comstock Seed Co.
[4] From FS Collection
[5] From Native Seed Co.

Figure 1. Effect of treatments on crested wheatgrass cover.*



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

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



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

Future Plans

Sampling

Beginning in summer 2010, we will continue to collect cover and density data, as described above for seeded species. We will also establish additional plots in 2010 for comparisons between years.

Analysis

Data will be analyzed using mixed model analysis, with blocks and years considered random and other treatments considered fixed.

Management Applications:

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

Products:

We will conduct a field tour on August 17, 2010 to look at results of applying crested wheatgrass reduction methodologies and seeding native species.

Publications:

Interim results will be presented at scientific meetings and during field tours for scientists, agency resource specialists, agricultural producers, and other interest groups. Final results will be published in refereed journals.

Presentations:

McAdoo, Kent. Nevada crested wheatgrass diversification study. Great Basin Native Plant Selection and Increase Project Annual meeting. March 31, 2009; Boise, ID.

Project Title: Effect of Herbicide Application Timing on Crested Wheatgrass Control and Subsequent Native Plant Reestablishment Success

Project Location: USDA-ARS, Dubois, ID

Principal Investigator and Contact Information:

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Project Description:
Crested wheatgrass stands in much of the western United States are stable in near monocultures that are resistant to native plant reestablishment. Attempts to modify these stands, to increase diversity, will require a reduction in crested wheatgrass so other seeded species can become established. Experiments were initiated in the spring 2008 to determine whether: (1) glyphosate efficacy differs among combinations of crested wheatgrass physiological state (timing of application) and disturbance, and (2) establishment of seeded native plants is improved when crested wheatgrass control treatments are more effective.

Methods

Effect of crested wheatgrass phenological stage on herbicide efficacy
Two experiments are being conducted at the U.S. Sheep Experiment Station (USSES) headquarters property near Dubois, Idaho to determine the relationships among total nonstructural carbohydrate (TNC) trend, phenological stage and efficacy of glyphosate to control crested wheatgrass. The first experiment will characterize the TNC trend in relation to plant phenology. The experiment is a completely randomized design. A factorial combination of year (2 levels), and date (~10 levels), will be assigned completely at random to each plant (10 replications). Plants were collected and dried in the laboratory. Growth stages were classified for each plant, and root crowns and stem bases were excised for TNC analysis.

The second experiment is a completely randomized design in a split-plot arrangement with repeated measures. A factorial combination of year (2 levels; 2008 or 2009) and date (~8 levels) was assigned to main plots (1 x 2 m) completely at random. Within each main plot a random half (1 x 1 m) was assigned to a clipping treatment. The clipped half was generally clipped two weeks prior to the main plot spray date. In mid June (2009) it was clear that a two week delay between clipping and spraying didn't give the crested wheatgrass enough time to grow, so subsequent spray dates were delayed to 28 or 56 days after clipping. At the time these plots were selected, corners of the main plot were permanently marked with fiberglass rods. At clipping, herbicide application, two weeks after application, and in mid-June the year after herbicide application, digital photographs will be taken from 2m above ground. In mid-June, the year after herbicide application, crested wheatgrass biomass will be clipped and weighed. The photographs will be analyzed for crested wheatgrass cover. Analysis of variance will be used to determine whether year, timing of herbicide application, or clipping prior to application had an effect on crested wheatgrass cover and biomass.

Large scale seeded plot experiment

The large scale plot experiment is being conducted within a 50-ha, well established crested wheatgrass seeding near Aberdeen, Idaho. The site is mapped to two soil map units, the Portino silt loam, 4 to 8 percent slopes (Coarse-silty, mixed, superactive, mesic Xeric Haplocalcids) and the Portneuf silt loam, 2 to 4 percent slopes (Coarse-silty, mixed, superactive, mesic Durinodic Xeric Haplocalcids). Both soil units are correlated with the Loamy 8-12 ARTRW8/PSSP ecological site. The historical plant composition for this site included bluebunch wheatgrass, Thurber needlegrass, western wheatgrass, arrowleaf balsamroot, Wyoming big sagebrush, Sandberg bluegrass, green rabbitbrush and bottlebrush squirreltail.

The large scale plot experiment is a split-plot arrangement of a completely randomized design with repeated measures. A factorial combination of treatment year (2 levels; 2008 or 2009), spring disking (2 levels; yes or no), and glyphosate treatments (4 levels; none, vegetative stage, reproductive stage or autumn regrowth application) was assigned completely at random to 80 main plots (61 x 43m). A random half of each main plot (30.5 x 21.5m, subplots) was seeded with a native mix. Between adjacent main plots there is a minimum 12m buffer in all directions. Sampling, within each subplot, is conducted on a central 24 x 37m core sampling area.

For all herbicide treatments, the recommended rate (3.2 L/ha) of glyphosate was applied with a tractor pulled sprayer. For the disking treatments a tractor pulled disk was used in the spring before the soils had dried.

The seeded subplots were seeded with a mix of native grasses, forbs and shrubs common to the sites historical plant community (Table 1). Seeding each year occurred in early November. A Truax Rough Rider rangeland drill was used for the seeding.

Table 1. Seed mix.

Species	kg-PLS/ha
Broadcast	
Maple Grove Lewis flax	0.45
Mtn. Home Sandberg bluegrass	0.22
Blue penstemon	0.45
Wyoming big sagebrush	0.06
Rubber rabbitbrush	0.17
Drilled	
Anatone bluebunch wheatgrass	3.59
Magnar basin wildrye	0.90
Bannock thickspike wheatgrass	0.67
Thurber's needlegrass	0.67

Reseeding success is evaluated for two growing seasons after each treatment and seeding year. Data collection includes cover and density of seeded species, crested wheatgrass and invasive plants. Cover will be determined by line point intercept. Density will be determined by counting plants in sample quadrates or appropriately sized belt transects.

Results from 2009

Effect of crested wheatgrass phenological stage on herbicide efficacy

Crested wheatgrass plants have been collected and greenness and phenological stages have been classified for each sample date in 2008 and 2009 (Figure 1). When sampling began, in late May 2008 (d 151), most of the crested wheatgrass tillers were green and in a vegetative stage. By mid July 2008 (d 193), some tillers were beginning to senesce and the green tillers were mostly in a reproductive stage. By mid September 2008 (d 257), almost all tillers were senesced and the few remaining green tillers were in seed development and seed ripening stages. With little or no autumn green-up, no herbicide applications were made in 2008. Growth was initiated earlier in 2009 than in 2008. This is likely due to the snow pack thawing at the site by April 4 (d 94), whereas in 2008 the snow pack remained until April 25 (d 116). By late May 2009 (d 149), tillers were predominately in an elongation stage, whereas in late May 2008 (d 151) tillers were predominately in a vegetative stage. In 2009, 98mm of June precipitation (218% of normal) helped to extend the time when most tillers were green beyond mid July (d 198). In 2008, plants were beginning to exhibit senescence by late May (d 148).

Tillers were predominately vegetative or nonexistent in plants that were subjected to clipping two weeks prior to sampling (data not shown). In 2008, the only sample time when emerged tillers were abundant in clipped plants was mid June (d 165). By the late June sampling (d 179), few new tillers had emerged and all were in the early vegetative stage. By mid July (d 193) and throughout mid August (d 226), no tillers were emerging from clipped plants and no phenological stage ratings could be made. By late October (d 296), a few tillers were emerging from clipped plants and the emerged tillers were in early vegetative stages. In 2009, tillers had emerged from clipped plants from the time of the first clipped plant sampling May 1 (d 121) through the late June (d 177) sampling. In mid July (d 198), the clipped plants had few emerged tillers and they were all early vegetative stage. The clipped plants that were sampled in early November (d 310) were clipped in mid July (d 198) and many tillers had finally emerged, but development was slow and they were all in the early vegetative stage.

Timing of herbicide application in 2008 had a significant effect on glyphosate efficacy. Crested wheatgrass biomass was 231 g m^{-2} in unsprayed plots. Crested wheatgrass biomass was <1 g m^{-2} in plots sprayed June 6 (d 158) at 2X the recommended herbicide application rate. Crested wheatgrass biomass was less, compared with the unsprayed control plots, when plots were sprayed at the recommended herbicide application rate on June 20 (d 172, 46 g m^{-2}), but not for plots sprayed on July 7 (d 189, 217 g m^{-2}).

Large scale seeded plot experiment

Precipitation was less than normal in 2008 and above normal in 2009, owing to above normal June precipitation. Crested wheatgrass control treatments were begun earlier than 2008 in 2009, with the exception of the 2nd herbicide application and seeding which were completed on about the same date as in 2008.

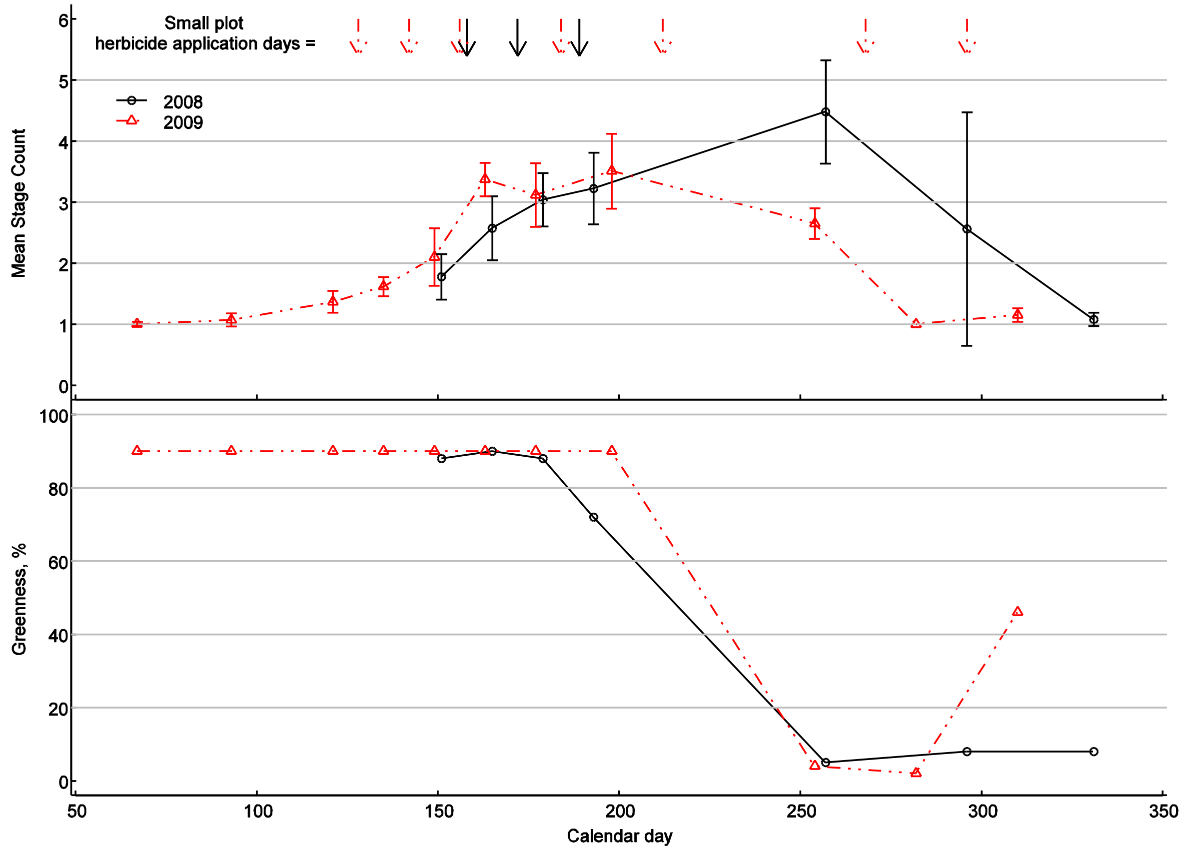

Figure 1. Mean stage count and greenness for crested wheatgrass plants collected over 2 years. Mean stage count classes are for green tillers and follow the classification system described by Moore et al. (1991). Greenness is plotted as the mean of the greenness class midpoint for ten sampled plants. Greenness classes for the plants were classified into 1 of 6 categories based on the percentage of green tillers (0, 1 to 20, 21 to 40, 41 to 60, 61 to 80, or 81 to 100 percent). Calendar days when herbicide was applied to adjacent small plots are also indicated for 2008 and 2009.

Mature crested wheatgrass density in 2009 was reduced by disking in late May 2008. Mature crested wheatgrass density was less in plots sprayed with the recommended herbicide application rate compared with unsprayed plots regardless of the date sprayed (1st date, June 9; 2nd date, June 19, or 3rd date, October 24) if first disked but only in the first 2 spray dates if not disked. The seeding had no effect on mature crested wheatgrass density.

Mature Sandberg bluegrass density in 2009 was reduced by disking in late May 2008 and herbicide application resulted in no further reduction in density. In undisked plots, herbicide did not reduce mature Sandberg bluegrass density except for the late October spraying which was as effective as spring disking. Fall seeding in 2008 had no effect on mature Sandberg bluegrass density in 2009.

Cheatgrass density was generally low in 2009 (6 plants m^{-2}); however, herbicide application on June 9, 2008 and June 19, 2008, regardless of whether disked, reduced cheatgrass density in 2009 (1 and 2 plants m^{-2}, respectively). Disking in 2008 had no effect on cheatgrass density in

2009; however, plots that were not disked in 2008 had significantly greater cheatgrass density in 2009 if they were seeded in 2008.

Emergence and survival of seeded forbs and shrubs in 2009 was poor regardless of the crested wheatgrass control treatments that were applied in 2008. Total seeded forb seedling density was less than 1 plant m^{-2} and total seeded shrub seedling density was less than 1 plant per 100 m^2. The disking treatment tended to reduce the emergence and survival of seeded grasses. Total seeded grass density in 2009 was 33 plants m^{-2} in the undisked plots compared with 25 plant m^{-2} in the disked plots. The reduction in seedling density due to disking was significant for needlegrass (2.1 vs 1.3 m^{-2}), marginally non-significant for Sandberg bluegrass (4.8 vs 2.1 m^{-2}), and non-significant for the wheatgrass/wildrye group.

Plans for 2010

Large plot cover and density will be measured for the second year in 2008 plots and for the first year in 2009 plots.

Literature Cited

Moore, K. J.; Moser, L. E.; Vogel, K. P.; Waller, S. S.; Johnson, B. E.; Pededsen, J. F. 1991. Describing and quantifying growth stages of perennial forage grasses. Agronomy Journal. 83: 1073-1077.

Management Applications:

When this study is complete, land managers can use this information to choose efficacious crested wheatgrass control practices and increase the likelihood that subsequent native seeding efforts are successful.

Presentations:

Moffet, Corey. Eastern Idaho crested wheatgrass diversification study. Great Basin Native Plant Selection Increase Project Annual meeting. March 31, 2009; Boise, ID.

Project Title: Revegetation Equipment Catalog

Project Location: Texas Tech University, Lubbock, TX

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Project Description:
The Revegetation Equipment Catalog is an online repository of descriptions, photos and company information for equipment that is used for revegetation efforts in the US. With pages on topics ranging from "All-terrain Vehicles" through "Fertilizing and Mulching" to "Transport Trailers", the catalog is an important reference for information about revegetation equipment.

<u>2009 Activities and Results</u>
Prior to 2009, the catalog was hosted on websites at the Texas A&M University. During 2009, the catalog was shifted to being mirrored at Texas Tech University. The TTU site is now up and running, and will shortly be indexed and listed on WWW search engines.

<u>Future Plans</u>
During 2010, the catalog will be updated and maintained, and the duplicate site at Texas A&M will be closed down, so that the TTU site is the primary hosting site for the catalog. When this is done, the TAMU site will host a "redirect" page that will send visitors on to the TTU-hosted site, should they try to access the site through TAMU. The ability to track website traffic and visitors' locations will also be added in 2010.

Presentations:
Shaw, Nancy; Cox, Robert; Ganguli, Amy; Newingham, Beth; St. John, Loren; Ogle, Dan; Truax, Jim. Seeding strategies and equipment for re-establishing Wyoming big sagebrush communities. Great Basin Native Plant Selection and Increase Annual meeting. March 31, 2009; Boise, ID.

Project Title: Calibration of Drills for Rehabilitation and Restoration Seedings on Western Wildlands

Project Location: USDA Forest Service, Missoula Technology and Development Center (MTDC), Missoula, MT

Principal Investigator and Contact Information:

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Project Description:
Emphasis on reestablishment of diverse native communities for post-fire restoration, increasing resistance to weed invasion, roadway enhancement and other rangeland restoration projects necessitates use of equipment designed to properly plant species with seeds of diverse sizes and shapes at appropriate rates and depths and in compatible combinations. Once seed mixes are developed and seeds have been procured, it is necessary to calculate the appropriate seeding rates for each component of the mix and to calibrate the drill to distribute each mix at the desired rate.

The standard rangeland drill and a number of newer drills are now in use. Operators must be familiar with this equipment if it is to be used properly to improve the potential for seeding success, reduce waste of costly seed and decrease costs. Project 2400 9E92E89: Drill calibration video training is being conducted to provide a video that will describe drill parts and mechanisms and demonstrate three common methods of drill calibration. It will also illustrate some of the differences among drills. The video will include a glossary of standard terms used in describing seed quality and drill operation.

Collaborators on the project include the USDI Bureau of Land Management Vale Equipment Shop, Vale, OR; USDA NRCS Aberdeen Plant Materials Center, Aberdeen, ID; Truax Company, Inc., New Hope, Minnesota; USDA Forest Service Rocky Mountain Research Station, Boise, ID.

Script for the video was developed in spring 2009. Filming was conducted at the USDI Bureau of Land Management Vale Equipment Shop, Vale, OR and at the Oregon State University Malheur Experiment Station, Ontario, OR in April. Editing of the film is being completed by MTDC in Missoula. Copies of the video will be made available to Forest Service District Offices. A shorter version of the video may be linked to the Revegetation Equipment Catalog.

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

Project Location: Utah State University, Logan, Utah

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

<u>Materials and Methods</u>
Trials were established at Cache Junction and Nephi, Utah. Herbicide treatments were applied to plots measuring 6 ft wide and 60 ft in length. Herbicides were applied with a CO_2- pressurized backpack sprayer calibrated to deliver 20 gpa at 30 psi. Spring applications were made April 29 and May 1 and fall applications November 30 and 23 at Nephi and Cache Junction, respectively. Two applications of Roundup were used to suppress weed growth at Cache Junction, while one hand weeding was used to remove weeds at the Nephi site. Species were seeded perpendicular to the herbicide plots on November 23, 2009 at Cache Junction and November 25, 2009 at Nephi. At Nephi a modified cone seeder was used to plant two rows of each species spaced 2.5 ft apart. At Cache Junction, species were seeded in strips 7 feet wide with plant rows 8 inches apart with a Tye no-till drill. A list of species seeded at each location is included in Table 1. Because field bindweed was prevalent at the Cache Junction location, only grass species were seeded at that location. Species germination and growth will be recorded during 2010.

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

Nephi	
Utah sweetvetch	*Astragalus filipies*
Prairie clover	*Dalea ornata*
Searle's prairie clover	*Dalea searlsiae*
Sulfur-flower buckwheat	*Eriogonum umbellatum*
Nevada goldeneye	*Heliomeris multiflorum* var. *nevadensis*
Silky lupine	*Lupinus sericeus*
Big blue penstemon	*Penstemon cyaneus*
Globe mallow	*Spharalcea*
Big bluegrass ('Sherman")	*Poa secunda*
Bluebunch wheatgrass ('Anatone')	*Pseudoroegneria spicata*

Cache Junction	
Slender wheatgrass ('First Strike')	*Elymus trachycaulus*
Basin wildrye ('Magnar')	*Leymus cinereus*
Big bluegrass ('Sherman')	*Poa secunda*
Bluebunch wheatgrass ('Anatone')	*Pseudoroegneria spicata*

Results

There are no results to report at this time.

Direction for 2010

During the spring, species establishment and growth will be recorded for each species and herbicide. A second research site will be established in 2010 containing all of the treatments and species included in the trial established in 2009.

Soil samples will be taken from each plot in the Nephi field trial to a 6-inch depth. Soil samples will be taken as close to seedling germination as possible. Soil cores will be frozen until extractions can be performed. The level of imazapic remaining in the soil will be determined by running extracted samples through an HPLC. Petri-dish trials will also be initiated to evaluate seed germination in response to increasing herbicide rates.

Presentations:

Ransom, Corey; Edvarchuk, Kim. Identification of herbicides for use in native forb seed production. Great Basin Native Plant Selection and Increase Project Annual meeting. March 31, 2009; Boise, ID.

Project Title: Native Plant Selection, Seed Biology and Seeding Equipment and Technology

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

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Project Description:

1. Plant Materials

Development of plant materials of native forbs has been conducted at the USDA Forest Service, Lucky Peak Nursery, Idaho Botanical Garden, Orchard Research Site and Wells Research Site.

Project Status

Seed Collection

Ninety collections were made in 2009, this included 37 collections of *Artemisia tridentata* subspecies for genetics research being conducted by Bryce Richardson (see report this document).

Buy-back Program

Seeds of pooled collections of *Penstemon acuminatus* (Northern Basin and Range), *Eriogonum heracleoides* (Northern Basin and Range, two growers) and *Machaeranthera canescens* (Snake River Plain/Northern Basin and Range, two growers) were distributed to private growers through the Buy-back program.

Seed Distribution

Collections were distributed to the USDA Agricultural Research Service Western Regional Plant Introduction Station/Seeds of Success Program for addition to the GRIN system (Table 1).

Anatone bluebunch wheatgrass (*Pseudoroegneria spicata*): G0 seed was provided to the USDA ARS Aberdeen Plant Materials Center for production of Stock Seed.

Seventy-seven collections were distributed to cooperators and other users (Table 2). The bulk of these went to the USDA FS National Seed Laboratory for development of seed testing protocols.

Table 1. Germplasm conservation samples contributed to the Seeds of Success Program/ARS Western Regional Plant Introduction Station.

Symbol	Scientific Name	Common Name	Eco-region	Ecoregion Name	County	State
ALAC 1	*Allium acuminatum*	Tapertip onion	80f	Owyhee Uplands and Canyons	Owyhee	ID
ASFI 1	*Astragalus filipes*	Basalt milkvetch	80a	Dissected High Lava Plateau	Twin Falls	ID
BASA 81	*Balsamorhiza sagittata*	Arrowleaf balsamroot	80b	Semiarid Hill and Low Mountains	Elko	NV
CROC 15	*Crepis occidentalis*	Western hawksbeard	80f	Owyhee Uplands and Canyons	Owyhee	ID
ERHE 7	*Eriogonum heracleoides*	Wyeth eriogonum	11n	Deschutes River Valley	Jefferson	OR
EROV 65	*Eriogonum ovalifolium*	Cushion buckwheat	12j	Unwooded Alkaline foothills	Owyhee	ID
ERUM 61	*Eriogonum umbellatum*	Sulphur-flower buckwheat	80j	Semiarid Uplands	Elko	NV
ERUM 62	*Eriogonum umbellatum*	Sulphur-flower buckwheat	12f	Semiarid Foothills	Adams	ID
ERUM 12	*Eriogonum umbellatum*	Sulphur-flower buckwheat	80f	Owyhee Uplands and Canyons	Malheur	OR
ERUM 13	*Eriogonum umbellatum*	Sulphur-flower buckwheat	80f	Owyhee Uplands and Canyons	Malheur	OR
ERUM 17	*Eriogonum umbellatum*	Sulphur-flower buckwheat	11i	Continental Zone Foothills	Baker	OR
ERUM 18	*Eriogonum umbellatum*	Sulphur-flower buckwheat	80j	Semiarid Uplands	Owyhee	ID
ERUM 19	*Eriogonum umbellatum*	Sulphur-flower buckwheat	12f	Semiarid Foothills	Elmore	ID
ERUM 36	*Eriogonum umbellatum*	Sulphur-flower buckwheat	12f	Semiarid Foothills	Elmore	ID
ERUM 47	*Eriogonum umbellatum*	Sulphur-flower buckwheat	80f	Owyhee Uplands and Canyons	Owyhee	ID
ERUM 5	*Eriogonum umbellatum*	Sulphur-flower buckwheat	80f	Owyhee Uplands and Canyons	Harney	OR
ERUM 63	*Eriogonum umbellatum*	Sulphur-flower buckwheat	80d	Pluvial Lake Basins	Crook	OR
ERUM 64	*Eriogonum umbellatum*	Sulphur-flower buckwheat	11n	Deschutes River Valley	Jefferson	OR
LOGR 28	*Lomatium grayi*	Gray's biscuitroot	80j	Semiarid Uplands	Elko	ID
LOGR 16	*Lomatium grayi*	Gray's biscuitroot	12f	Semiarid Foothills	Washington	ID
LOGR 22	*Lomatium grayi*	Gray's biscuitroot	80f	Owyhee Uplands and Canyons	Owyhee	ID
LOGR 30	*Lomatium grayi*	Gray's biscuitroot	11a	John Day/ Clarno Uplands	Wheeler	OR
LOLE 4	*Lomatium bicolor*	Wasatch biscuitroot	12f	Semiarid Foothills	Camas	ID

LOMA 1	*Lomatium macrocarpum*	Bigseed biscuitroot	11n	Deschutes River Valley	Jefferson	OR
LOTR 37	*Lomatium triternatum*	Nineleaf biscuitroot	12h	Mountain Home Uplands	Elmore	ID
LOTR 21	*Lomatium triternatum*	Nineleaf biscuitroot	80f	Owyhee Uplands and Canyons	Malheur	ID
LOTR 30	*Lomatium triternatum*	Nineleaf biscuitroot	12c	Camas Prairie	Camas	ID
LOTR 31	*Lomatium triternatum*	Nineleaf biscuitroot	12c	Camas Prairie	Camas	ID
LOTR 41	*Lomatium triternatum*	Nineleaf biscuitroot	9g	Klamath/Goose Lake Warm Wet Basin	Lake	OR
LOTR 64	*Lomatium triternatum*	Nineleaf biscuitroot	11n	Deschutes River Valley	Jefferson	OR
LOTR 65	*Lomatium triternatum*	Nineleaf biscuitroot	11n	Deschutes River Valley	Jefferson	OR
LOTR 66	*Lomatium triternatum*	Nineleaf biscuitroot	11n	Deschutes River Valley	Jefferson	OR
LUAR 27	*Lupine argenteus*	Silvery lupine	80b	Semiarid hill and low mountains	Elko	NV
LUAR 35	*Lupine argenteus*	Silvery lupine	80a	Dissected high lava plateau	Twin Falls	ID
PEAC 11	*Penstemon acuminatus*	Sharpleaf penstemon	12j	Unwooded Alkaline foothills	Malheur	OR
PEAC 13	*Penstemon acuminatus*	Sharpleaf penstemon	80l	Salt Shrub Valley	Harney	OR
PEAC 14	*Penstemon acuminatus*	Sharpleaf penstemon	12h	Mountain Home Uplands	Elmore	ID
PEAC 35	*Penstemon acuminatus*	Sharpleaf penstemon	16k	Southern Forested Mountains	Owyhee	ID
PEAC 39	*Penstemon acuminatus*	Sharpleaf penstemon	12h	Mountain Home Uplands	Elmore	ID
PEAC 4	*Penstemon acuminatus*	Sharpleaf penstemon	12h	Mountain Home Uplands	Ada	ID
PEAC 40	*Penstemon acuminatus*	Sharpleaf penstemon	12h	Mountain Home Uplands	Gooding	ID
PEAC 43	*Penstemon acuminatus*	Sharpleaf penstemon	80l	Salt Shrub Valley	Harney	OR
PEAC 44	*Penstemon acuminatus*	Sharpleaf penstemon	12h	Mountain Home Uplands	Elmore	ID
PEAC 45	*Penstemon acuminatus*	Sharpleaf penstemon	12j	Unwooded Alkaline foothills	Owyhee	ID
PEAC 7	*Penstemon acuminatus*	Sharpleaf penstemon	12h	Mountain Home Uplands	Elmore	ID
PEAC 8	*Penstemon acuminatus*	Sharpleaf penstemon	12h	Mountain Home Uplands	Elmore	ID
PEDE 12	*Penstemon deustus*	Hotrock penstemon	80f	Owyhee Uplands and Canyons	Harney	OR
PEDE 18	*Penstemon deustus*	Hotrock penstemon	80f	Owyhee Uplands and Canyons	Malheur	OR

PEDE 22	*Penstemon deustus*	Hotrock penstemon	80e	High Desert Wetlands	Harney	OR
PEDE 24	*Penstemon deustus*	Hotrock penstemon	80g	High Lava Plains	Malheur	OR
PEDE 25	*Penstemon deustus*	Hotrock penstemon	16k	Southern Forested Mountains	Boise	ID
PEDE 27	*Penstemon deustus*	Hotrock penstemon	16f	Foothill Shrublands-Grasslands	Elmore	ID
PEDE 3	*Penstemon deustus*	Hotrock penstemon	80j	Semiarid Uplands	Owyhee	ID
PEDE 35	*Penstemon deustus*	Hotrock penstemon	11i	Continental Zone Foothills	Baker	OR
PEDE 40	*Penstemon deustus*	Hotrock penstemon	80g	High Lava Plains	Lake	OR
PEDE 41	*Penstemon deustus*	Hotrock penstemon	80g	High Lava Plains	Harney	ID
PEDE 43	*Penstemon deustus*	Hotrock penstemon	80f	Owyhee Uplands and Canyons	Malheur	ID
PEDE 45	*Penstemon deustus*	Hotrock penstemon	80f	Owyhee Uplands and Canyons	Malheur	ID
PEDE 5	*Penstemon deustus*	Hotrock penstemon	12f	Semiarid Foothills	Adams	ID
PEDE 6	*Penstemon deustus*	Hotrock penstemon	12f	Semiarid Foothills	Adams	ID
PEDE 7	*Penstemon deustus*	Hotrock penstemon	11f	Canyons and Dissected Highlands	Adams	ID
PEDE 2	*Penstemon deustus*	Hotrock penstemon	16f	Foothill Shrublands-Grasslands	Boise	ID
PESP 1	*Penstemon speciosus*	Royal penstemon	12h	Mountain Home Uplands	Ada	ID
PESP 10	*Penstemon speciosus*	Royal penstemon	12h	Mountain Home Uplands	Ada	ID
PESP 2	*Penstemon speciosus*	Royal penstemon	12h	Mountain Home Uplands	Ada	ID
PESP 23	*Penstemon speciosus*	Royal penstemon	11o	Cold Basins	Grant	OR
PESP 35	*Penstemon speciosus*	Royal penstemon	12j	Unwooded Alkaline foothills	Payette	ID
PESP 47	*Penstemon speciosus*	Royal penstemon	80g	High Lava Plains	Lake	OR
PESP 8	*Penstemon speciosus*	Royal penstemon	80j	Semiarid Uplands	Owyhee	ID
PESP 9	*Penstemon speciosus*	Royal penstemon	80f	Owyhee Uplands and Canyons	Malheur	OR
SPGR 47	*Sphaeralcea grossulariifolia*	Gooseberryleaf globemallow	12j	Unwooded Alkaline foothills	Owyhee	ID
SPGR 48	*Sphaeralcea grossulariifolia*	Gooseberryleaf globemallow	12j	Unwooded Alkaline foothills	Owyhee	ID

Table 2. Seed lots distributed to cooperators in 2009.

Species	Common Name	Seed Origin (county, state)	Affiliation	Kg
Achnatherum thurberianum	Thurber's needlegrass	Ada, Idaho	USDA FS Rocky Mountain Research Station	0.45
Achnatherum thurberianum	Thurber's needlegrass	Ada, Idaho	USDA FS Lucky Peak Nursery	0.45
Achnatherum thurberianum	Thurber's needlegrass	Ada, Idaho	OSU Malheur Experiment Station	0.10
Achnatherum thurberianum	Thurber's needlegrass	Malheur, Oregon	USDA ARS Western Regional Plant Introduction Station	0.10
Agoseris glauca	Pale agoseris	Elmore, Idaho	USDA FS National Seed Lab	0.08
Agoseris glauca	Pale agoseris	Harney, Oregon	USDA FS National Seed Lab	0.13
Agoseris grandiflora	Bigflower agoseris	Humboldt, Nevada	USDA FS Rocky Mountain Research Station	4.54
Artemisia tridentata ssp. *wyomingensis*	Wyoming big sagebrush	Elmore, Idaho	University of Idaho	0.32
Balsamorhiza hookeri	Hooker's balsamroot	Malheur, Oregon	USDA FS National Seed Lab	0.49
Balsamorhiza hookeri	Hooker's balsamroot	Camas, Idaho	USDA FS National Seed Lab	0.23
Balsamorhiza hookeri	Hooker's balsamroot	Ada, Idaho	USDA FS National Seed Lab	0.32
Balsamorhiza hookeri	Hooker's balsamroot	Ada, Idaho	USDA FS National Seed Lab	0.43
Balsamorhiza hookerii	Hooker's balsamroot	Washoe, Nevada	USDA FS Rocky Mountain Research Station	0.18
Chaenactis douglasii	Douglas' dustymaiden	Owyhee, Idaho	USDA ARS Bee Biology and Systematics Laboratory	0.00
Chaenactis douglasii	Douglas' dustymaiden	Owyhee, Idaho	Private Grower	0.59
Chaenactis douglasii	Douglas' dustymaiden	Boise, Idaho	USDA FS National Seed Lab	0.12
Chaenactis douglasii	Douglas' dustymaiden	Boise, Idaho	USDA FS National Seed Lab	0.07
Chaenactis douglasii	Douglas' dustymaiden	Elmore, Idaho	USDA FS National Seed Lab	0.08
Chaenactis douglasii	Douglas' dustymaiden	Owyhee, Idaho	USDA FS National Seed Lab	0.19
Chaenactis douglasii	Douglas' dustymaiden	Malheur, Oregon	USDA FS National Seed Lab	0.04
Chaenactis douglasii	Douglas' dustymaiden	Malheur, Oregon	USDA FS National Seed Lab	0.07
Crepis acuminata	Tapertip hawksbeard	Elmore, Idaho	USDA FS National Seed Lab	0.14
Crepis acuminata	Tapertip hawksbeard	Harney, Oregon	USDA FS National Seed Lab	0.18
Crepis acuminata	Tapertip hawksbeard	Ada, Idaho	USDA FS National Seed Lab	0.03
Crepis occidentalis	Largeflower hawksbeard	Washington, Idaho	USDA FS National Seed Lab	0.10
Crepis occidentalis	Largeflower hawksbeard	Malheur, Oregon	USDA FS National Seed Lab	0.07
Crepis occidentalis	Largeflower hawksbeard	Malheur, Oregon	USDA FS National Seed Lab	0.03
Crepis occidentalis	Largeflower hawksbeard	Owyhee, Idaho	USDA FS National Seed Lab	0.05
Dalea ornata	Blue Mountain prairie clover	Malheur, Oregon	Agriculture Research Service	0.91
Dalea ornata	Blue Mountain prairie clover	Malheur, Oregon	USDA FS Rocky Mountain Research Station	0.23
Eriogonum heracleoides	Parsnipflower buckwheat	Cache, Utah	USDA FS Rocky Mountain Research Station	0.45
Eriogonum heracleoides	Parsnipflower buckwheat	Owyhee, Idaho	USDA FS Rocky Mountain Research Station	0.84
Eriogonum heracleoides	Parsnipflower buckwheat	Cache, Utah	OSU Malheur Experiment Station	0.20
Eriogonum heracleoides	Parsnipflower buckwheat	Cache, Utah	USDA FS National Seed Lab	0.57

Eriogonum heracleoides	Parsnipflower buckwheat	Cache, Utah	USDA FS National Seed Lab	1.04
Eriogonum heracleoides	Parsnipflower buckwheat	Malheur, Oregon	USDA FS National Seed Lab	0.43
Eriogonum heracleoides	Parsnipflower buckwheat	Harney, Oregon	USDA FS National Seed Lab	0.28
Eriogonum ovalifolium	Cushion buckwheat	Harney, Oregon	USDA FS National Seed Lab	0.06
Eriogonum umbellatum	Sulphur-flower buckwheat	Owyhee, Idaho	USDA FS Rocky Mountain Research Station	0.91
Eriogonum umbellatum	Sulphur-flower buckwheat	Northern Basin & Range/Snake River Plain	Private Grower	4.72
Eriogonum umbellatum	Sulphur-flower buckwheat	Northern Basin & Range/Snake River Plain	Private Grower	4.72
Eriogonum umbellatum	Sulphur-flower buckwheat	Owyhee, Idaho	OSU Malheur Experiment Station	0.10
Eriogonum umbellatum	Sulphur-flower buckwheat	Elmore, Idaho	Utah State University	0.10
Leymus cinereus	Basin wildrye	Malheur, Oregon	Agriculture Research Service	0.10
Lomatium dissectum	Fernleaf biscuitroot	Ada, Idaho	OSU Malheur Experiment Station	2.00
Lomatium dissectum	Fernleaf biscuitroot	Malheur, Oregon	OSU Malheur Experiment Station	2.00
Lomatium dissectum	Fernleaf biscuitroot	Ada, Idaho	OSU Malheur Experiment Station	0.60
Lomatium dissectum	Fernleaf biscuitroot	Washington, Idaho	OSU Malheur Experiment Station	0.79
Lomatium grayi	Gray's biscuitroot	Davis, Utah	USDA FS Rocky Mountain Research Station	0.28
Lomatium grayi	Gray's biscuitroot	Gooding, Idaho	USDA FS Rocky Mountain Research Station	0.31
Lomatium grayi	Gray's biscuitroot	Washington, Idaho	OSU Malheur Experiment Station	0.55
Lomatium nudicaule	Barestem biscuitroot	Malheur, Oregon	USDA FS Rocky Mountain Research Station	0.23
Lomatium triternatum	Nineleaf biscuitroot	Malheur, Oregon	USDA FS Rocky Mountain Research Station	0.18
Lomatium triternatum	Nineleaf biscuitroot	Lake, Oregon	OSU Malheur Experiment Station	0.30
Lupinus argenteus	silvery lupine	Sanpete, Utah	USDA FS Rocky Mountain Research Station	18.16
Machaeranthera canescens	hoary tansyaster	Elmore, Idaho	USDA FS National Seed Lab	0.04
Machaeranthera canescens	hoary tansyaster	Crook, Oregon	USDA FS National Seed Lab	0.47
Penstemon acuminatus	Sharpleaf penstemon	Norther Basin & Range	Private Grower	1.86
Penstemon acuminatus	Sharpleaf penstemon	Snake River Plains	Private Grower	5.58
Penstemon acuminatus	Sharpleaf penstemon	Elmore, Idaho	USDA FS Rocky Mountain Research Station	1.36

Penstemon acuminatus	Sharpleaf penstemon	Elmore, Idaho	OSU Malheur Experiment Station	0.05
Penstemon acuminatus	Sharpleaf penstemon	Elmore, Idaho	OSU Malheur Experiment Station	0.05
Penstemon cyaneus	Blue penstemon	Lincoln, Idaho	USDA FS Rocky Mountain Research Station	4.54
Penstemon cyaneus	Blue penstemon	Lincoln, Idaho	OSU Malheur Experiment Station	0.15
Penstemon cyaneus	Blue penstemon	Lincoln, Idaho	Utah State University	0.10
Penstemon deustus	Scabland penstemon	Baker, Oregon	USDA FS Rocky Mountain Research Station	1.00
Penstemon deustus	Scabland penstemon	Baker, Oregon	OSU Malheur Experiment Station	0.03
Penstemon deustus	Scabland penstemon	Baker, Oregon	OSU Malheur Experiment Station	0.01
Penstemon deustus	Scabland penstemon	Baker, Oregon	OSU Malheur Experiment Station	0.01
Penstemon speciosus	Royal penstemon	Payette, Idaho	USDA FS Rocky Mountain Research Station	0.39
Penstemon speciosus	Royal penstemon	Northern Basin & Range/Snake River Plain	USDA FS Rocky Mountain Research Station	0.76
Penstemon speciosus	Royal penstemon	Northern Basin & Range/Snake River Plain	USDA FS Rocky Mountain Research Station	0.66
Penstemon speciosus	Royal penstemon	Malheur, Oregon	OSU Malheur Experiment Station	0.07
Pseudoroegneria spicata	Bluebunch wheatgrass	Asotin, Washington	USDA NRCS Aberdeen Plant Materials Center	1.95
Sphaeralcea coccinea	Scarlet globemallow	Uintah, Utah	USDA FS Rocky Mountain Research Station	22.70
Sphaeralcea munroana	Munro's globemallow	Blaine, Idaho	USDA FS National Seed Lab	0.04
Sphaeralcea munroana	Munro's globemallow	unknown	USDA FS National Seed Lab	0.37
			TOTAL SEED DISTRIBUTED (kg)	**92.86**

Common gardens and other plant materials research
Data was collected from sulfur-flower buckwheat and fernleaf biscuitroot common gardens. Additional data will be collected in 2010. Royal penstemon data collection was completed. Bigflower agoseris continued to show good seed production, this will be monitored through 2010. Data analysis for bluebunch wheatgrass common gardens continues.

2. Reestablishing Diverse Native Wyoming Big Sagebrush Communities: A Comparison of seeding equipment and techniques
Additional collaborators: Robert Cox, Texas Tech University, Lubbock, TX; Loren St. John, USDA NRCS Aberdeen Plant Materials Center, Aberdeen, ID; Dan Ogle, USDA NRCS Idaho State Office, Boise, ID; Mike Pellant, USDI BLM, Boise, ID; Tom Warren, USDI BLM, Elko, NV

<u>Objectives and Methods</u>
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 - the East Humboldt fire about 10 miles Southwest of Elko and the Gopher fire, about 10 miles North of Deeth, NV. Thirty-five plots were established in five blocks (7 plots per block) at each location. Two seeding rates of native species plus a control of no seed were seeded into the plots on November 7-10, 2006. An untreated "double control" (no seed and no drill) was included to provide adequate comparison. Species and rates seeded are listed in Table 3. 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. Personnel from the NRCS Plant Materials Center in Aberdeen, ID, including Brent Cornforth, Charlie Bair and Boyd Simonson, did the seeding. 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 of each drill. On December 19, 2006, autonomous weather stations were placed at each location to record rain, temperature and soil moisture.

Table 3. Species seeded and rates, in PLS/m^2

	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*	*169.9*
Total Drill + Broadcast	**635.8**	**409.6**

Project Status

Plot data was taken in June 2007 and 2008 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.

Density of all seeded species was similar between drill types, but greater at one site than at the other. There was also a very large loss of density from 2007 to 2008. Density of drilled species was much greater at the Humboldt site than at the Gopher site, and mostly greater in areas seeded with the Rangeland drill than with the Minimum-till drill. Densities were much lower in 2008 than in 2007. Density of broadcast species was greater at the Humboldt site in 2007, but greater at the Gopher site in 2008. Minimum-till seeded areas had greater density of broadcast species than Rangeland drill seeded areas in both 2007 and 2008. Density also dropped greatly from 2007 to 2008. Density of Wyoming big sagebrush in 2007 was greater at the Humboldt site compared to the Gopher site; in 2008 both sites were similar. The Minimum-till drill provided greater density of sagebrush than did the Rangeland drill. Sagebrush density dropped greatly between years. Density of cheatgrass seedlings was much greater at the Gopher site than at the Humboldt site.

Management Applications:
Results will aid in assessing seeding risks, selecting seed mixes, seeding rates and seeding strategies. The results should allow managers to better understand how the respective drills differ in their abilities to seed native species in a diverse mix and their impacts on residual native species, soil crusts and cheatgrass. Such information will help managers in selecting seeding equipment that meets both the site requirements and the seeding goals.

Products:
A manuscript on this study is being prepared for an issue of Rangeland Ecology and Management that will focus on wildland restoration. Results have been presented at several meetings and at the East Humboldt site during a Nevada BAER field tour.

3. Equipment and Strategies to Enhance the Post-wildfire Establishment and Persistence of Great Basin Native Plants
Additional Cooperators: Robert Cox, Texas Tech University, Lubbock, TX; Mike Pellant, USDI BLM, Reno, NV; David Pyke, USGS Corvallis, OR; Dan Ogle, USDA NRCS Idaho State Office, Boise, ID; Loren St. John, USDA NRCS, Aberdeen Plant Materials Center, Aberdeen, ID; Beth Newingham, University of Idaho, Moscow, ID.

<u>Objectives and Methods</u>
This study further investigates the capability of the Truax Rough Rider drill and the Kemmerer rangeland drill to reestablish Wyoming big sagebrush plant communities following wildfire. The study will test seeding rates and methods for establishing Wyoming big sagebrush along with a mixture of other native grasses, forbs and shrubs. Data collection will follow methods that are currently being recommended by the USGS for BLM use as standard techniques for ES&R monitoring. 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.

Major objectives:

1) Identify seeding methodologies, planting season and seeding rates to successfully establish Wyoming big sagebrush on burned rangelands.
2) Compare establishment and persistence of native species (grasses, forbs and shrubs) seeded with a standard rangeland drill or with a minimum-till rangeland drill. Utilize

native forbs from Great Basin Native Plant Selection and Increase Project Research when possible.

3) Compare the physical impacts of the modified rangeland drill and the minimum-till drill with respect to planting residual cheatgrass (*Bromus tectorum*) or other invasive weed seeds and on recovery of residual native plants and biological soil crusts.
4) Utilize ES&R protocols being evaluated by USGS in addition to other data collected for this research to make quantitative vegetation measurements for comparing treatment effects. ES&R protocol data will be added to the ES&R database to promote future monitoring and will be available to other researchers.
5) Establish studies that will allow long-term evaluation of the effects of livestock use on ES&R mixed seedings of native grasses, forbs and shrubs
6) Compare physical and chemical characteristics of soil conditions created by the seeding treatments to provide an assessment of seedbed conditions, and document climatic conditions and variability to better assist managers in implementing successful restoration activities.

<u>2009 Activities</u>

Data collection for plots established in 2007 at the Glass Butte study site near Burns, Oregon and the Mountain Home study site near Mountain Home, Idaho was completed in late May and early June 2009. Plots at the site West of Snowville, Utah, seeded in fall 2008, were evaluated in June 2009. 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. Data collection involved up to10 field workers, and required six weeks to complete all three sites. In addition to vegetation data, soil data including dust emissions, infiltration, soil stability and soil chemistry, were collected from selected treatments and nonburned plots at the Utah site by Beth Newingham, Amy Ganguli and Ben Wissinger.

<u>Future Plans</u>

Data will be collected from the Utah field plots in late May and early June 2010. As a suitable burned site could not be located for fall 2009 seeding, the fourth site will be located in 2010 and seeded in November. Data from those plots will be collected in June 2011 and 2012.

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 as well as their impacts on biological soil crusts, residual native species and planting of cheatgrass or other weed seeds. This research should provide a better understanding of techniques that could best be used to seed Wyoming big sagebrush. 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:

Products expected from this project include continued equipment development and modification (see report by J. Truax, this document), field tours for managers and practitioners, fact sheets and brochures, a website to facilitate public access of the project information (http://www.fs.fed.us/rm/boise/research/shrub/fire.shtml), and likely publication in an agency or journal venue.

4. Calibration of Drills for Rehabilitation and Restoration Seedings on Western Wildlands

Project Manager: Lisa Outka-Perkins, USDA FS Missoula Technology and Development Center, Missoula, MT.

Additional Collaborators: Loren St. John, USDA Aberdeen Plant Materials Center, Aberdeen, ID; Jim Truax, Truax Company, New Hope, MN; USDA BLM Vale Equipment Center, Vale, OR.

Emphasis on establishment of diverse native communities to repair damaged wildlands necessitates proper calibration of drills to plant seeds at prescribed rates. Planners, operations personnel and contractors are often not fully trained in calibrating drills or aware of the options available when using newer drills with multiple seed boxes. Standard settings are often used to seed commonly planted species such as wheatgrasses through rangeland drills. However, when more complex seed mixtures are used, it is necessary to carefully calibrate each mix. Seeding at high rates wastes expensive seed and results in excessive competition among seeded species. Seeding at low rates leads to inadequate stands and leaves sites open to invasion by weeds. Agency personnel require training to administer seedings and check drill calibration. Likewise, training is needed for contractors to assure proper equipment calibration and use.

Project Status

A DVD is being developed for use in training sessions to familiarize users (land managers, contractors and others) with standard calibration procedures and seeding strategies that may be used with drills having single, double or triple seed boxes. Filming was completed in 2009. The video script and an accompanying summary of calibration methods were written. Final videography is being conducted at the USDA FS Missoula Technology and Development Center. Project completion is expected by early summer 2010.

5. Effect of Storage Temperature, Duration and Packaging Material on Wyoming Big Sagebrush Seed Viability

Additional collaborators: Robert Cox, Texas Tech University, Lubbock, TX; Robert Karrfalt, USFS National Seed Laboratory, Dry Branch, GA

Objectives and Methods

Specific objectives of the study are to answer the question, “what conditions allow long-term storage of Wyoming big sagebrush seed?” Answering this question will improve managers’ ability to seed Wyoming big sagebrush in post-fire and other restoration projects by identifying how Wyoming big sagebrush seed should be stored over the long-term, thereby allowing it to be purchased when prices are low and stored until needed for restoration activities.

To evaluate the influence of different storage conditions on the long-term viability of Wyoming big sagebrush seed, packets containing small amounts of seed (approximately 1.5g each) from five different wild locations in the Great Basin were stored at two purity levels (<30% and >60% purity) and in two types of storage bag (4mil poly-sheet and woven poly-mesh). Samples of all combinations of seed source, purity and storage material were stored at one of three storage temperatures: -12^{o}C (10^{o}F), 1.6^{o}C (35^{o}F), and ambient warehouse temperature. Therefore, the study was established in a split plot arrangement, allowing comparison of effects due to source, purity, temperature and storage bag type over a 50-month sampling period. The response variable to be evaluated is percent germination of sagebrush seed in each storage condition, measured as the average of four 100-seed germination tests. To evaluate changes in percent germination over time, tests will be done after 3, 6, 9, 12, 15, 18, 27, 36, and 48 months of storage. Overall, 270 poly-sheet and 270 poly-mesh bags will be used for this portion of the study: 5 seed sources x 2 purity levels x 3 temperatures x 9 sample dates = 270 bags of each type. On each sample date, 30 source x purity x temperature treatment bags of each type will be removed from storage and tested for percent germination and moisture content.

A separate analysis will compare source, purity, seed moisture content and storage temperature in a split-split plot arrangement. The same sampling dates and response variable will be used as in the above analysis. This will include 1,320 poly sheet bags (including the 270 from the previous analysis), representing the full factorial of 5 seed sources x 2 purity levels x 4 moisture contents x 3 storage temperatures x 9 sampling dates. On each sampling date, 120 bags representing the source x purity x moisture content x storage temperature factorial will be removed from storage and tested to determine percent germination and moisture content. Therefore, a total of 1,080 bags will be stored during the study, with 150 bags sampled on each sampling date (a total of 120 poly-sheet bags and 30 poly-mesh bags will be sampled on each date; 30 of the poly-sheet bags will be used in both analyses).

<u>2009 Activities</u>
In 2009, seedlots at each storage condition were tested for germination viability in April. Along with germination tests of each seedlot, temperature, moisture content and packaging type combination, moisture content has also been tested and recorded.

<u>Future Plans</u>
Germination and moisture tests of each seed packet will continue every 12 months for the remainder of the study (approximately 4 years, or until viability reaches zero). Forbs of the Asteraceae family being considered for inclusion on the GBNPSIP species list may be added to this study to determine whether duration of viability may be a consideration in their use.

Management Applications:
Land managers, seed producers and vendors, and restoration planners will benefit by using the information produced by this study to understand how sagebrush seed may be stored to improve long-term viability of the seed. The ability to store Wyoming big sagebrush seed over longer periods will help to ameliorate the greatest logistical obstacles to restoring this species: unpredictable supply and demand for the seed, which results in high seed prices, and the need to use late-fall ripened seed quickly.

Products:
Products expected from this project include fact sheets and brochures and likely publication in an agency or journal venue.

7. Native Forb Seedling Establishment
Additional Collaborators: Nicholas Williams, Erin Denney and Matthew Fisk, USDA Forest Service, Rocky Mountain Research Station, Boise, ID.

Objectives and Methods
Although considerable research has been conducted on cultural practices for native forbs being developed for restoration use by the GBNPSIP, data on field seeding techniques and success are lacking. Species included in the study consist of *Achillea millefolium, Agoseris grandifolia, Eriogonum umbellatum, Lomatium triternatum, Penstemon deustus* and *Penstemon speciosus*. Objectives of this field and laboratory study are to examine: 1) timing and percentage of field germination, 2) distribution of seed by depth as a result of the seeding technique, 3) phenological and morphological development of seedlings, 4) seedling survival and establishment, and 5) effects of annual weather conditions on seedling emergence, growth and survival.

2009 Activities
Small plots (1 x 3m, 5 replications) were seeded at the rate of 300 PLS/m^2 in November 2009 in the Skate Fire (summer 2009 burn) at the northwest edge of Boise, ID. Soil samples were taken from the surface, 1 and 2cm depths following seeding to examine seed distribution in the soil. Samples were germinated in the laboratory to determine seed distribution.

Future Plans
Seedings will be repeated over a 3-year period to assess the impacts of annual weather conditions on germination and seedling growth and survival.

Management Applications:
Land managers require information on performance of native forbs in wildland seedings in order to begin using them effectively in seedings.

Meetings and Field Days
Organized GBNPSIP annual meeting, 2009 March 31, Boise, ID.

Co-organizer, Revegetation Technology and Equipment Council 2009 workshop: GPS Applications for Revegetation, Society for Range Management Annual Meeting, 2009 February 8, Albuquerque, NM.

Co-organizer: Workshop: Developing a successful native plant materials program, 2009 April 1-2. USDA FS RMRS GBNPSIP and USDI BLM Great Basin Restoration Initiative.

Co-organizer: Workshop: sustaining vegetative landscapes in the West: interactions with climate change. Ecological Society of America Annual Meeting, 2009 August 30, Albuquerque, NM.

Toured with members of Senator Harry Reid's staff and Mike Pellant, BLM, in the Boise area to discuss cheatgrass, fire and restoration issues, 2009 April 15.

Nevada BLM ES&R annual meeting, 2009 April 21-23, Elko, NV. Provided field tour discussion on drill seeding study.

GBNPSIP Exhibit/Poster Displays

- Society for Range Management 62nd Annual Meeting, 2009 February 8-12, Albuquerque, NM.
- GBNPSIP annual meeting, 2009 March 31, Boise, ID.
- Workshop: Developing a successful native plant materials program, 2009 April 1-2, Ontario Idaho
- Summer Farm Festival and Oregon State University, Malheur Experiment Station Field Day, 2009 July 8, Ontario, OR.

Publications:

Hardegree SP; Jones, TA; Monaco, TA; Roundy, BA; Shaw, NL; Moffet, CA; Redente, EF. Assessment of range planting as a conservation practice. U.S. Department of Agriculture, Natural Resources Conservation Service, Conservation Effects Assessment Project Project. (in review)

Hild, AL; Shaw, NL; Paige, GB; Williams, MI. 2009. Integrated reclamation: approaching ecological function? p. 578-596. In: Barnhisel, RI, ed. 2009. National Meeting of the American Society of Mining and Reclamation. Revitalizing the environment: proven solutions and innovative approaches. 2009 May 30 – June 5, Billings, MT. Lexington, KY: American Society of Mining and Reclamation. http://www.treesearch.fs.fed.us/pubs/33648

Karrfalt, R; Shaw, NL. Ten steps to a successful native plant materials program (in review).

Parkinson, H.; Zabinski, C; Shaw, N. Growth characteristics of six forbs selected for revegetation in the Great Basin. Research Note. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. (in revision)

Parkinson, H.; Zabinski, C; Shaw, N. The effects of native grasses and cheatgrass on the growth of five Great Basin forbs. Research Note. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. (in revision)

Parkinson, H.; Zabinski, C; Shaw, N. The response of four Great Basin forbs to increasing densities of cheatgrass. Research Note. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. (in revision)

Scholten, M; Donahue, J; Shaw, NL; Serpe, MD. 2009. Environmental regulation of dormancy loss in *Lomatium dissectum* (Apiaceae) seeds. Annals of Botany 103:1091-1101. http://www.treesearch.fs.fed.us/pubs/32868

Shaw, NL; Pellant, M, eds. 2009. Great Basin Native Plant Selection and Increase Project FY08 progress report. Boise, ID: USDA Forest Service, Rocky Mountain Research Station, Grassland, Desert and Shrubland Research Program. 170 p. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/2008_Progress_Report.pdf, http://www.treesearch.fs.fed.us/pubs/33646

Shock, CC; Feibert, EBG; Saunders, LD; Shaw, N. 2009. Native wildflower seed production with limited subsurface drip irrigation. Oregon State University Agricultural Experiment Station, Special Report 1094:157-176.
http://www.cropinfo.net/AnnualReports/2008/NativeWildflowerSeedProductionWithLimitedDripIrrigation.html, http://www.treesearch.fs.fed.us/pubs/33645

Shock, CC; Feibert, EBG; Shaw, N. 2009. Native perennial forb tolerance to rate and mixtures of postemergence herbicides. Oregon State University Agricultural Experiment Station, Special Report 1094:177-179.
http://www.cropinfo.net/AnnualReports/2008/NativeForbToleranceToPostemergenceHerbicides.html, http://www.treesearch.fs.fed.us/pubs/33644

Shock, CC; Ishida, J; Feibert, EBG; Shaw, N. 2009. Native perennial forb tolerance to repeated annual applications of postemergence herbicides. Oregon State University Agricultural Experiment Station, Special Report 1094:180-184.
http://www.cropinfo.net/AnnualReports/2008/NativeForbToleranceToRepeatedAnnualPostEmergenceHerbicides.html, http://www.treesearch.fs.fed.us/pubs/33643

St. John, L; Ogle, D; Shaw, N. 2009. Hotrock penstemon plant guide. Aberdeen, ID: U.S. Department of Agriculture, Natural Resources Conservation Service, Aberdeen Plant Materials Center. 3 p. ftp://ftp-fc.sc.egov.usda.gov/ID/programs/plant/hotrock.pdf, http://www.treesearch.fs.fed.us/pubs/33642

St. John, L; Ogle, D; Shaw, N. 2009. Sharpleaf penstemon plant guide. Aberdeen, ID: U.S. Department of Agriculture, Natural Resources Conservation Service, Aberdeen Plant Materials Center. 3 p. http://www.treesearch.fs.fed.us/pubs/32623

Tilley, DJ; Ogle, D; St. John, L; Shaw, N. 2009. Royal penstemon plant guide. Aberdeen, ID: U.S. Department of Agriculture, Natural Resources Conservation Service, Aberdeen Plant Materials Center. 3 p. http://www.plant-materials.nrcs.usda.gov/pubs/idpmcpg8289.pdf, http://www.treesearch.fs.fed.us/pubs/33641

Presentations and Posters:

Cox, RD, NL Shaw, and M Pellant. 2009. The effectiveness of rangeland and minimum-till seed drills for large-scale restoration of sagebrush wildlands. Ecological Society of America Annual Meeting, 2009 August 2-7, Albuquerque, NM. Presentation. Abstract.

Hardegree, SP, BA Roundy, NL Shaw, CA Moffet, TA Monaco, TA Jones, and EF Redente. 2009. Assessment of range planting as a conservation practice. Conservation Effects Assessment Project Symposium. Society for Range Management 62nd Annual Meeting, 2009 February 8-12, Albuquerque, NM. Presentation. Abstract.

Hild, AL, NL Shaw, G Paige, and M Williams. 2009. Integrated reclamation: approaching ecological function? 26th Annual American Society of Mining and Reclamation Meeting and 11th Billings Land Reclamation Symposium, 2009 May 30 – June 5, Billings, MT. Presentation. Abstract.

Jensen, SL, C Jones and NL Shaw. 2009. Plant Materials available for Great Basin Ecoregions. Workshop: Developing a Successful Native Plant Program, 2009 April 1-2, Ontario, OR. Presentation.

Karrfalt, R. and N Shaw. 2009. Long-term storage for Wyoming big sagebrush. Workshop: Developing a Successful Native Plant Program, 2009 April 1-2, USDA FS RMRS GBNPSIP and USDI BLM GBRI, Ontario, OR. Poster.

Newingham, BA, AC Ganguli, and NL Shaw. 2009. Comparing the effects of fire and restoration drilling on soil properties n the Great Basin. Great Basin Native Plant Selection and Increase Project meeting, 2009 March 31, Boise, ID. Presentation.

Shaw, NL. 2009. Evaluation of native plant materials for the Great Basin. Society for Ecological Restoration International Meeting, 2009 August 23-29, Perth, Western Australia. Presentation. Abstract.

Shaw, N. 2009. Native plant materials and seeding strategies for the Great Basin. USDI Nevada Annual ES&R Meeting, 2009 April 21-23, Elko, NV. Presentation.

Shaw, N, R Cox, A Ganguli, and J Truax. 2009. Seeding strategies and equipment for re-establishing Wyoming big sagebrush communities. Great Basin Native Plant Selection and Increase 2009 Annual Meeting, 2009 March 31, Boise, ID. Presentation.

Shock, C, E Feibert, L Saunders, and N Shaw. 2009. Do these plants need water? Great Basin Native Plant Selection and Increase 2009 Annual Meeting, 2009 March 31, Boise, ID. Presentation.

Shock, C, E Feibert, L Saunders, and N Shaw. 2009. Where did all the weeds go? Great Basin Native Plant Selection and Increase 2009 Annual Meeting, 2009 March 31, Boise, ID. Presentation.

Shock, CC, EBG Feibert, LD Saunders, NL Shaw, SK Mohan, and RK Sampangi. 2009. Desert Parsley (*Lomatium* spp.) seed production challenges. Workshop: Developing a Successful Native Plant Program, 2009 April 1-2, USDA FS RMRS GBNPSIP and USDI BLM GBRI, Ontario, OR. Poster.

Shock, CC, EBG Feibert, LD Saunders, NL Shaw, SK Mohan, and RK Sampangi. 2009. Irrigation and mechanization for seed production of sulfur-flower buckwheat, a native forb. Workshop: Developing a Successful Native Plant Program, 2009 April 1-2, USDA FS RMRS GBNPSIP and USDI BLM GBRI, Ontario, OR. Poster.

Shock, CC, EBG Feibert, LD Saunders, NL Shaw, SK Mohan, and RK Sampangi. 2009. Sharpleaf and sagebrush penstemon seed yield response to irrigation. Developing a successful native plant program. Workshop: Developing a Successful Native Plant Program, 2009 April 1-2, USDA FS RMRS GBNPSIP and USDI BLM GBRI, Ontario, OR. Poster.

St. Clair, B, RC Johnson, and N Shaw. 2009. Genetic diversity and genecology of bluebunch wheatgrass. Great Basin Native Plant Selection and Increase 2009 Annual Meeting, 2009 March 31, Boise, ID. Presentation.

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

Project: Truax Company, Inc, New Hope, MN

Principal Investigators and Contact Information:

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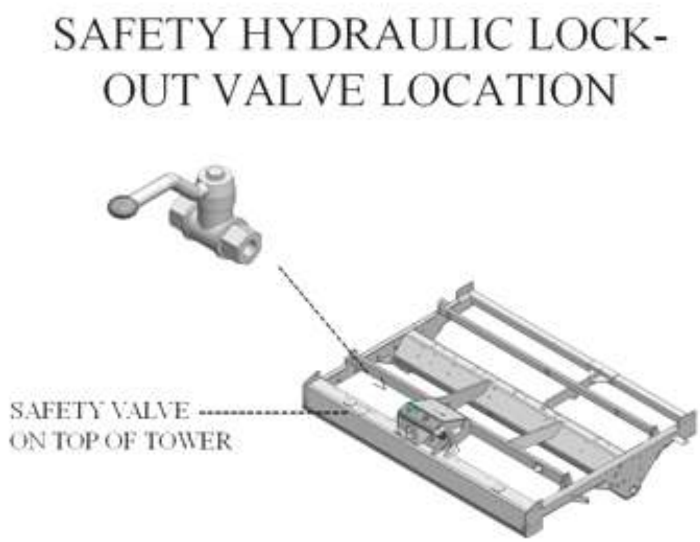
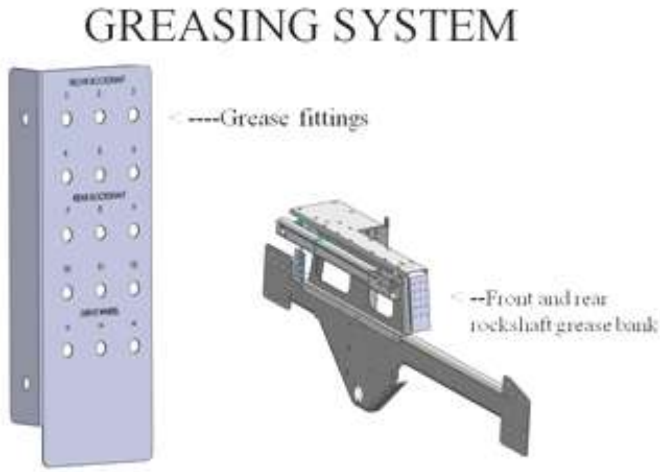
Project Description:
The evolution of the Roughrider continued during 2009 and additional developments will evolve in the future. During the last year, effort was focused primarily on three areas: transport safety, planter parallelograms and seed metering.

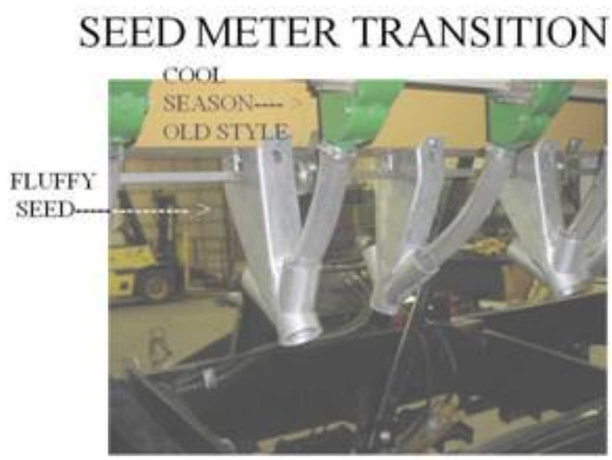
1. A hydraulic valve was added between the quick disconnects and the float adjustment valve to prevent the planters from dropping to the ground in the event there is a catastrophic failure of hydraulic hoses between the drill and the towing vehicle.



2. A centralized greasing system was added to allow all servicing to be done without the operator having to crawl under and around the planters and rockshaft. A grease bank is now mounted under the speed changer for easy access.



3. The seed meter transition for the fluffy seed box has been redesigned to include an angled delivery spout that helps straighten the seed tube from the seed box to both ranks of planter boots.



4. The seed meter cup for the cool season box has been redesigned to include two spouts and an integral gate to direct the seed flow to either spout. Two important advantages can be achieved with this design. First, each spout is angled so as to direct the seed in a straighter line to double- rank drills. Secondly, the gate allows the operator to cut delivery from in-row planting next to the disc to a second tube that can broadcast without disassembly of the hoses.

5. Early production planters utilize a three bar parallelogram which has been changed to a four bar style in order to help stabilize the unit. When planting on side hills and especially rough terrain, this improvement prevents frame breakage.

In addition to these improvements work continues on the gauge wheel that is bolted to the planting disc. It is hoped that by bonding urethane directly to steel we can achieve a gauge wheel that won't pull away from the planting disc when planting into mud and snow. Developmental work is being done on a retainer to hold the small drive wheel in contact with the large end wheel when planting rough sites. Lastly, an effort is being made to monitor and prevent plugging of the seed tubes in muddy conditions.

Continuous input from the field regarding problems and suggestions for change are requested.

Presentations:
Truax, Jim. 2009. Truax Roughrider Drill – Purpose and Evolution. Developing a Successful Native Plant Program Workshop, 2009 April 1-2; Ontario, OR.

Truax, Jim; Breyer, Dwayne. Drill seeding – calibration for seeding multi-species mixes. Developing a Successful Native Plant Program Workshop, 2009 April 1-2; Ontario, OR.
Field demonstation.

Shaw, Nancy; Cox, Robert; Ganguli, Amy; Newingham, Beth; St. John, Loren; Ogle, Dan; Truax, Jim. Seeding strategies and equipment for re-establishing Wyoming big sagebrush communities. Great Basin Native Plant Selection and Increase Annual meeting. March 31, 2009; Boise, ID.

Consultations:
Edited script and provided recommendations for filming a video on calibration of rangeland drills being prepared by the USDA Forest Service, Missoula Technology and Development Center, Missoula, MT.

Assisted with USDA ARS, U.S. Sheep Experiment Station/NRCS Aberdeen Plant Materials Center crested wheatgrass diversification seeding near Aberdeen, ID.

Project Title: Establishment of Native Forbs Following Mechanical Soil Disturbance in Wyoming Big Sagebrush Communities in the Great Basin

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

Principal Investigators and Contact Information:

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Project Description:

Currently, seed mixes used for restoration generally do not include native forbs, mainly due to their high cost. Because these species have not been included in past restoration efforts there is a lack of information about planting and establishing native forbs in wildland settings. As these native forbs become more available on the market, the lower costs will facilitate land managers' ability to include these species in seed mixes used for restoration. This creates a need to determine the best methods of establishing native forbs in wildland settings. The main objective of this study is to evaluate native forb establishment in Wyoming big sagebrush communities using four different mechanical planting methods.

<u>Methods</u>

This study was established on two sites (referred to as North and South) in Tooele County, Utah. Each site has four complete treatment blocks. Two of which were treated in 2008 and two that were replications treated in 2009. Each block includes five randomly placed treatments. The five treatments included an untreated control, broadcast seeding followed by a Lawson aerator, broadcast seeding followed by a Dixie harrow, broadcast seeding followed by an Ely chain and a rangeland drill seeding using a Truax drill. The seed mix used for the study consisted of only native forbs (Table 1).

Table 1. Seed mix used on the project.

Species	Rate (bulk lbs/acre)
Munro Globemallow (*Sphaeralcea munroana*)	0.5
Blue Flax (*Linum lewisii*)	1.0
Northern Sweetvetch (*Hedysarum boreale*)	1.0
Silvery Lupine (*Lupinus argenteus*)	1.5
Palmer Penstemon (*Penstemon palmeri*)	0.5
Utah Milkvetch (*Astragalus utahensis*)	0.6
Arrowleaf Balsamroot (*Balsamorhiza sagittata*)	2.0
Firecracker Penstemon (*Penstemon eatonii*)	0.29
Tapertip Hawksbeard (*Crepis acuminata*)	0.16
Total	**7.55**

Data Collection

Data from the 2008 treated blocks was collected in June 2009. Five permanently established 100 ft. belts were positioned in a stratified random design along a 100 ft transect in each treatment plot. A total of 100 subsamples were collected from each plot. Percent cover of all shrubs, grasses and forbs was collected using a modified Daubenmire cover class method. Density data of all perennial species was also collected. Data will be collected each year for 3-5 years following treatment.

Results

One year after treatment there were no significant differences in seeded species density between treatments. The density of seeded species between sites however was significantly different. The average density of seeded species on the North site is 0.04 plants/m^2 and on the South site the density is 0.004 plants/m^2. While establishing native forbs into a Wyoming big sagebrush community was the main objective of this project it is also important to look at how the mechanical treatments affected other components in the community. Average sagebrush cover on the control plot was 10.7%. After treating with the mechanical treatment, aerator, chain, drill, or harrow, the average cover of sagebrush decreased to 3%, 5.6%, 7.6% and 1.5%, respectively. Conversely, the average percent cover of bare ground went from 35.4% on the control plots to 54.2% on the aerator plots, 52.6% on the chained plots, 41.4% on the drill plots and nearly doubled to 62% on the harrow plots. The difference in cover of annual species was not significant by treatment; however the trend shows that the harrow treatment resulted in higher percent cover of annual species (Fig. 1).

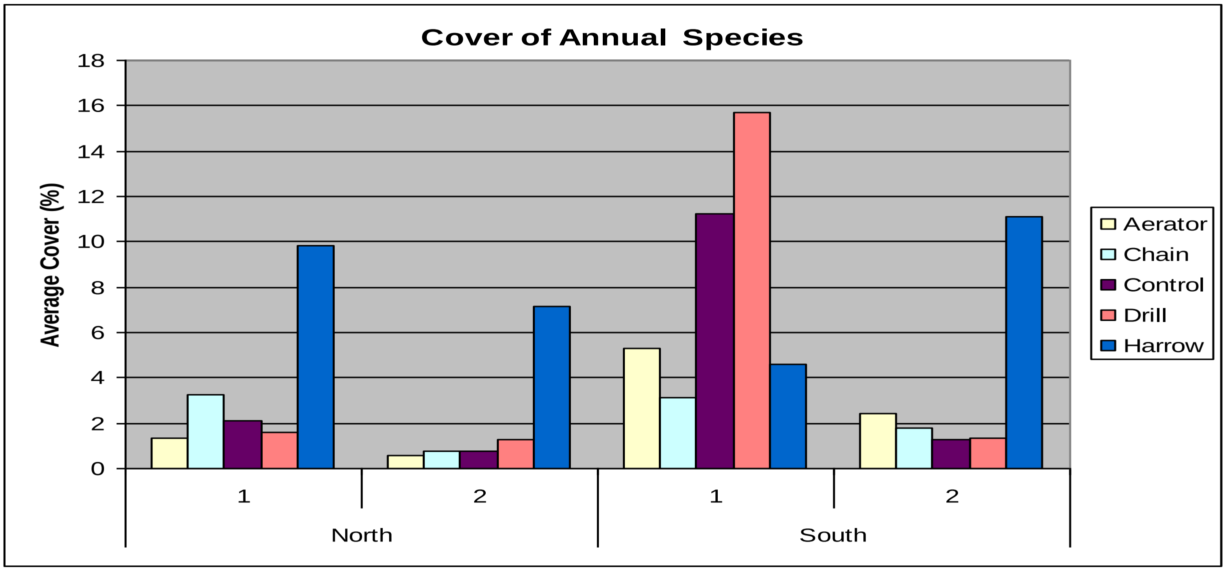

Figure 1. Average percent cover of all annual species separated out by site and block.

Management Applications:
With just one year of data, and no significant difference between data, it is difficult to make any definite management suggestions. However, looking at the trend of the density data for the seeded species, the broadcast treatment followed by the Ely chain appears to be the most successful at establishing native forbs. When selecting a mechanical implement to reseed native forbs into a Wyoming big sagebrush community, consider how much of the sagebrush should be removed. The other management implication that can be drawn from the data at this point is that more disturbance can result in higher annual species cover. The mechanical treatment that caused the most disturbance was the Dixie harrow treatment; perhaps not the most ideal treatment method if there are a lot of annuals present on the site. As we continue to collect more data over the next several years the results will provide us with better guidelines for seeding native forbs in Wyoming big sagebrush communities.

Products:
This study will provide guidelines for planting native forbs in Wyoming big sagebrush communities. Results will be reported through symposia, workshops and appropriate publications.

Presentations:
Jensen, Scott L.; Jones, Covy; Vernon, Jason; Summers, Danny. The quest for natives: Cultural practices, species screening, harvesting equipment and private growers. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2009 March 31; Boise, ID.

Appendix I. Research species and their occurrence in Great Basin states.

Family Species	Common Name	Idaho	Nevada	Oregon	Utah
Apiaceae	**Carrot Family**				
Lomatium dissectum	Fernleaf biscuitroot	✓	✓	✓	✓
Lomatium grayi	Gray's biscuitroot	✓	✓	✓	✓
Lomatium nudicaule	Barestem biscuitroot	✓	✓	✓	✓
Lomatium triternatum	Nineleaf biscuitroot	✓	✓	✓	✓
Perideridia bolanderi	Bolander's yampah	✓	✓	✓	✓
Asteraceae	**Sunflower or Aster Family**				
Achillea millefolium	Western yarrow	✓	✓	✓	✓
Agoseris grandiflora	Bigflower agoseris	✓	✓	✓	✓
Agoseris heterophylla	Annual agoseris	✓	✓	✓	✓
Artemisia tridentata tridentata	Basin big sagebrush	✓	✓	✓	✓
Artemisia tridentata vaseyana	Mountain big sagebrush	✓	✓	✓	✓
Artemisia tridentata wyomingensis	Wyoming big sagebrush	✓	✓	✓	✓
Balsamorhiza hookeri	Hooker balsamroot	✓	✓	✓	✓
Balsamorhiza sagittata	Arrowleaf balsamroot	✓	✓	✓	✓
Blepharipappus scaber	Rough eyelashweed	✓	✓	✓	
Chaenactis douglasii	Douglas false-yarrow	✓	✓	✓	✓
Crepis acuminata	Tapertip hawksbeard	✓	✓	✓	✓
Crepis intermedia	Gray hawksbeard	✓	✓	✓	✓
Crepis occidentalis	Western hawksbeard	✓	✓	✓	✓
Enceliopsis nudicaulis	Nakedstem sunray	✓	✓		✓
Erigeron speciosus	Aspen Fleabane	✓	✓	✓	✓

Asteraceae continued		**Idaho**	**Nevada**	**Oregon**	**Utah**
Eriophyllum lanatum	Oregon sunshine	✓	✓	✓	✓
Gaillardia aristata	Common gaillardia	✓		✓	✓
Heliomeris multiflora multiflora	Showy goldeneye	✓	✓		✓
Heliomeris multiflora nevadense	Nevada goldeneye		✓		✓
Heterotheca villosa	Hairy false goldenaster	✓	✓	✓	✓
Machaeranthera canescens	Hoary aster	✓	✓	✓	✓
Wyethia amplexicaulis	Mule-ears	✓	✓	✓	✓
Boraginaceae	**Borage Family**				
Amsinckia menziesii var. *intermedia*	Common fiddleneck	✓	✓	✓	✓
Amsinckia tessellata	Bristly fiddleneck	✓	✓	✓	✓
Lappula occidentalis	Flatspine stickseed	✓	✓	✓	✓
Plagiobothrys tenellus	Pacific popcornflower	✓	✓	✓	✓
Brassicaceae	**Mustard Family**				
Descurainia pinnata	Western tansymustard	✓	✓	✓	✓
Capparaceae	**Caper Family**				
Cleome lutea	Yellow beeplant	✓	✓	✓	✓
Cleome serrulata	Rocky Mountain beeplant	✓	✓	✓	✓
Fabaceae	**Legume Family**				
Astragalus eremiticus	Hermit milkvetch	✓	✓	✓	✓
Astragalus filipes (*A. stenophyllus*)	Threadstalk milkvetch	✓	✓	✓	✓
Dalea ornata	Prairie clover	✓	✓	✓	
Dalea searlsiae	Searl's prairie clover		✓		✓
Lupinus arbustus	Longspur lupine	✓	✓	✓	✓

Fabaceae continued		**Idaho**	**Nevada**	**Oregon**	**Utah**
Lupinus argenteus	Silvery lupine	✓	✓	✓	✓
Lupinus caudatus	Tailcup lupine	✓	✓	✓	✓
Lupinus polyphyllus	Bigleaf lupine	✓	✓	✓	
Lupinus sericeus	Silky lupine	✓	✓	✓	✓
Hydrophyllaceae	**Waterleaf Family**				
Phacelia hastata	Silverleaf phacelia	✓	✓	✓	✓
Phacelia linearis	Threadleaf phacelia	✓	✓	✓	✓
Lamiaceae	**Mint Family**				
Agastache urticifolia	Nettleleaf giant hyssop	✓	✓	✓	✓
Liliaceae	**Lily Family**				
Allium acuminatum	Tapertip onion	✓	✓	✓	✓
Linaceae	**Flax Family**				
Linum lewisii	Blue flax	✓	✓	✓	✓
Loasaceae	**Loasa Family**				
Mentzelia veatchiana	Veatch's blazingstar		✓	✓	
Malvaceae	**Mallow Family**				
Sphaeralcea ambigua	Globemallow		✓		✓
Sphaeralcea coccinea	Scarlet globemallow	✓	✓	✓	✓
Sphaeralcea grossulariifolia	Gooseberryleaf globemallow	✓	✓	✓	✓
Sphaeralcea munroana	Munro globemallow	✓	✓	✓	✓
Sphaeralcea parvifolia	Small-flower globemallow		✓		✓
Papaveraceae	**Poppy Family**				
Argemone munita	Flatbud pricklypoppy	✓	✓	✓	✓

Poaceae	Grass Family			
		Idaho	Nevada	Oregon	Utah
Achnatherum hymenoides	Indian ricegrass	✓	✓	✓	✓
Achnatherum thurberianum	Thurber's needlegrass	✓	✓	✓	✓
Elymus elymoides	Bottlebrush squirreltail	✓	✓	✓	✓
Hesperostipa comata	Needle and thread	✓	✓	✓	✓
Leymus cinereus	Great Basin wildrye	✓	✓	✓	✓
Poa secunda	Sandberg bluegrass	✓	✓	✓	✓
Pseudoroegneria spicata	Bluebunch wheatgrass	✓	✓	✓	✓
Polemoniaceae	**Phlox Family**				
Eriastrum sparsiflorum	Great Basin woollystar	✓	✓	✓	✓
Ipomopsis aggregata	Scarlet gilia	✓	✓	✓	✓
Polygonaceae	**Buckwheat Family**				
Eriogonum heracleoides	Wyeth buckwheat	✓	✓	✓	✓
Eriogonum microthecum	Slender buckwheat	✓	✓	✓	✓
Eriogonum ovalifolium	Cushion buckwheat	✓	✓	✓	✓
Eriogonum sphaerocephalum	Rock buckwheat	✓	✓	✓	
Eriogonum sphaerocephalum var. sphaerocephalum	Rock buckwheat	✓	✓	✓	
Eriogonum umbellatum	Sulfur-flower buckwheat	✓	✓	✓	✓
Scrophulariaceae	**Snapdragon Family**				
Penstemon acuminatus	Sharpleaf penstemon	✓	✓	✓	
Penstemon cyaneus	Blue penstemon	✓			
Penstemon deustus	Scabland penstemon	✓	✓	✓	✓
Penstemon pachyphyllus	Thickleaf penstemon		✓		✓
Penstemon speciosus	Royal penstemon	✓	✓	✓	✓

Appendix II. Great Basin Native Plant Selection and Increase Project 2009 seed collections

Species	Common Name	No. Collections
Achnatherum thurberianum	Thurber needlegrass	37
Agastache urticifolia	Nettleleaf giant hyssop	1
Agoseris spp.	Agoseris	2
Agoseris heterophylla	Annual agoseris	1
Allium spp.	Onion	1
Amsinckia spp.	Fiddleneck	3
Amsinckia intermedia	Common fiddleneck	1
Amsinckia tesselata	Bristly fiddleneck	2
Argemone munita	Flatbud pricklypoppy	2
Artemisia tridentata	Big sagebrush	4
Artemisia tridentata tridentata	Basin big sagebrush	24
Artemisia tridentata vaseyana	Mountain big sagebrush	21
Artemisia tridentata wyomingensis	Wyoming big sagebrush	18
Astragalus filipes	Threadstalk milkvetch	7
Balsamorhiza hookeri	Hooker balsamroot	8
Balsamorhiza sagittata	Arrowleaf balsamroot	4
Blepharipappus scaber	Rough eyelashweed	3
Chaenactis spp.	False-yarrow	1
Chaenactis douglasii	Douglas false-yarrow	6
Cleome serrulata	Rocky Mountain beeplant	1
Crepis acuminata	Tapertip hawksbeard	3
Crepis occidentalis	Western hawksbeard	1
Cryptantha spp.	Cryptantha	1
Dalea ornata	Western prairie clover	8
Dalea searlsiae	Searl's prairie clover	6
Descurainia pinnata	Western tanseymustard	1
Enceliopsis nudicaulis	Nakedstem sunray	3
Epilobium brachycarpum	Tall annual willowherb	1
Eriastrum sparsiflorum	Great Basin woollystar	1
Eriogonum heracleoides	Wyeth buckwheat	11
Eriogonum ovalifolium	Cushion buckwheat	2

Eriogonum umbellatum	Sulfur-flower buckwheat	17
Frasera albomarginata	Desert frasera	2
Gilia spp.	Gilia	1
Heliomeris multiflora var. *nevadensis*	Nevada goldeneye	6
Hesperostipa comata	Needle and thread	6
Ipomopsis aggregata	Scarlet gilia	6
Lappula occidentalis	Flatspine stickseed	1
Leymus cinereus	Great Basin wildrye	4
Linum lewisii	Lewis flax	3
Linum subteres	Sprucemont flax	1
Lomatium spp.	Biscuitroot	1
Lomatium dissectum	Fernleaf biscuitroot	8
Lomatium grayi	Gray's biscuitroot	1
Lomatium nudicaule	Nakedstem biscuitroot	4
Lomatium triternatum	Nineleaf biscuitroot	9
Lupinus spp.	Lupine	2
Lupinus arbustus	Longspur lupine	2
Lupinus argenteus	Silvery lupine	2
Lupinus malacophyllus	Jawleaf lupine	1
Lupinus prunophilus	Hairy bigleaf lupine	1
Lupinus sericeus	Silky lupine	2
Machaeranthera canescens	Hairy false goldenaster	9
Mentzelia spp.	Blazingstar	3
Nicotiana attenuata	Coyote tobacco	4
Oenothera caespitosa	Tufted evening primrose	1
Penstemon spp.	Penstemon	4
Penstemon acuminatus	Sharpleaf penstemon	12
Penstemon deustus	Scabland penstemon	8
Penstemon eatonii	Firecracker penstemon	1
Penstemon pachyphyllus	Thickleaf penstemon	3
Penstemon speciosus	Royal penstemon	9
Phacelia crenulata	Cleftleaf wildheliotrope	1
Phlox longifolia	Longleaf phlox	1
Plectritis spp.	Seablush	1
Poa secunda	Sandberg bluegrass	1

Pseudoroegneria spicata	Bluebunch wheatgrass	1
Sphaeralcea grossulariifolia	Gooseberryleaf globemallow	2
Sphaeralcea coccinea	Scarlet globemallow	2
Sphaeralcea munroana	Munro globemallow	4
Thelypodium milleflorum	Manyflower thelypodium	2
TOTALS:	**71 species**	**334 collections**

Appendix III. Stock Seed Production Contract

Utah Crop Improvement Association

4855 Old Main Hill
Logan, Utah 84322-4855

Email: ucia@mendel.usu.edu
Website: www.utahcrop.org

Phone: 435.797.2082
Fax: 435.797.0642

Stock Seed Production Contract

This agreement is entered into by and between the **Utah Crop Improvement Association** located in Logan, Utah hereinafter referred to as UCIA and **(fill in name)** hereinafter referred to as Seed Grower. This agreement entered into on (date). This contract shall be in force for period of (00) years. Commencing (date), and ending (date).

Seed Grower: **Email:**

Contract Number: UCIA 0001

Address:

City/State: **Phone:**

Stock Seed Details:

Species	
Common Name	
Variety Name/Germplasm ID	
Certification Class or PVG Category and Generation	
Stock Seed Lot # and Quantity (lb)	

Note: As a prerequisite for accepting the stock seed listed above the seed grower acknowledges the following terms, conditions, and agreements for seed production and buy-back by UCIA for distribution as stock seed for the purpose of additional seed field production. Specific alterations or options as noted in the following Terms and Agreements may be listed in the Addendum section and duly initialed by both parties.

TERMS AND AGREEMENTS:

UCIA agrees to**:**

1. Provide stock seed or other propagative materials for planting of seed field. Sale price of stock seed will be determined by UCIA with input from the entity providing the seed, and may in some cases be provided free of charge.
2. Purchase ___________lb PLS of seed produced by the Seed Grower at $________ /lb PLS. If the total amount of seed produced in the first harvest is less than that specified in this contract, the

seed grower shall provide at least 50% of the seed produced from each year's production until the amount specified is met. To account for price differences from year to year the price may be renegotiated. The renegotiated price must be within 25% of the UCIA Standardized Market Price (SMP*).

3. Allow the Seed Grower the first option to purchase up to ___% of the seed sold to UCIA so long as it shall be used to expand the Seed Grower's seed fields or for seed production elsewhere. Such seed may not be downgraded and/or sold commercially.
4. Pay for shipping and seed analysis costs. If the seed is not conditioned when purchased by the UCIA the Seed Grower may be charged for conditioning costs.
5. Negotiate on a case by case basis the payment of establishment costs for species that require more than one year after seedling establishment for plants to produce seed, or require special processes for establishment (e.g., greenhouse seedling production and/or transplanting). The establishment advance shall be deducted from the purchase price when seed is sold to the UCIA unless other arrangements are specifically negotiated.

The **SEED GROWER** agrees to

1. Plant the seed provided within one year of delivery or return it to UCIA. Late summer planting is preferred but seed may be dormant seeded or spring planted (or other specified planting method) if mutually agreed by UCIA and Seed Grower.
2. Plant the seed at the recommended, appropriate rate for seed production, unless it is mutually agreed that the suggested seeding rate is not reasonable, needed or possible.
3. Ensure that the field is entered into certification through the applicable official Seed Certification Agency and pay all associated fees (e.g., seedling inspections, crop inspection, seed sampling, testing, and tagging).
4. Make a reasonable effort to ensure that the seed crop meets certification standards and requirements. Examples are planting in rows, controlling weeds and volunteer crops, roguing off types, maintaining proper isolation distances, avoiding contamination during harvest and conditioning, etc.
5. Provide the UCIA, upon request, any and all applicable seedling or other field inspection reports, conditioning reports, seed sample analysis reports, etc. completed during the certification and conditioning process.
6. Be timely in irrigation, weed control, harvesting, and all other agronomic practices required for seed production within the Seed Growers control.
7. Accept the risk associated with seed production, including the additional risk associated with growing forb, shrub or grass species for which agronomic practices may not be fully defined.
8. Contact UCIA regarding seed availability for UCIA purchase under this contract before seed is otherwise offered for sale or otherwise utilized.
9. Make all reasonable efforts to preserve the lowest numeric generation possible while producing the seed. If the generation of seed produced cannot be maintained at the next sequential level of the original stock seed due to volunteers, loss of stand, or isolation requirements, the seed grower shall inform the UCIA. If one or more generations are lost due to these conditions the above purchase price may be renegotiated.
10. Notify UCIA of any intentions to remove field from production before such action is taken, in order to allow for reasonable renegotiation of contract; it is anticipated that the stand life of any perennial species seed field will be for at least the number of years specified in the contract.

It is **MUTUALLY AGREED** that:

1. UCIA may purchase additional seed as needed and available. Amount and purchase price of

additional seed may be renegotiated, but must be within 25% of the UCIA SMP.

2. Seed produced in excess of the contracted purchase amount may be sold commercially as the eligible or downgraded class or generation of certified seed.
3. Seed quality standards for individual species including purity, viability, weed seed, and diseased seed may be mutually defined by the two parties before signing of this contract. Seed not meeting such standards may be purchased at the discretion of the UCIA.
4. Failure to abide by the terms of this contract can disqualify the grower from receiving consideration for additional seed lots.

Performance:
The Seed Grower, without consent of the UCIA, may not assign performance of this contract. This contract is binding upon heirs, successors, and administrators or assignees as the original parties are now bound.

Crop Failure:
In the event there is a crop failure the Seed Grower waives compensation for his services and use of the land. Neither Seed Grower nor UCIA will be liable for failure to perform the contract if crop failure is due to acts of God, inclement weather, fires, or other causes beyond reasonable control.

Payment:
Payment for seed grown by the Seed Grower shall be made upon completion of final seed conditioning, testing, and delivery. Payment shall be made within 30 days after delivery of seed to UCIA. Negotiated establishment costs (item UCIA 5. above) will be paid within 30 days of the determination of stand establishment.

***SMP** is updated yearly by UCIA with a survey of estimated prices obtained from numerous seed growers, conditioners, dealers, and buyers that provide a representative estimate of current end use seed prices.

Signatures:

________________________________ (Seed Grower) ______ Date

________________________________ (UCIA) ______Date

Addendums:____
____
____
____
____
____

Initialed by Seed Grower _______Date_____ UCIA______ Date_____