Great Basin Native Plant Selection and Increase Project FY08 Progress Report

USDI Bureau of Land Management, Great Basin Restoration Initiative
USDA Forest Service, Rocky Mountain Research Station, Grassland, Shrubland and Desert Ecosystem Research Program, Provo, UT and Boise, ID
USDA Agricultural Research Service, Bee Biology and Systematics Laboratory, Logan, UT
USDA Agricultural Research Service, Eastern Oregon Agricultural Research Center, Burns, OR
USDA Agricultural Research Service, Forage and Range Research Laboratory, Logan, UT
USDA Agricultural Research Service, Western Regional Plant Introduction Station, Pullman, WA
USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center, Aberdeen, ID
USDA Forest Service, National Seed Laboratory, Dry Branch, GA
USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR
USDA Forest Service, Region 6, Pendleton, OR
USDA Forest Service, Missoula Technology and Development Center, Missoula, MT
Utah Division of Wildlife Resources, Great Basin Research Center, Ephraim, UT
Utah Crop Improvement Association, Logan, UT
Eastern Oregon Stewardship Services, Prineville, OR
Truax Company, Inc., New Hope, MN
Harold Wiedemann, Texas A & M University, College Station, TX
Colorado State University Cooperative Extension, Tri-River Area, Grand Junction, CO
Oregon State University, Malheur Experiment Station, Ontario, OR
Boise State University, Boise, ID
Brigham Young University, Provo, UT
Montana State University, Bozeman, MT
Texas Tech University, Lubbock, TX
University of Idaho, Moscow, ID
University of Nevada, Reno, NV
Utah State University, Logan, UT
Private seed industry

Great Basin Native Plant Selection and Increase Project FY08 Progress Report

May 2009

COOPERATORS

USDI Bureau of Land Management, Great Basin Restoration Initiative
USDA Forest Service, Rocky Mountain Research Station, Grassland, Shrubland and Desert Ecosystem Research Program, Provo, UT and Boise, ID
USDA Agricultural Research Service, Bee Biology and Systematics Laboratory, Logan, UT
USDA Agricultural Research Service, Eastern Oregon Agricultural Research Center, Burns, OR
USDA Agricultural Research Service, Forage and Range Research Laboratory, Logan, UT
USDA Agricultural Research Service, Western Regional Plant Introduction Station, Pullman, WA
USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center, Aberdeen, ID
USDA Forest Service, National Seed Laboratory, Dry Branch, GA
USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR
USDA Forest Service, Region 6, Pendleton, OR
USDA Forest Service, Missoula Technology and Development Center, Missoula, MT
Utah Division of Wildlife Resources, Great Basin Research Center, Ephraim, UT
Utah Crop Improvement Association, Logan, UT
Eastern Oregon Stewardship Services, Prineville, OR
Truax Company, Inc., New Hope, MN
Harold Wiedemann, Texas A & M University, College Station, TX
Colorado State University Cooperative Extension, Tri-River Area, Grand Junction, CO
Oregon State University, Malheur Experiment Station, Ontario, OR
Boise State University, Boise, ID
Brigham Young University, Provo, UT
Montana State University, Bozeman, MT
Texas Tech University, Lubbock, TX
University of Idaho, Moscow, ID
University of Nevada, Reno, NV
Utah State University, Logan, UT
Private seed industry

Great Basin Native Plant Selection and Increase Project
2008 Annual Report

The Interagency Native Plant Materials Development Program (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) provision for in situ and ex situ conservation of important populations; 6) management or re-establishment of wildland shrub stands to improve seed availability and conserve native populations; 7) evaluation of the potential for increasing native plant diversity in established crested wheatgrass stands in the Great Basin while minimizing weed invasion; 8) investigation of the biology of native forbs, emphasizing seed germination and seedling establishment; 9) examination of interactions among restoration species and between restoration species and invasive exotics; 10) evaluation of rangeland drills and strategies for establishing diverse native communities; and 11) science delivery.

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

Nancy Shaw
USDA Forest Service
Rocky Mountain Research Station
Boise, ID
nshaw@fs.fed.us

Mike Pellant
USDI Bureau of Land Management
Great Basin Restoration Initiative
Boise, ID
Michael_Pellant@blm.gov

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/nifc/st/en/prog/fire/more/gbri.html

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

Table of Contents

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

Principal Investigators and Contact Information:

R.C. Johnson, Research Agronomist
USDA-ARS, Western Regional Plant Introduction Station
Box 646402, Washington State University
Pullman, WA 99164
509.335.3771, fax: 509.335.6654
rcjohnson@wsu.edu

Barbara Hellier, Horticulture Crops Curator
USDA-ARS, Western Regional Plant Introduction Station
Box 646402, Washington State University
Pullman, WA 99164
509.335.3763, fax: 509.335.6654
bhellier@ wsu.edu

Project Description:
Genetic information to identify locally adapted seed sources for restoration and reclamation is generally lacking. An understanding of the geographic and ecological distance that plant material should be transferred from original source populations is critically needed. *Allium acuminatum* Hook. (Taper-tip onion) is an important Great Basin forb associated with healthy rangeland and good habitat for sage-grouse. Studies using molecular markers and phenotypic traits have been conducted to determine genetic variation and seed transfer zones of *A. acuminatum* across the Great Basin. Genetic resource management strategies based on biological conservation principals are being developed and made available to land managers for field application. In addition, *ex-situ* conservation will be carried out at the USDA-ARS gene bank at Pullman, WA. Gene bank conservation will provide 1) readily available, source-identified genetic resources for research and increase and 2) security back-up of *in-situ* sites. Overall, this project will provide seed zones and seeds for restoration, providing long-term benefits to degraded Great Basin landscapes though improved genetic resources.

<u>Objectives</u>

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

Project Status:

Collections

In 2005, *A. acuminatum* bulbs were collected from 55 populations throughout eastern Oregon, southern Idaho and northeastern Nevada (Fig. 1) as described by Adair et al. (2006). Each of the two collecting teams 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; these 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. *A. acuminatum* was collected in 20 of the Level IV Omernick Ecoregions across the Great Basin.

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

Molecular Markers

Using nine primer pairs and Sequence Related Amplified Polymorphisms (SRAP) (Li and Quiros, 2001), 167 unambiguous polymorphic markers were scored for each of the 55 *A. acuminatum* collections. The STRUCTURE program as described by Evanno et al. (2005) was used with the marker data to find five main *A. acuminatum* groups for Great Basin germplasm. Although there was overlap, the groups tended to cluster in different geographic areas across the collection area. Thus, molecular markers showed differences among *A. acuminatum* populations from different collection locations and are further evidence of genetic variation across the landscape.

Common Gardens

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

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 was 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 were 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 (*Allium acuminatum)* (Taper-tip onion*)* collected in the Great Basin and measured in Central Ferry (CF) and Pullman (PU), WA common gardens, 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/diameter	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

†Values were significant at the P<0.05

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 was associated with location for bolting date. Flowers/umbel at Central Ferry and Pullman was the variable that had 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 variable (Table 1). These results, showing strong location effects, indicate a strong potential for differences in adaptation associated with different Great Basin environments.

Correlation between plant traits and climatic/environmental factors was significant for numerous factors (Table 2). Bolting date showed relatively strong correlations with elevation, maximum temperature, minimum temperature, and precipitation. Elevation had four significant correlations with plant variables, maximum and minimum annual temperatures had three each, and latitude and precipitation had two each (Table 2). These data linking plant traits with climatic/environmental factors at their collection locations indicate that developing seed transfer zones for *A. acuminatum* should be possible.

Table 2. Linear correlation between selected variables measured in 2007 and collection location environmental factors averaged over sites (n=55).

A. acuminatum variable	Lat.	Long.	Elev.	Slope	Aspect	Max. temp.	Min. temp.	Precip.
Bolting date	ns	ns	0.46**	ns	ns	-0.50**	-0.56**	0.31*
Flower color	-0.36**	ns	0.32*	ns	ns	ns	ns	ns
Flowers/umbel	ns	ns	ns	ns	ns	ns	ns	ns
Leaf length	ns	ns	ns	ns	ns	ns	ns	ns
Leaf width	-0.31*	ns	ns	ns	ns	ns	ns	ns
Leaf habit	ns	ns	ns	-0.37**	-0.30*	ns	ns	ns
Seeds/plant	ns	ns	ns	ns	ns	-0.28*	-0.30*	0.42**
Flowering date	ns	ns	ns	ns	ns	-0.28*	-0.34**	ns
Scape diameter	ns	ns	0.29*	ns	ns	ns	ns	ns
Scape length	ns	ns	ns	ns	ns	ns	ns	ns
Umbel diameter	ns	ns	ns	ns	ns	ns	ns	ns
Survival	ns	ns	0.46**	ns	ns	ns	ns	ns

P<0.05(*), P<0.01(**), and ns (not significant).

Principal components and regression models

Principal component analysis was used to simplify key plant traits into sets of linear functions, the principal components, to be used in modeling seed zones. 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 loaded positively for all traits, and most were relatively equal in strength. The exceptions were bolting date, flower color, length/width, and scape length/diameter, which had relatively low loading (Table 3). 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 (Table 3). 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 traits except those with very small loading factors (Table 3).

Table 3. Eigenvectors (loading factors) and correlations for principal components 1 and 2 for *Allium acuminatum* collected in the Great Basin.

	Loading factors		Correlation coefficient	
Trait (n=53)	Prin1	Prin2	Prin1	Prin2
Bolting date	0.1377	-0.3761	0.32*	-0.65**
Flower color	0.0083	-0.3760	0.02	-0.65**
Flowers/umbel	0.3677	-0.0771	0.85**	-0.13
Leaf length	0.3665	0.1954	0.84**	0.34*
Leaf length/width	0.0594	0.3130	0.14	0.54**
Leaf width	0.3541	-0.1104	0.82**	-0.19
Seeds/plant	0.3227	-0.1120	0.74**	-0.19
Scape diameter	0.3639	-0.2218	0.84**	-0.39**
Scape length/diameter	0.0299	0.5020	0.07	0.87**
Scape length	0.3203	0.3063	0.74**	0.53**
Days flower-maturity	0.2234	0.3255	0.52**	0.57**
Survival	0.2798	-0.2122	0.65**	-0.37**
Umbel diameter	0.3380	0.0666	0.78**	0.12

*,**Correlations significant at P<0.05 and P<0.01, respectively

Correlations between principal component 1 and environmental variables showed that spring precipitation was significant (r = -0.28, P<0.05) and the coefficients associated with precipitation were generally stronger than those for temperature. No temperature or precipitation factors were significantly correlated with principal component 2. However, principal component 2 was correlated with latitude (r= -0.34, P<0.05) and elevation (r= -0.42, P<0.01).

The regression model for principal component 1 includes coefficients for elevation, precipitation, and temperature, and for principal component 2, elevation and temperature (Table 4). Correlations between environmental factors and plant growth and development variables also indicated that elevation, precipitation, and temperature were important factors for adaptation zones of *A. acuminatum* (Table 2).

Table 4. Regression equations for principal component 1 and 2 linking plant traits and environmental factors.

		Principal component 1	
Variable	df	Regression coefficient	Regression P-value
Intercept	1	11.345	0.002
Elevation	1	0.0023	0.013
Precip May	1	-0.1241	0.001
MinTemp May	1	2.358	0.002
MinTemp June	1	-2.576	0.001
		Principal component 2	
Variable	df	Regression coefficient	Regression P-value
Intercept	1	4.0406	0.006
Elevation	1	-0.0021	0.004
Precip May	1	-0.0626	0.015
Precip Oct	1	0.0737	0.024

Principal component 1 R^2=0.37 and principal component 2 R^2=0.29

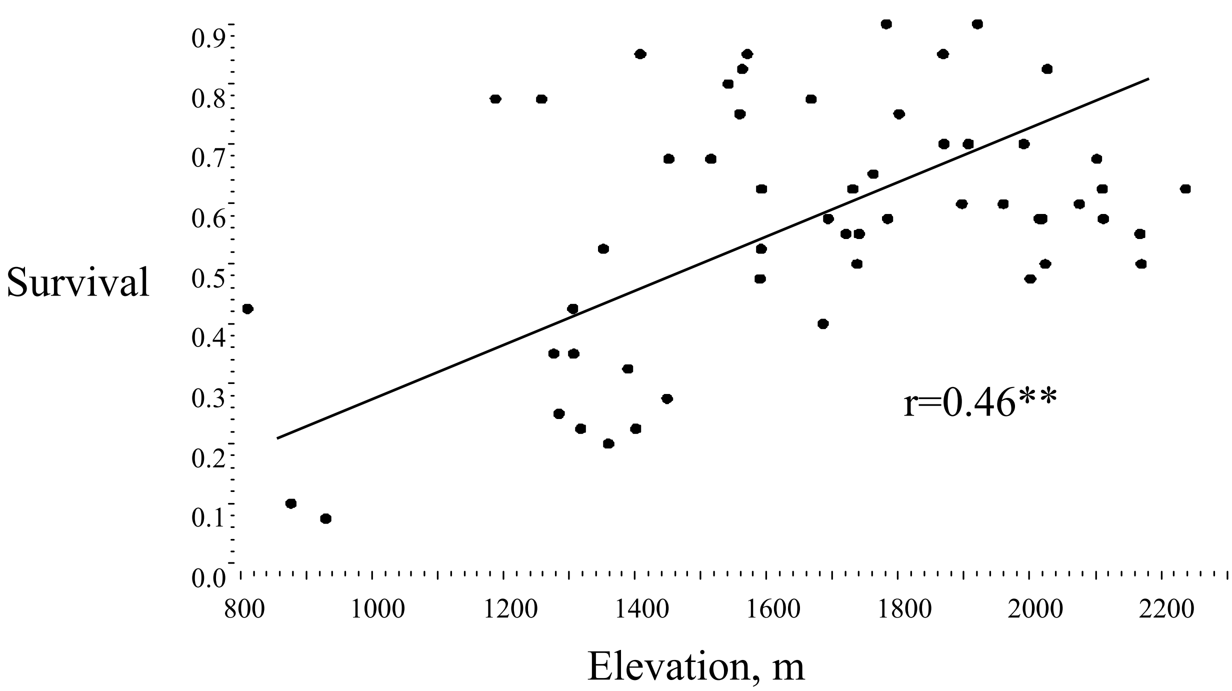


Figure 2. Relationship between elevation at bulb source location and frequency of survival for *Allium acuminatum* bulbs in common gardens.

As shown in Table 2 and Fig 2, the frequency of bulb survival in common gardens generally increased as bulb source location elevation increased. The reason for this may be that lower elevation populations are naturally less likely to survive. But if we assume that populations are well adapted to their native lower elevation locations, their fitness for survival was lower when moved to our common garden sites. In any case, for successful restoration, the importance of understanding the interaction of environment with plant adaptation is indicated.

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) and regression coefficients (Table 4).

Future plans
The regression models in Table 4 are being used to map potential seed transfer zones for *A. acuminatum*. A manuscript for peer reviewed publication is being prepared that will summarize results and recommendations. The seed transfer zones will be used to select adapted material for restoration in the Great Basin.

Work on seed production and stand establishment will be pursued. For *Allium* there are two options for establishing field stands; sowing of true seed or dormant bulbs. Both methods are used in production of *A. cepa,* onion and *A. sativum,* garlic. The small size of *A. acuminatum* bulbs lends themselves to planting with conventional mechanical seeders. In 2009 and 2010 direct sowing of dormant bulbs will be tested at different planting density rates in relation to seed yield. In addition, the planting of true seed at different seeding rates and densities, weed control, methods for lifting bulbs from soil, and mechanical harvest will be examined in future trials. This will give the needed information on stand establishment and agronomic factors for seed production.

Publication:

Johnson, R.C. 2008. Genebanks pay big dividends to agriculture, the environment, and human welfare. Public library of science (PLoS) http://biology.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pbio.0060148

Management Applications:

This work is providing the needed tools to develop adapted *A. acuminatum* germplasm for restoration in the Great Basin. In addition, long-term conservation and management of germplasm is being conducted within the National Plant Germplasm System. This provides security back-up for native populations that may be lost as a result of climate change and disturbances such as fire and invasive weeds. The work on seed production and stand establishment above will provide guidance for procedures to grow key populations of *A. acuminatum* and provide them for restoration efforts.

Products:

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

Literature Cited:

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

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

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

Project Title: Adapted Indian Ricegrass for the Great Basin

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

Principal Investigators and Contact Information:

R.C. Johnson, Research Agronomist
USDA-ARS, Western Regional Plant Introduction Station
Box 646402, Washington State University
Pullman, WA 99164
509.335.3771, fax: 509.335.6654
rcjohnson@wsu.edu

Mike Cashman, Biologist
USDA-ARS, Western Regional Plant Introduction Station
Box 646402, Washington State University
Pullman, WA 99164
509.335.6219, fax: 509.335.6654
mjcashman@wsu.edu

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. This material was established in common gardens in 2007 and data on plant variables taken in 2007 and 2008. This work shows that seed source location was strongly associated with variation in plant variables. In addition, plant variables were linked to numerous climatic and environmental factors. In the next phase, this information will be used to identify 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 will be used to develop seed zones for the central and northern Great Basin,

<u>Objectives</u>

1. Collect Indian Ricegrass from diverse ecological sites 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. Compare the patterns of variation in plant traits among Indian ricegrass populations collected in the Great Basin.
4. Identify seed transfer zones along with complementary *in situ* conservation sites.
5. Make source identified plant material available for utilization through the Western Regional Plant Introduction Station seed repository and the National Plant Germplasm System.

In spring 2007, a diverse set of 120 Indian ricegrass accessions from the USDA germplasm collection was planted in a two common gardens at Central Ferry, WA, one under dryland and the other under light irrigation conditions forming two growing environments. Each garden was randomized into 5 complete blocks with 600 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 variables on each plant.

Table 1. 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 (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	36.9	<0.01	<0.01	0.43
Leaf length (cm)	15	29.6	0.93	<0.01	0.93
Leaf length/Leaf width	8.9	45.2	<0.01	<0.01	0.64
Leaf length x Leaf width	29.6	56.2	0.12	<0.01	0.73
Inflorescences/plant	13	73.9	<0.01	<0.01	0.36
Seeds/inflorescence	50	41.9	0.60	<0.01	0.42
Culm length (cm)	25	21.5	0.35	<0.01	0.51
Inflorescence length (cm)	15	26.6	0.13	<0.01	0.67
Culm to inflorescence length (cm)	1.8	28.7	0.96	<0.01	0.26
Habit (1-9)	5	21.3	0.31	<0.01	0.47
Leaf texture (1-9)	5	24.6	<0.01	<0.01	0.18
Leaf abundance (1-9)	5	23.2	0.15	<0.01	0.22
Leaf roll (1-9)	4	37.1	0.03	<0.01	0.36
Crown diameter (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 weight–regrowth (g)	20.7	78.83	<0.01	<0.01	0.40

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

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	35.4	0.93	<0.01	0.43
Leaf length (cm)	13.29	29.1	0.55	<0.01	0.22
Leaf length/Leaf width	9.571	40.2	0.85	<0.01	0.30
Leaf length*Leaf width	22.01	55.0	0.67	<0.01	0.51
Inflorescences/plant	105.6	59.3	0.20	<0.01	0.63
Seeds/inflorescence	44.92	42.4	0.31	<0.01	0.44
Culm length (cm)	27.30	22.5	0.95	<0.01	0.05
Inflorescence length (cm)	13.02	24.9	0.18	<0.01	0.72
Culm to inflorescence length	2.212	27.0	0.27	<0.01	0.78
Habit (1-9)	6	21.1	0.17	<0.01	0.48
Leaf texture (1-9)	6	21.0	0.97	<0.01	0.78
Leaf abundance (1-9)	4	32.3	0.04	<0.01	0.78
Leaf roll (1-9)	7	20.5	0.53	<0.01	0.59
Crown diameter (cm^2)	35.0	50.3	0.86	<0.01	0.39
Dry weight (g)	46.92	76.2	0.72	<0.01	0.54
Regrowth (g)	11.54	92.1	0.01	<0.01	0.01
Dry weight-regrowth (g)	36.30	80.9	0.18	<0.01	0.29

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

For the 2007 analysis, collection location effects were all highly significant (Table1). Thus, Indian ricegrass populations varied strongly depending on the seed source 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.

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 show that Indian ricegrass populations differ as a function of seed source locations, suggests that plant adaptation will vary depending climatic/environmental factors.

Table 3. Linear correlation between traits and environmental factors for Indian ricegrass (Central Ferry WA, 2007)							
Variable	Elev.	Lat.	Long.	Max Temp.†	Min. Temp.†	Precip.	Frost free
Full heading	ns	ns	ns	ns	ns	ns	ns
Initial blooming	0.24*	ns	ns	-0.34**	-0.35**	0.19*	0.31**
Maturity date	ns	0.23*	ns	ns	ns	ns	ns
Leaf width	-0.30**	ns	ns	ns	0.19*	ns	0.26**
Leaf length	-0.22*	ns	ns	ns	0.21*	ns	0.22*
Leaf length/Leaf width	ns	ns	0.28**	ns	ns	ns	ns
Leaf length*Leaf width	-0.34**	0.21*	ns	ns	0.23*	ns	0.27**
Inflorescences/plant	ns	-0.22*	ns	0.33**	0.32**	-0.20*	0.24*
Seeds/inflorescence	-0.25**	0.40**	ns	ns	ns	ns	ns
Culm length	ns	0.19*	0.21*	ns	ns	0.28**	ns
Infloresence length	ns	0.20*	ns	ns	ns	ns	ns
Culm to Inflorescence length	ns	ns	0.22*	ns	ns	0.22*	-0.25**
Habit	ns	-0.38**	ns	0.26**	ns	ns	0.20*
Leaf texture	0.31**	ns	ns	ns	-0.24*	ns	-0.27**
Leaf abundance	ns	0.23*	ns	ns	ns	ns	-0.28**
Leaf roll	0.28**	ns	0.26**	ns	-0.24*	ns	-0.29**
Dry weight	-0.27**	ns	ns	0.19*	0.29**	ns	0.26***
Regrowth weight	-0.28**	ns	ns	0.20*	0.28**	ns	0.35**
Dry wt–regrowth	-0.26**	ns	ns	0.19*	0.27**	ns	0.24*

*,**, P<0.05 and P<0.01, respectively.
†Average annual values.

Correlations of selected plant variables showed that a number of climatic and environmental factors were linked to plant variables (Tables 3 and 4). In 2007, the frost-free period correlated with plant variables in 13 of 20 cases (Table 3). Frequent correlations were also observed for elevation, latitude and average temperature. For 2008, the frost-free period was less often correlated with plant variables than in 2007, but most climatic/environmental factors had numerous significant correlations with plant variables (Table 4). In many cases a plant factor was consistently correlated with an environmental factor both years, as, for example, with seeds per inflorescence (Table 4). But for maturity date, correlations with temperature factors, precipitation and frost-free period were observed in 2008 but not in 2007.

Table 4. Linear correlation between traits and environmental factors for Indian ricegrass (Central Ferry, WA, 2008).							
Variable	Elev.	Lat.	Long.	Max. Temp.†	Min. Temp.†	Precip.	Frost Free
Full heading	-0.22*	ns	ns	0.28**	0.24*	-0.28**	0.24*
Initial blooming	-0.21*	ns	ns	0.24*	0.25**	-0.26**	ns
Maturity date	-0.32**	ns	-0.23*	0.43**	0.43**	-0.35**	0.44**
Leaf width	-0.26**	0.28**	-0.22*	ns	ns	ns	ns
Leaf length	-0.22*	ns	ns	ns	ns	ns	ns
Leaf length/ Leaf width	ns	ns	0.24*	ns	ns	ns	ns
Leaf length* Leaf width	-0.32**	0.30**	ns	ns	ns	ns	0.23*
Inflorescences/plant	ns	ns	ns	ns	ns	0.23*	ns
Seeds/inflorescence	-0.25**	0.41**	ns	-0.26**	-0.19*	0.30**	ns
Culm length	ns	0.30**	ns	-0.23*	ns	0.27**	ns
Infloresence length	ns	0.23*	ns	-0.23*	ns	0.29**	ns
Culm to Inflorescence length	ns	ns	ns	ns	ns	ns	ns
Habit	ns	-0.22*	-0.34**	0.30**	0.22*	-0.38**	0.24*
Leaf texture	0.24*	-0.36**	0.22*	ns	ns	ns	ns
Leaf abundance	-0.23*	ns	ns	0.20*	0.20*	ns	0.20*
Leaf roll	ns	-0.29**	0.21*	ns	ns	ns	ns
Crown diameter	ns	0.19*	ns	ns	ns	ns	ns
Dry weight	ns	ns	ns	ns	ns	ns	ns
Regrowth weight	-0.24**	ns	ns	ns	ns	ns	0.24*
Dry wt–regrowth	ns	ns	ns	ns	ns	ns	ns

*,**, P<0.05 and P<0.01, respectively.
†Average annual values.

Future plans

The results so far show that variation across the landscape in Indian ricegrass was related to the location where the seeds were collected, and that many plant variables were linked to basic climatic and environmental data. This is strong evidence that adaptation of Indian ricegrass varies across the Great Basin and differences in adaptation should be considered in revegetation planning. What is needed now is to examine the plant variables for redundancy within and between years, reduce the plant variables to a smaller set of adaptive traits, complete a principal component analysis, and use regression modeling with the principal component scores to develop and map seed zones. For this initial Indian ricegrass study, objectives 1, 2, and 3 have been completed. Our goal is to finish this initial study to develop seed zones and provide germplasm for Indian ricegrass revegetation in the Great Basin.

For the northern and central Great Basin, objective 1 relating to germplasm collection has been completed and work is now underway to establish common gardens at Central Ferry, WA and Reno, NV (Fig. 1).

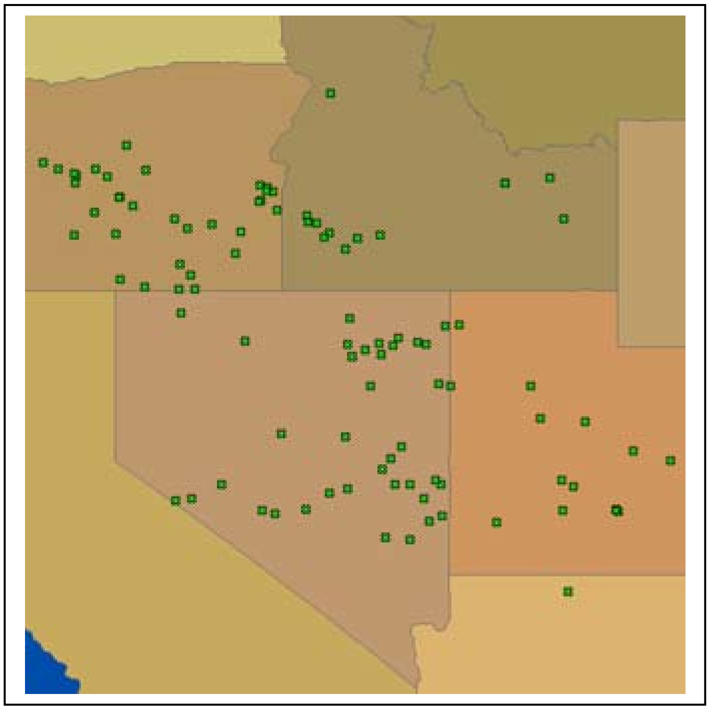


Figure 1. Seed collections of Indian ricegrass made in 2007 and 2008 for common studies of adaptation to Great Basin environments.

Publications and Technology Transfer:

Johnson, R.C. 2008. Genebanks pay big dividends to agriculture, the environment, and human welfare. Public Library of Science (PLoS) http://biology.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pbio.0060148

Cashman M. J. 2008. Phenotypic variation of *Achnatherum hymenoides* (Roemer & J.A. Schultes) Barkworth in relation to environmental factors. Master of Science Special Project, Washington State University, Pullman WA.

Management Applications:

Results from this study will be used to develop seed zones for plant materials needed for revegetation and restoration in the Great Basin and adjacent areas.

Products:

Seed zones and germplasm for revegetation in the Great Basin and peer reviewed journal articles outlining the Indian ricegrass adaption.

Key collections will be conserved within the National Plant Germplasm System.

Project Title: Establishment and maintenance of certified Generation 1 (G1) seed, propagation of native forbs, plant display nursery evaluation and development of technology to improve the diversity of introduced grass stands

Project Location: NRCS Aberdeen, ID Plant Materials Center

Principal Investigators and Contact Information:

Loren St. John, Center Manager
Aberdeen Plant Materials Center,
P.O. Box 296, Aberdeen, ID 83210
208.397.4133, fax 208.397.3104
Loren.Stjohn@id.usda.gov

Dan Ogle, Plant Materials Specialist, Boise, ID
USDA-NRCS, 9173 West Barnes Drive, Suite C, Boise, ID 83709
208.685.6987, fax 208.378.5735
Dan.Ogle@id.usda.gov

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

Project Status:

I. Seed Production

Anatone Germplasm Bluebunch Wheatgrass
Currently 4.2 acres are in production. Estimated seed yield from 2008 seed crop is 478 pounds. Shipped 775 pounds of Generation 2 Certified seed to commercial growers in 2008.

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. Seed will be harvested from this field beginning in 2009.

Snake River Plains Germplasm Fourwing Saltbush
Estimated seed yield from 2008 crop is 15 pounds. No seed was requested by commercial growers in 2008.

Northern Cold Desert Germplasm Winterfat
Estimated seed yield from 2008 crop is 8 pounds. No seed was requested by commercial growers in 2008.

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 made available to cooperators for transplanting at field sites. Due to no plant establishment of *Lomatium* species and minimal success with greenhouse propagation of *Penstemon* species, no plants were made available to cooperators. All plants that were successfully propagated in the PMC greenhouse were transplanted into seed production 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.

On May 15, 2008 the sulphur-flowered buckwheat plots were treated with a wick application of 100 percent Roundup to control weeds and on June 10-11 all plots were hand weeded. The following table shows harvest date and seed yield for the accessions that were harvested:

Species	Harvest Date	Clean seed (pounds)
ERUM	8/13	12.6
LODI	NA	NA
LOGR	NA	NA
LOTR	7/3	2.6
PEAC	NA	NA
PEDE	NA	NA
PESP	8/8	1.5

By early July, the *Lomatium* species were completely dormant. The only *Lomatium* to flower and set seed was LOTR. LODI and LOGR have yet to flower after 3 years of establishment. It is thought that most of their energy is still going to development of the taproot. In early November 2008 the dormant *Lomatium* plots were treated with a spray application of Roundup to control weeds that were still green. PEAC and PEDE (short-lived species) had died out to the point that no seed was harvested in 2008.

The Rocky Mountain Research Station in Boise, ID cleaned the seed that was harvested from the plots. Some of the seed was utilized for the seeding trial conducted at Snowville, UT for the Equipment and Strategies to Enhance the Post-wildfire Establishment and Persistence of Great Basin Native Plants study.

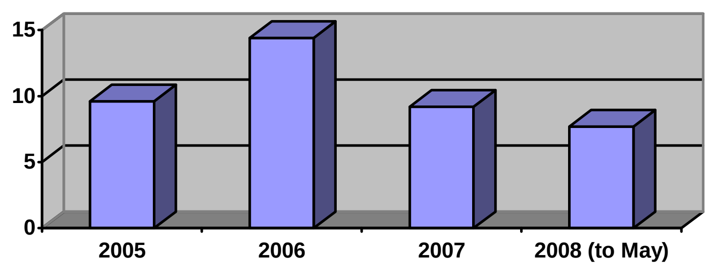
III. Orchard Display Nursery Evaluation Summary (2005-2008) Final Report

Introduction

The Orchard Display Nursery was planted on November 16, 2004 in cooperation with the Great Basin Native Plant Selection and Increase Project. The nursery includes 82 accessions of 27 native and introduced grass, forb and shrub species. Each accession was planted in 7 x 60 foot plots. The remaining area was planted to a cover crop mix of 50% Anatone bluebunch wheatgrass, 20% Bannock thickspike wheatgrass, 20% Magnar basin wildrye and 10% Snake River Plain fourwing saltbush.

The test site is located on a loamy 10-12 inch precipitation ecological site that historically supported a Wyoming big sagebrush – bluebunch wheatgrass – Thurber's needlegrass plant community. Total precipitation at the Orchard Test Site for water year 2005 was 9.6 inches, 2006 was 14.4 inches and for 2007 was 9.2 inches. At the time of the 2008 evaluation on May 5, the Orchard range site had received 7.70 inches of precipitation for water year 2008 (USDA 2008).

Yearly cumulative precipitation, Orchard Range Site



The Orchard display nursery was evaluated from 2005 to 2008. This report summarizes the evaluations conducted at the site.

Materials and Methods

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

The first evaluation of the plots for initial establishment was conducted on April 27, 2005 using a frequency grid. The grid measured approximately 40 x 41 inches, having four 10-inch columns (to incorporate one drill row per column) and five rows, totaling 20 cells. The first grid was laid on the rows approximately two grid lengths (80 inches) into the plot. Counts were made of the cells that contained at least one plant. Grids were subsequently flipped and evaluated three more times giving a total of eighty evaluated cells. Total area for one grid is approximately 1 m²; total area evaluated is therefore approximately 4 m^2. A conservative estimate of plant density (plants/m^2) is the total number of cells containing at least one plant divided by four.

The second evaluation occurred on May 25, 2005. The 2006 evaluation was conducted on May 31, the 2007 evaluation took place on May 16 and the 2008 evaluation was completed on May 1. The methods followed in 2006 and 2007 were the same as described above; however, the frame was evaluated five times for a total of 100 cells or 5 m^2. Total counts were then divided by five for approximate plants/m^2. Numbers for approximate plants/m^2 were then divided by 10.8 to calculate approximate plants/ft^2. It is important to note that because cells with plants were counted and not number of plants per cell, the best possible score is 100 hits per five frames which converts to 20 plants/m^2 or 1.85 plants/ft^2. Actual plant density may be higher than the numbers indicated below. All tables have been arranged with accessions ranked from highest plant density to the lowest at the time of the final evaluation in 2008. Data were not analyzed for significance.

Native Grasses

There were forty-seven accessions of native grasses planted. Overall the native grasses established well considering the limited amount of precipitation received over the winter and early spring of 2005. Especially good stands were observed in the bluebunch wheatgrass and Snake River wheatgrass plots during 2005. There was a marked decrease in plant density between the first and second evaluations with some notable exceptions. Seven of nine bluebunch wheatgrass accessions and three of four Snake River wheatgrass accessions increased in density from the first evaluation to the second. This is possibly due to receiving 2.5 inches of precipitation during that period and/or from a lack of pressure by black grass bugs (*Labops* sp.). Most of the native grasses decreased steadily in density from 2005 to 2007 (Table 1).

In 2005 the best performing Indian ricegrass accession was White River, having a plant density of 0.56 plants/ft^2 during the first evaluation and 0.17 plants/ft^2 during the second evaluation. In 2006 through 2008 there were no plants of any Indian ricegrass accessions observed in the evaluation grids and very few seen within their respective plots.

In 2005 the squirreltail plots had as high as 0.54 plants/ft^2 for Fish Creek. In 2006 all squirreltail accessions had decreased. Fish Creek maintained the best plant density with 0.26 plants/ft^2. Densities remained essentially the same in 2007. In 2008 Fish Creek increased in density from 0.22 to 0.67 plants/ft^2.

Bannock thickspike wheatgrass had a density of 1.04 plants/ft^2 and stayed essentially the same at the second evaluation of 2005. In 2006 Bannock had dropped to nearly half of the original density to 0.58 plants/ft^2. The 2007 evaluations showed small declines from established plots. In 2008 Bannock decreased to 0.28 plants/ft^2 and Schwendimar fell in density to 0.17 plants/ft^2.

Revenue and San Luis slender wheatgrass both showed 0.00 plants/ft^2 in 2006. Pryor slender wheatgrass similarly dropped in density but had 0.02 plants/ft^2. In 2007 and 2008 no slender wheatgrass plants could be found in any of the evaluated grids.

The western wheatgrass accessions had less dramatic declines in density from 2005 to 2006, but still showed poor stands with Rodan having the highest density of 0.13 plants/ft^2. In 2007 and 2008 all accessions had zero plants surviving.

The bluebunch wheatgrass accessions had the highest average densities of all the native grasses. All decreased slightly in density from 2005 to 2006, but still maintained good stands. P-12, Wahluke and Jim Creek all had densities over 1.00 plants/ft^2. Columbia, Anatone, P-7 and P-15 had densities between 0.50 and 1.00 plants/ft^2 while P-5 and Goldar both shared low densities. In 2007 densities were generally slightly lower, but still higher than all other species as a whole. The highest density recorded in 2007 was Jim Creek at 1.07 plants/ft^2. In 2008 Jim Creek, Wahluke, P-12 and P-7 had the best plant densities with 1.10, 1.10, 0.82 and 0.75 plants/ft^2 respectively.

Snake River wheatgrass accessions had good densities the establishment year with three accessions having densities greater than 1.00 plants/ft^2. Numbers declined slightly yet steadily over the next two years. In 2007 the best density was from SERDP with 0.70 plants/ft^2. In 2008 SERDP had risen in density to 0.80 plants/ft^2 making it the top performer of the group. Densities of other accessions remained essentially the same as 2007.

The basin wildrye accessions had fair to good stands in 2005, but decreased steadily from 2005 to 2008. U108-02 and Trailhead retained the highest densities in 2006 at 0.24 and 0.26 plants/ft^2 respectively. By 2007 the best density was achieved by Trailhead with 0.17 plants/ft^2. U108-02 and U100-01 had similar densities with 0.11 and 0.13 plants/ft^2 respectively. In 2008 basin wildrye had poor stands from all accessions, the best being 0.09 plants/ft^2 from U108-02.

Sheep fescue stands remained poor from 2005 to 2006 with Covar slightly increasing from 0.00 to 0.07 plants/ft^2. In 2007 Covar still had 0.07 plants/ft^2, and Initial Point had decreased to 0.00 plants/ft^2. In 2008 the fescues persisted with minimal stands.

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

All five of the Sandberg bluegrass accessions increased in density from 2005 to 2006. The best stands were observed in the High Plains and Mountain Home plots with respective stands of 0.54 and 0.35 plants/ft^2. In 2007 all stands had been reduced to 0.00 plants/ft^2. In 2008 however, Hanford Source increased to 0.56 plants/ft^2 showing a stand that had been hidden under the dense weed canopy.

Table 1. Density of native grasses seeded at the Orchard Research Site in fall 2004.

Native Grasses Species	Name or accession	4/27/05	5/25/05	5/30/06	5/16/07	5/1/08
		Plants/ft²				
Indian ricegrass	Rimrock	0.37	0.20	0.00	0.00	0.00
	White River	0.56	0.17	0.00	0.00	0.00
	Nezpar	0.42	0.17	0.00	0.00	0.00
	Ribstone	0.14	0.09	0.00	0.00	0.00
	Paloma	0.05	0.00	0.00	0.00	0.00
Squirreltail	Fish Creek	0.97	0.54	0.26	0.22	0.67
	Sand Hollow	0.37	0.20	0.19	0.20	0.24
	Toe Jam Creek	0.58	0.17	0.00	0.00	0.02
	Shaniko Plateau	0.81	0.52	0.06	0.09	0.00
	9019219	0.02	0.02	0.00	0.00	0.00
Thickspike wheatgrass	Bannock	1.04	1.07	0.58	0.43	0.28
	Schwendimar	0.69	0.52	0.39	0.24	0.17
	Critana	0.90	0.56	0.24	0.17	0.00
	Sodar	0.37	0.30	0.15	0.07	0.00
Slender wheatgrass	Revenue	1.00	0.93	0.00	0.00	0.00
	San Luis	0.60	0.69	0.00	0.00	0.00
	Pryor	0.30	0.30	0.02	0.00	0.00
Western wheatgrass	Rodan	0.28	0.35	0.13	0.00	0.00
	Rosana	0.05	0.20	0.04	0.00	0.00
	Arriba	0.16	0.15	0.06	0.00	0.00
Bluebunch wheatgrass	Jim Creek	0.83	1.02	1.02	1.07	1.10
	Wahluke	0.97	1.26	1.02	0.98	1.10
	P-12	1.34	1.59	1.04	0.89	0.82
	P-7	0.93	1.15	0.67	0.57	0.75
	Columbia	1.30	1.23	0.84	0.83	0.65
	Anatone	0.81	1.15	0.80	0.69	0.47
	P-15	0.60	0.93	0.54	0.50	0.41
	Goldar	0.51	0.37	0.33	0.19	0.24
	P-5	0.42	0.61	0.22	0.13	0.17
Snake River wheatgrass	SERDP	1.02	0.94	0.67	0.70	0.80
	Secar	1.00	1.11	0.76	0.56	0.54
	Expedition	1.27	1.44	0.54	0.41	0.34
	E-26	0.21	0.23	0.22	0.13	0.11
Basin wildrye	U108-02	0.56	0.57	0.24	0.11	0.09
	U100-01	0.53	0.41	0.11	0.13	0.06
	Trailhead	0.60	0.52	0.26	0.17	0.04
	Magnar	0.28	0.22	0.04	0.04	0.02
	U70-01	0.30	0.22	0.02	0.02	0.02
	Washoe	0.21	0.09	0.09	0.06	0.00
Sheep fescue	Covar	0.16	0.00	0.07	0.07	0.06
	Initial Point	0.21	0.04	0.02	0.00	0.02
Thurber's needlegrass	Thurber's	0.00	0.00	0.00	0.00	0.00
Sandberg bluegrass	Hanford Source	0.00	0.00	0.19	0.00	0.56
	Mountain Home	0.00	0.00	0.35	0.00	0.03
	High Plains	0.25	0.00	0.54	0.00	0.00
	Sherman	0.00	0.00	0.02	0.00	0.00
	Toole County, MT	0.00	0.00	0.04	0.00	0.00

Introduced Grasses

Although many of the introduced grass accessions had fair emergence, an outbreak of black grass bugs at the time of the first evaluation in 2005 was noted. The infestation appeared limited to the introduced grass section of the nursery. Plants were covered with yellow spots making the plants appear yellow-green overall. Although most of the stands of the introduced grasses decreased from the first to the second evaluation, many stands had recovered and increased by 2006 indicating that many plants thought to be dead during the second evaluation in 2005 were still alive. However, the plants of crested wheatgrass were very small when compared to the other wheatgrasses in the nursery and still appeared to be recovering from black grass bug pressure. The 2007 and 2008 evaluations showed most established plots with reduced densities, many accessions dropping out completely (Table 2).

In 2006 all of the crested wheatgrass accessions increased in density or remained approximately where they were in 2005. Ephraim rose from 0.28 to 1.23 plants/ft^2; however, many of the plants were small in size due to the black grass bug infestation during the spring of 2005. In 2007 the best density was obtained from Nordan with 0.67 plants/ft^2. Ephraim had dropped from 1.23 to 0.02 plants/ft^2. In 2008 Nordan and Roadcrest had both increased in density to 0.88 and 0.71 plants/ft^2 respectively. The remaining crested wheatgrass plots had few remaining plants.

Both Siberian wheatgrass accessions similarly increased from 2005 to 2006, but decreased in 2007. In 2007 Vavilov was down to 0.26 plants/ft^2 and P-27 had 0.00 plants/ft^2. In 2008 Vavilov had rebounded to 0.54 plants/ft^2.

The three pubescent wheatgrass accessions decreased from 2005 to 2006 with the highest density in 2006 coming from Manska at 0.28 plants/ft^2. Manska continued to have the best density in 2007 with 0.13 plants/ft^2. Plant densities in 2008 remained low with Luna having the best stand with 0.22 plants/ft^2.

Rush intermediate wheatgrass, had 0.60 plants/ft^2 in 2005. Plant density decreased to 0.00 plants/ft^2 in 2006 and did not recover through 2008.

Prairieland and Eejay Altai wildrye had zero plants in 2006. Pearl Altai wildrye had 0.02 plants/ft^2. In 2007 Prairieland and Eejay again had 0.00 plants/ft^2 and Pearl increased slightly to 0.04 plants/ft^2. There were no live plants detected in 2008.

The Russian wildrye accessions all increased in density with the exception of Tetracan which decreased slightly. The best stand was recorded in the Bozoisky Select plot with 0.58 plants/ft^2. Bozoisky Select had the best stand in 2007 with 0.35 plants/ft^2. Bozoisky II had the next best rating with 0.26 plants/ft^2. In 2008 the Russian wildrye plots had poor stands. The top performer was Bozoisky Select with 0.11 plants/ft^2.

Table 2. Density of exotic grasses seeded at the Orchard Research Site in fall 2004.

Introduced Grasses Species	Name or accession	4/27/05	5/25/05	5/30/06	5/16/07	5/8/08
		Plants/ft²				
Crested wheatgrass	Nordan	1.30	1.19	1.10	0.67	0.88
	Roadcrest	1.30	0.07	0.52	0.19	0.71
	Hycrest	0.39	0.24	0.15	0.07	0.04
	Ephraim	0.65	0.28	1.23	0.02	0.00
	CD-II	0.56	0.24	0.20	0.00	0.00
	Douglas	0.28	0.04	0.09	0.00	0.04
Siberian wheatgrass	Vavilov	0.65	0.20	0.61	0.26	0.54
	P-27	0.09	0.02	0.33	0.00	0.00
Pubescent wheatgrass	Luna	0.79	0.54	0.13	0.00	0.22
	Manska	0.69	0.65	0.28	0.13	0.09
	Greenleaf	0.60	0.59	0.15	0.09	0.02
Intermediate wheatgrass	Rush	0.60	0.56	0.00	0.00	0.00
Altai wildrye	Pearl	0.35	0.15	0.02	0.04	0.00
	Prairieland	0.56	0.39	0.00	0.00	0.00
	Eejay	0.16	0.28	0.00	0.00	0.00
Russian wildrye	Bozoisky Select	0.72	0.54	0.58	0.35	0.11
	Syn-A (Bozoisky II)	0.21	0.13	0.24	0.26	0.09
	Mankota	0.46	0.28	0.32	0.19	0.02
	Tetracan	0.42	0.20	0.17	0.07	0.04

Forbs and Shrubs

Despite some good stands in 2005, all of the forb and shrub accessions except for Eagle western yarrow had zero plants during the 2006 evaluation. Eagle had 0.07 plants/ft^2 in the frequency grids along with a small stand of plants at one end of the seeded plot. In 2007 more plants of Eagle had either germinated from the original seeding, or seed had spread from established plants. Plant density for Eagle in 2007 was 0.24 plants/ft^2. Snake River Plains fourwing saltbush also had a single plant found in the plots, increasing its density from 0.00 to 0.02 plants/ft^2. In 2008 Eagle was the only forb or shrub accession with plants detected in the evaluation, with a density of 0.21 plants/ft² (Table 3).

Table 3. Density of forbs and shrubs seeded at the Orchard Research Site in fall 2004.

Species	Name or accession	4/27/05	5/25/05	5/30/06	5/16/07	5/8/08
		Plants/ft²				
Western yarrow	Eagle	0.51	0.50	0.07	0.24	0.21
	Great Northern	0.19	0.09	0.00	0.00	0.00
Utah sweetvetch	Timp	0.14	0.02	0.00	0.00	0.00
Firecracker penstemon	Richfield Selection	0.02	0.02	0.00	0.00	0.00
Scarlet globemallow		0.00	0.00	0.00	0.00	0.00
Lewis flax	Maple Grove	0.42	0.15	0.00	0.00	0.00
Blue flax	Appar	0.90	0.26	0.00	0.00	0.00
Wyoming big sagebrush		0.02	0.02	0.00	0.00	0.00
Fourwing saltbush	Snake River Plains	0.00	0.00	0.00	0.02	0.00
	Wytana	0.00	0.00	0.00	0.00	0.00
	Rincon	0.00	0.00	0.00	0.00	0.00
Gardner's saltbush	9016134	0.00	0.00	0.00	0.00	0.00
Winterfat	Hatch	0.28	0.17	0.00	0.00	0.00
	Northern Cold Desert	0.00	0.00	0.00	0.00	0.00
	Open Range	0.00	0.00	0.00	0.00	0.00
Forage kochia	Immigrant	0.00	0.00	0.00	0.00	0.00

Cover Crop

The cover crop consisted of a four species mix which contained: 50% Anatone bluebunch wheatgrass, 20% Bannock thickspike wheatgrass, 20% Magnar basin wildrye and 10% Snake River Plains fourwing saltbush. Four grids were examined during the first evaluation in 2005, one on each side of the nursery, and five grids were evaluated at the time of the second evaluation in 2005 and the 2006 evaluation. Total plant density was estimated at 0.37 plants/ft^2 at the first evaluation and 0.57plants/ft^2 at the second evaluation. In 2006 the cover crop density was 0.13 plants/ft^2. Cover crop densities increased in 2007 up to 0.20 plants/ft^2. In 2008 the cover crop density was 0.04 plants/ft^2.

Discussion

Despite significant populations of Russian thistle, native and introduced grasses had fair to good emergence and plant density during the establishment year. Germination and emergence might have been better with more precipitation during March and April of 2005 but emergence was good with the rain that was received. The majority of the plots showed decreased stands from 2005 to 2006 and again into 2007. By 2008 densities had for the most part stabilized, those species not well adapted to the site had died out, while adapted accessions persisted. The low precipitation at the site, especially the lack of moisture in July and August every year seems to have eliminated many of the less drought tolerant accessions.

One concern is the effect of black grass bugs on the introduced grasses. Plants subjected to black grass bug are normally affected by decreased seed yield and a reduction in palatability. Infestations rarely result in the death of established plants, but in poor water years establishing seedlings may be under enough stress for bug damage to kill the plants. The second evaluation in 2005 indicated a loss in plant densities; however it appears that many of the plants survived, although stunted (low vigor), through 2006. In 2007 many more plants had died, resulting in poor or no stands in many plots. In 2008 most accessions continued to decrease in plant density; however, a few accessions that had earlier proven adapted to the site conditions had small gains.

Snake River and bluebunch wheatgrasses had consistently good stands from essentially all accessions. Nordan and Roadcrest crested wheatgrass also performed well after recovering from black grass bug damage.

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

The PMC assisted Brigham Young University (BYU) Provo, UT and the Agricultural Research Service (ARS) Burns, OR in developing technology to improve the diversity of introduced grass stands by evaluating methods to introduce native species into established introduced plant communities. In 2005, the PMC modified a Truax Rough Rider range drill, mixed the seed and rice hull mixtures and completed the first year of seedings at sites in Utah and Oregon. In 2006, modified seed drop boots by the manufacturer were installed on the Truax drill and the second year of seeding was completed. In addition to these seedings, the PMC also seeded drill comparison trials near Elko, NV on recently burned rangeland to compare the Truax drill to the Kemmerer drill, 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, NV in cooperation with the University of Nevada Extension Service and near Aberdeen, Idaho in cooperation with the ARS Sheep Experiment Station. The following seed mixes were prepared and the sites planted in late October and early November.

South Fork, NV broadcast mix (12.5 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Mtn. Home Sandberg bluegrass	0.75	0.92
Appar blue flax	0.75	0.83
Eagle yarrow	0.20	0.45
Wyoming big sagebrush	0.20	1.31
Spiny hopsage	0.50	1.37
Rice Hulls		8.88

South Fork, NV Drill Mix (12.5 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Nezpar Indian ricegrass	2.00	2.03
Toe Jam Cr. squirreltail	2.00	2.26
Needle and thread	2.00	3.21
Magnar basin wildrye	2.00	2.10
Secar Snake River wheatgrass	1.00	1.08
Munro globemallow	0.50	0.76
Rice Hulls		2.32

Grandview, ID Broadcast Mix (12.90 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Maple Grove Lewis flax	0.40	0.43
Mtn. Home Sandberg bluegrass	0.20	0.24
Royal Penstemon	0.40	0.56
Wyoming big sagebrush	0.05	0.29
Rubber rabbitbrush	0.15	1.01
Rice Hulls		7.29

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	1.04
Bannock thickspike wheatgrass	0.60	0.74
Thurber's needlegrass	0.60	0.99
Rice Hulls		7.29

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

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

The minimum-till drill (Truax Rough Rider range drill) which has been modified by PMC personnel was provided by the FS Rocky Mountain Research Station. The PMC provided a trailer and tractor and the Utah Division of Wildlife provided an additional tractor. The modified rangeland drill (Kemmerer range drill) was provided by the BLM. In 2007, the PMC had made modifications to the Kemmerer drill by replacing the existing drop tubes with aluminum 3-inch diameter irrigation pipe to facilitate seed flow to the drill openers. The aluminum pipe provided a more slippery surface for the seed to flow. The drills were set up to both broadcast and drill seed in the same pass so species that require broadcasting or very shallow planting were broadcast and the deeper seeded species were drill seeded in alternating rows.

The PMC mixed the seed and rice hull mixtures and calibrated the drills prior to seeding.
A wildfire site near Snowville, UT was seeded during the week of November 10, 2008. A total of approximately 52.13 acres were seeded in plots to the following mixes:

Snowville, UT (Fall 2008) Cover Crop Mix (12.13 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Rimrock Indian ricegrass	4.50	4.61
Anatone bluebunch wheatgrass	4.00	4.50
Rice Hulls		6.32

Drill Mix 40.0 acres

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Rimrock Indian ricegrass	1.00	1.02
Munro globemallow	0.50	0.76
Anatone bluebunch wheatgrass	2.00	2.25
Toe Jam Cr. bottlebrush squirreltail	1.00	1.06
Sulphur-flower buckwheat	0.24	0.48
Rice Hulls		1.59

10X Broadcast Mix (5 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Wyoming big sagebrush	0.95	5.42
Rubber rabbitbrush	0.50	3.38
Eagle yarrow	0.15	0.17
Mtn. Home Sandberg bluegrass	0.40	0.49
Royal penstemon	0.09	0.13
Rice Hulls		4.17

5X Broadcast Mix (30 acres)

Species	Pounds PLS/ac	Pounds Bulk Seed/ac
Wyoming big sagebrush	0.45	2.57
Rubber rabbitbrush	0.50	3.38
Eagle yarrow	0.15	0.17
Mtn. Home Sandberg bluegrass	0.40	0.49
Royal penstemon	0.09	0.13
Rice Hulls		7.03

This study will be repeated in the fall of 2009. Location of the study to be determined based on areas that burn during the 2009 fire season. PMC personnel also assisted in collection of monitoring data from the Mountain Home site, which was planted in 2007.

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

St. John, L.; Cornforth, B.; Simonson, B.; Ogle, D.; and D. Tilley. 2008. Technical Note 20: Calibrating the Truax Rough Rider Drill for restoration plantings. Aberdeen Plant Materials Center, Aberdeen, ID. Revised April, 2008. 14 p.

St. John, L.; Ogle, D.; and N. Shaw. 2009. Hotrock Penstemon Plant Guide. Aberdeen Plant Materials Center, Aberdeen, ID. January 8, 2009. 3 p.

St. John, L.; D. Ogle; and N. Shaw. 2009. Sharpleaf Penstemon Plant Guide. Aberdeen Plant Materials Center, Aberdeen, ID. January 20, 2009. 3 p.

St. John, L. Equipment Strategies to Enhance the Post-Wildfire Establishment and Persistence of Great Basin Native Plants. Aberdeen Plant Materials Center, Aberdeen, ID. October 2, 2008. 4 p.

St. John, L.; D. Tilley and D. Ogle. 2008. Great Basin Native Plant Selection and Increase Project - 2007 Annual Report. Aberdeen Plant Materials Center, Aberdeen, ID. January 23, 2008. 14 p.

Tilley, D.J. and L. St. John 2006. Orchard Display Nursery Evaluation Summary (2005-2008). Aberdeen Plant Materials Center, Aberdeen, ID. October 15, 2008. 9 p.

Tilley, D.J.; Ogle, D.; St. John, L. and N. Shaw. 2008. Royal Penstemon Plant Guide. Aberdeen Plant Materials Center, Aberdeen, ID. October 6, 2008. 3 p.

Tilley, D.J. 2008 Orchard Display Nursery Evaluation Summary (2005-2007). Aberdeen Plant Materials Center, Aberdeen, ID. January 15, 2008. 14 p.

Presentations:

Loren St. John. 2008. Aberdeen PMC report of Activities 2007. Great Basin Native Plant Selection and Increase project. 13 Feb. 2008. Salt Lake City, UT.

Management Applications:

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

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

3. The Orchard Display Nursery has been established for 4 years. The best performing native accessions identified in 2008 are: Fish Creek germplasm bottlebrush squirreltail, ‘Bannock’ thickspike wheatgrass, Jim Creek germplasm bluebunch wheatgrass, SERDP Snake River wheatgrass, Hanford source Sandberg bluegrass and Eagle germplasm western yarrow.

Products:

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

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

3. Technical Note 20: Calibrating the Truax Rough Rider Drill for Restoration Plantings was revised and should be a useful guide to calibrating the drill. Plant Guides were developed for Royal penstemon, Hotrock penstemon and Sharpleaf penstemon.

Project Title: Phylogeographic Characterization of Genetic Diversity in Basalt Milkvetch

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

Principal Investigators and Contact Information:

Shaun Bushman, Geneticist (Plants)
USDA-ARS Forage and Range Research Lab
Utah State University, Logan, UT 84322-6300
435.797.2901, fax: 435.797.3075
shaun.bushman@ars.usda.gov

Doug Johnson, Plant Physiologist
USDA-ARS Forage and Range Research Lab
Utah State University, Logan, UT 84322-6300
435.797.3067, fax: 435.797.3075
doug.johnson@ars.usda.gov

Kishor Bhattarai, Ph.D. Student
Department of Plants, Soils, and Climatology
Utah State University
Logan, UT 84322-4820
435.764.0649
kishorbhattarai9@yahoo.com

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 reports to GBSNIP. Exploratory molecular marker-based diversity and population structure was 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 significant population structure ($P < 0.001$). Two groups of populations were prominent in their distinction, one group from Canada and another group from central Nevada (Figure 1). No other groups of accessions were apparent. In support of this, Bayesian analysis conducted with the program STRUCTURE v2.1 was also used to explore population structure in the accessions. Between two and 16 population structures were tested. A general increase in fit was found as the numbers of structures increased up to six (Figure 2), and significant admixture among some populations was detected as the number of structures increased. Thus the data analysis suggests two distinct populations (central Nevada and British Columbia), and one meta-population that encompasses the remaining accessions. The large meta-population comprises collections from Oregon, Idaho, northern Nevada, California, and Washington states.

Within-population genetic diversity estimates found 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). This indicates that level-III ecoregions are not the most accurate means to explain molecular variation in *A. filipes*. Rather, the most parsimonious explanation of variation would be a central meta-population in Oregon, with newer colonies spread out from there. A manuscript describing the population structure and genetic diversity is under preparation and intended for submission to a conservation genetics 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 thesis, which he successfully defended in spring 2007. Manuscripts summarizing the study results were published in Rangeland Ecology and Management (Bhattarai et al., 2008), and a manuscript describing his rhizobial research was also submitted to Rangeland Ecology and Management.

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

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

Publications:

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

Bhattarai, K., D.A. Johnson, J. Kosanke. 2009. Rhizobial strains for basalt milkvetch. Rangeland Ecology and Management (submitted 1/6/09).

Bhattarai, K., D.A. Johnson, T.A. Jones, K.J. Connors, D.R. Gardner. 2008. Physiological and morphological characterization of ecotypes of basalt milkvetch (*Astragalus filipes*): Basis for plant improvement. Rangeland Ecology and Management 61:444-455.

Bushman B.S., K. Bhattarai, D.A. Johnson. 2009. Population structure of *Astragalus filipes* collections from the western U.S.A. and Canada. Conservation Genetics (in preparation).

Johnson, D.A. T.A. Jones, K.J. Connors, K. Bhattarai, B.S. Bushman, K.B. Jensen. 2008. Notice of release of NBR-1 Germplasm Basalt Milkvetch. Native Plants Journal 9:127-132.

Presentations:

Johnson, D.A. 2009. 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, Utah.

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, revegetation of disturbed areas, and beautifying roadsides. This native legume will be of use where introduced species are not desired. The attractive foliage and flowers of basalt milkvetch make it an excellent choice for use in wildflower seed mixtures.

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

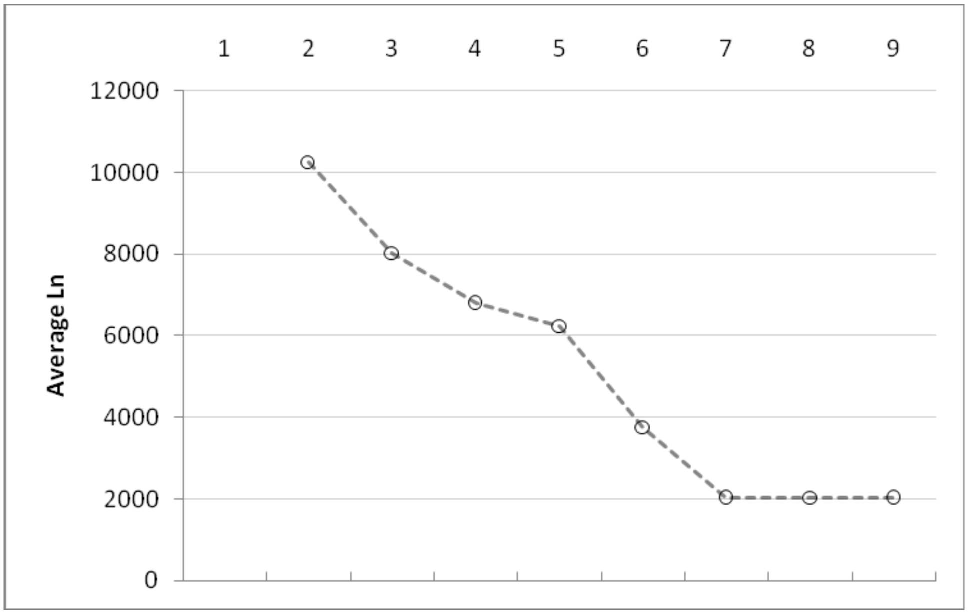


Figure 2. The difference in log likelihood estimates of testing 2 to 9 population structures using Bayesian clustering in the program STRUCTURE 2.2. The lower plateau of differences between structure tests suggest that no appreciable fit to the model is obtained by increasing the structures tested past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

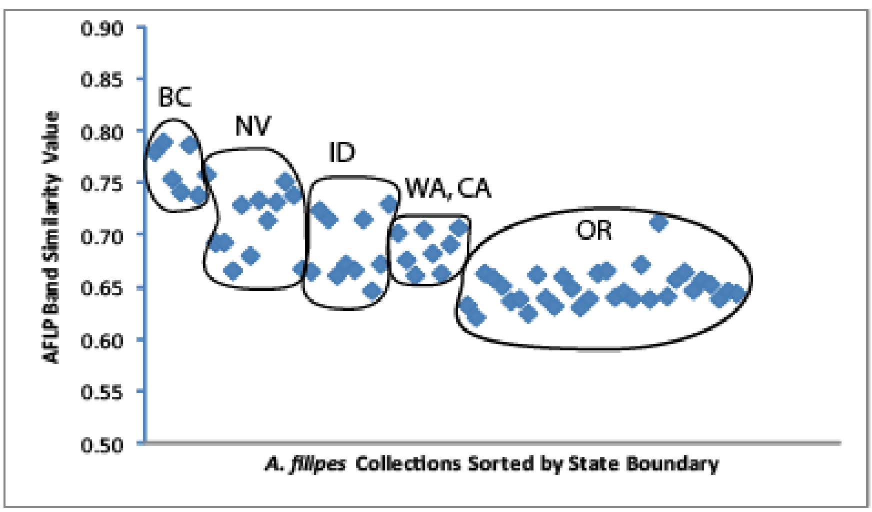


Figure 3. Average within-collection similarity values sorted (A) by decreasing value within level-III ecoregions or (B) by decreasing value within state/province boundary.

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.

Principal Investigators and Contact Information:

Brad St.Clair, Research Geneticist
USDA Forest Service, Pacific Northwest Research Station
3200 SW Jefferson Way, Corvallis, OR 97331-4401
541.750.7294, fax: 541.750.7329
bstclair@fs.fed.us

R.C. Johnson, Research Agronomist
USDA-ARS, Western Regional Plant Introduction Station
Box 646402, Washington State University, Pullman, WA 99164
509.335.3771, fax: 509.335.6654
rcjohnson@wsu.edu

Nancy L. Shaw, Research Botanist
USDA Forest Service, Rocky Mountain Research Station
322 E. Front Street, Suite 401, Boise, ID 83702
208.373.4360, fax: 208.373.4391
nshaw@fs.fed.us

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.

<u>Objectives</u>

1. Using common gardens, determine the magnitude and patterns of genetic variation among bluebunch wheatgrass populations from a wide range of source environments in the Great Basin, Columbia Basin, and adjacent areas.

2. Relate genetic variation to environmental variation at collection locations.
3. Compare common cultivars of bluebunch wheatgrass to native sources.
4. Develop seed transfer guidelines.

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 16 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 is currently being used in germination tests to evaluate population variation in germination rates. Preliminary analyses have been done to evaluate differences among test sites, populations, and families within populations, and to look at the relationship between population variation and climatic variation at source locations.

Preliminary Results

Differences among test sites for traits of growth and phenology were generally large (Table 1). Plants grown at the warmest and driest site, Central Ferry, were largest, whereas plants grown at the coolest, wettest site, Pullman, were smallest. Height growth and seed production (as measured by inflorescence number) was greatest at Lucky Peak. Reproductive phenology was delayed at the coolest site, Pullman, as indicated by later dates of heading, anthesis, and seed maturation. Despite large differences among test sites, correlations of population means between test sites were generally large ($r>0.70$) for the same traits measured at different sites; thus, population x test site interactions, although significant, were not large.

Considerable variation was found between populations evaluated at each test site (Table 2). For most traits, more than 30% of the variation among individual plants was attributed to differences among populations. Variation among families within populations was small. Population differences were generally larger at the Lucky Peak and Central Ferry test sites.

Correlations of population means with climates at the seed sources were weak (Table 3; mostly $r<0.30$). Although the correlations were weak, larger plants were generally from areas with greater precipitation, 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 areas with later spring frost, earlier fall frosts, cooler summers, and greater precipitation. These relationships make sense from an adaptation perspective.

Future Plans

In the next year we will complete the germination tests of seed collected from different populations in the common gardens and undertake a more thorough analysis of the data including multivariate analyses to reduce the number of traits to a few uncorrelated traits, development of regression models of traits using climate data, evaluation of alternative seed zones for delineating populations, and comparisons of cultivars with range-wide populations. Recommendations for seed transfer, seed zones, and genetic conservation will be made. Results will be reported at meetings and in a peer-reviewed journal.

Table 1. Trait means for bluebunch wheatgrass measured at three test sites.

Trait	Test Site		
	Central Ferry	Lucky Peak	Pullman
Dry weight (g)	65	38	23
Crown width (cm)	6.0	5.7	4.8
Height (cm)	28	55	26
Inflorescence no.	21	52	26
Heading date (Julian days)	128	132	139
Anthesis date (Julian days)	141	144	158
Maturity date (Julian days)	182	189	198
Plant form (1-9 prostrate to upright)	6.1	5.9	6.9
Leaf form (height:width ratio)	43	36	33
Leaf color (1-9 yellow to dark green)	3.4	3.3	3.1
Leaf pubescence (1-9 none to much)	4.4	5.4	4.7
Awn length (1-9 none to long)	4.5	4.6	4.5

Table 2. Percent of total variation (populations, families within population, and residual) attributed to variation among populations for traits measured at each test site.

Trait (2008 data)	% Population Variation		
	Central Ferry	Lucky Peak	Pullman
Dry wt	49	40	28
Crown width	42	37	26
Height	11	32	15
Inflorescence no.	36	20	25
Heading date	14	35	12
Anthesis date	6	11	11
Maturity date	33	55	45
Plant form	27	30	24
Leaf form	30	36	26
Leaf color	18	31	10
Leaf pubescence	35	13	37
Awn length	27	55	46

Table 3. Correlations between population means for individual plant traits measured at Lucky Peak test site and 30-yr climate normals of the seed sources.

Climate	Dry Wt	Inflor No.	Heading Date	Anthesis Date	Mature Date	Plant Form	Leaf Form	Awns
Jan Temp	0.12	0.11	0.02	0.17	0.15	-0.07	0.15	0.04
Aug Temp	-0.09	-0.01	-0.19	0.07	0.13	0.07	0.28	-0.33
Spring Frost Date	-0.03	-0.07	0.25	0.09	-0.07	0.04	-0.17	0.29
Fall Frost Date	-0.03	0.04	-0.21	-0.02	0.06	0.00	0.16	-0.26
Annual Precipitation	0.22	0.01	0.10	-0.03	0.02	-0.23	-0.28	0.27
Aug Precipitation	0.22	0.05	0.08	-0.17	-0.13	-0.21	-0.23	0.27

Publications:

St.Clair, J.B., G.R. Johnson, R.C. Johnson, N.L. Shaw, and V.J. Erickson. 2007. Seed zones for maintaining adapted plant populations. *In* Norcini, J. (ed.). Proceedings, Native Wildflower Seed Production Research Symposium, Orlando, FL. (http://nfrec.ifas.ufl.edu/Norcini/WFSympWeb/2007/Sympindex.htm)

Presentations:

St.Clair, J.B., V.J. Erickson, and G.R. Johnson. 2006. Developing regionally adapted seed for native plant restoration. Oregon/Washington USDI Bureau of Land Management Botany Meeting, Corvallis, OR.

St.Clair, J.B., V.J. Erickson, G.R. Johnson, and R.C. Cronn. 2006. Seed zone development for native plant restoration. USDA Forest Service, Region 6, Regional Botany Meeting, North Bonneville, WA.

St.Clair, J.B., G.R. Johnson, R.C. Cronn, and V.J. Erickson. 2006. Managing genetic resources: seed zones for native plant restoration. Plant Conservation Alliance Bi-Monthly Meeting, Washington, DC.

Johnson, R.C., B. Hellier, R. Adair, M. Cashman, J.B. St.Clair, N.L. Shaw, and V.J. Erickson. 2007. Uncovering adapted germplasm for the Great Basin: tapertip onion, bluebunch wheatgrass, and others. Great Basin Native Plant Selection and Increase Project 2007 Symposium, Society for Range Management 60th Annual Meeting, Reno, NV.

Johnson, R.C., V.J. Erickson, B. Hellier, J.B. St.Clair, and M. Cashman. 2007. Uncovering adapted native germplasm for successful restoration. Society for Ecological Restoration Northwest Chapter and Society of Wetland Scientists Northwest Chapter, Joint Meeting, Yakima, WA.

St.Clair, J.B. 2007. Seed transfer zones for native plants. Conservation Seed Workshop: Partnerships for Native Plant Materials Development/Local Ecotypes, American Seed Trade Association Annual Meeting, Washington, DC.

St.Clair, J.B., G.R. Johnson, R.C. Johnson, N.L. Shaw, and V.J. Erickson. 2007. Seed zones for maintaining adapted plant populations. Native Wildflower Seed Production Research Symposium, Orlando, FL. (*Published abstract and executive summary.)*

St.Clair, J.B., N.L. Shaw, R.C. Johnson, V.J. Erickson, G.R. Johnson, M. Horning, R.C. Cronn, and P. Olwell. 2007. Adapted germplasm for restoration: collaborative seed zones studies. Oregon/Washington USDI Bureau of Land Management Botany Meeting, Corvallis, OR.

St.Clair, J.B., R.C. Johnson, and N.L. Shaw. 2009. Genetic diversity and genecology of bluebunch wheatgrass (*Pseudoroegneria spicata*). Great Basin Native Plant Selection and Increase Project 2008 Annual Meeting, Boise, ID.

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, and workshops.

Project Title: The Quest for Natives; Cultural Practices, Species Screening, Harvesting Equipment, Private Growers

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

Principal Investigators and Contact Information:

Scott Jensen, Botanist
USDA FS RMRS Shrub Sciences Laboratory
735 N. 500 E., Provo, UT 84606-1865
801.356.5128, fax 801.375.6968
sljensen@fs.fed.us

Mark Anderson, Biological Science Technician
USDA FS RMRS Shrub Sciences Laboratory
735 N. 500 E., Provo, UT 84606-1865
801.356.5128, fax 801.375.6968
msanderson@fs.fed.us

Covy Jones, Biologist
Utah Division of Wildlife Resources
735 N. 500 E., Provo, UT 84606-1865
801.356.5108, fax 801.375.6968
cdjones@utah.gov

Species status:

Astragalus utahensis

Common garden data is being compiled.

Agoseris heterophylla

Two growers installed plantings of a G2 Humboldt County NV source of *Agoseris heterophylla* in the fall of 2008. Approximately 2 lbs of seed remain from our increase efforts. Lacking further grower demand this material will plant a series of harvest plots at our production facilities. We are again increasing this source as G3 with an expected 2009 production of 8 lbs.

Hesperostipa comata

Common garden data is being compiled.

Lupinus spp.

Common garden data is being compiled. Scott Jensen and graduate student Covy Jones initiated an extensive study assessing establishment techniques and cultural practices. Covy recently accepted a position as a plant materials biologist for the Utah Division of Wildlife Resources. For more information see Covy's Utah Division of Wildlife Resources report.

Products:
Equipment Evaluation

Hand Held Mechanical Harvester
Partnering with Mary Ann Davies at the Missoula Technology and Development Center we tested a hedge trimmer and a hand-held vacuum to see whether they might do a better job than common methods of collecting seed by hand. Neither the Garden Groom Pro hedge trimmer nor the Euro-Pro Shark hand-held vacuum is an improvement over common hand methods for collecting native seeds. For certain tasks in remote areas, simplicity just cannot be beat. See reference to article under Publications section.

Walk Behind Harvester
We purchased a push type seed harvester (Duncan Foss, Missouri Wildflower Nursery, 9814 Pleasant Hill Road, Jefferson City, Missouri 65109) to test in both wildland and production settings. The design incorporates an adjustable height, wheeled bin with a chain driven, adjustable speed reel and a hedge trimmer serving as the cutter bar. The unit's niche is monotypic wildland stands or small acreage agronomic stands where swathing and/or direct combining are not practical. For species where post-harvest drying is necessary prior to threshing, this is a less expensive alternative to a forage harvester. The unit retails for about $2,000. We tested the harvester on a wildland lupine stand in 2008. With some modifications to fortify a few week points the harvester will be a useful tool.

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

A single Lincoln County, NV source of Nevada goldeneye (*Heliomeris multiflora* Nutt. var. *nevadensis)* was increased in 2006, 2007, and 2008 (G1 – 2.0 lbs) at Fountain Green and Ephraim.

Wildland Seed Collections
In 2008 we made 85 collections. These were targeted toward several lupine species, scarlet gilia, Nevada goldeneye, and Lewis flax.

Bulk Collections for Research and Distribution to Growers
Sixty-five pounds of hairy bigleaf lupine *(Lupinus prunophilus*) were collected from a wildland stand in Juab County, UT.

Twenty-two pounds of longspur lupine (*Lupinus arbustus)* were collected from a wildland stand in Elko County, NV.

Species Screening
Several of the species initially selected in our program proved to have characteristics limiting their production in a commercial setting. Consequently, we have adopted a more selective approach to choosing species for further plant material work (Table 1). Potential species are initially screened based on potential market demand and germination and growth characteristics that are adaptable for current agronomic practices. 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.

Table 1. Genera in the screening process.

Genus	Common Name	Genus	Common Name
Amsinckia	fiddleneck	*Argemone*	flatbud pricklypoppy
Aster	aster	*Astragalus*	milkvetch
Castilleja	paintbrush	*Calochortus*	mariposa lily
Chaenactis	dustymaiden	*Cryptantha*	cryptantha
Enceliopsis	sunray	*Erigeron*	fleabane
Frasera	frasera	*Gaillardia*	blanketflower
Helianthus	sunflower	*Helianthella*	oneflower helianthella
Hymenopappus	hymenopappus	*Hymenoxys*	rubberweed
Iris	iris	*Nicotiana*	coyote tobacco
Lithospermum	stoneseed	*Lomatium*	biscuitroot
Oenothera	evening primrose	*Penstemon*	beardtongue
Packera	groundsel	*Phacelia*	phacelia
Potentilla	slender cinquefoil	*Thelypodium*	thelypod

New Candidate Species

Scarlet gilia *(Ipomopsis aggregata)*. One source planted at Ephraim, UT showed good establishment from seed, an upright growth habit and adequate seed retention. Generally the species flowers indeterminately and shatters seed upon maturation. Under minimal irrigation it functions as a short lived perennial with no seed production the first year, approximately 20% production year 2 and full production followed by mortality year 3. Based on 30” rows, a single machine harvest yielded the equivalent of 78 lbs of seed per acre while multiple hand harvests yielded 93 lbs per acre. Viability was low at 21% pls. The species is broadly distributed across nearly all counties of the Great Basin. Currently 11 sources have been collected and seeded for further evaluation.

Nevada goldeneye (*Heliomeris multiflora* var. *nevadensis*). A Lincoln Count, NV source planted from seed established poorly at Ephraim, UT and moderately at Fountain Green, UT. Inappropriate seeding depth may be responsible for observed establishment at both sites. Yield data was not taken. With supplemental water, plants produce a robust canopy the first year and continue to produce well at the current year 3. With supplemental water the species flowers indeterminately and shatters seed upon maturation. Its upright habit lends itself to a single combine harvest. The species has broad distribution across the southern Great Basin.

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 5 replicated blocks at Fountain Green, UT we seeded 4 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. N-sulate helps retain moisture as seedlings are germinating and limits frost damage. These same species were planted in sandy loam and loam soils at Spring Creek, NV and Vernon, UT, respectively.

Seed Distribution to Growers

We partnered with two growers, one in Spring Creek NV (Table 2), and a second in Vernon, UT (Table 3) to evaluate compatibility between the species planted, soil types, and cultural practices, while increasing stock seed of 18 seed sources.

The following sources were planted at these locations:

Table 2. 2008 Planting information Elko, NV.

Species	Common name	Lot no	County	State	Acreage seeded
Lupinus arbustus	Longspur lupine	LUARB6-P4-2008	Elko	NV	0.06
Lupinus prunophilus	Hairy bigleaf lupine	LUPR2-B8-2007	Juab	UT	0.07
Lupinus argenteus	Silvery lupine	LUAR3-U5-2007	Elko	NV	0.04
Agoseris heterophylla	Annual agoseris	AGHE2-U1-2007-Greenhouse-G2	Humboldt	NV	0.04
Lomatium nudicaule	Barestem biscuitroot	LONU2-P1-2008	Elko	NV	0.06
Cleome lutea	Yellow spiderflower	CLLU2-U2-2004	Nye	NV	0.58
Heliomeris nevadensis	Nevada goldeneye	HEMUN-B4-2006-Snow Field-G1	Lincoln	NV	0.09
Lithospermum ruderale	Western stoneseed	LIRU4-P1-2008	Elko	NV	0.06
Ipomopsis aggregata	Scarlet gilia	VNS - Dedicated Hunter			0.06
Argemone munita	Flatbud pricklypoppy	ARMU-P1-2008	Juab	UT	0.07
Mentzelia	Blazingstar	MENTZ-P1-2008	Juab	UT	0.02
Amsinckia menziesii	Menzies' fiddleneck	Amsin-P6-2008	Eureka	NV	0.06
Amsinckia menziesii	Menzies' fiddleneck	AMSIN-P4-2008	Elko	NV	0.03
Frasera albomarginata	Desert frasera	FRAL5-P1-2008	Iron	UT	0.06
Thelypodium milleflorum	Manyflower thelypody	THMI5-P2-2008	Eureka	NV	0.06
Lupinus sericeus	Silky lupine	LUSE4-B28-2006	Juab	UT	0.03
Potentilla gracilis	Slender cinquefoil	POGR9-P1-2008	Elko	NV	0.06

Table 3. 2008 Planting information, Vernon, UT.

Species	Common name	Lot #	County	State	Acreage Seeded
Agoseris heterophylla	Annual agoseris	U1-07, Snow Field Station	Humboldt	NV	0.72
Amsinckia menziesii	Menzies' fiddleneck	AMSIN-P4-2008	Elko	NV	0.07
Cleome lutea	Yellow spiderflower	CLLU2-U2-2004	Nye	NV	0.28
Heliomeris nevadensis	Nevada goldeneye	HEMUN-B4-2006-Snow Field-G1	Lincoln	NV	0.08
Lomatium nudicaule	Barestem biscuitroot	LONU2-P1-2008	Elko	NV	0.21
Lupinus argenteus	Silvery lupine	LUAR3-U5-2007	Elko	NV	0.04
Lupinus prunophilus	Hairy bigleaf lupine	LUPR2-B8-2007	Juab	UT	0.04
Penstemon pachyphyllus	Tthickleaf beardtongue	B5-03	White pine	NV	0.16
Potentilla gracillis	Slender cinquefoil	POGR9-P1-2008	Elko	NV	0.08
Thelypodium milleflorum	Manyflower thelypody	THMI5-P2-2008	Elko	NV	0.15

Seed Distribution to Cooperators

Oregon State University Malheur Experiment Station. Clinton C. Shock. Seed and cultural practice studies - *Lupinus arbustus, Lupinus prunophilus*, *Agoseris heterophylla*.

Brigham Young University. Bruce Roundy, Kurt Young. Seed studies - *Agoseris heterophylla, Lupinus arbustus, Astragalus utahensis.*

USDA-ARS, Forage & Range Research Laboratory. Ivan Mott, Tom Jones. 53 sources of *Hesperostipa comata*. Phylogeographical analysis of Needle and Thread accessions collected throughout the Great Basin.

Presentations:

Jensen, Scott L, S.B. Monsen, P. Fosse. Spatial and Temporal Seed Dispersal of Squarrose Knapweed (*Centaurea virgat*a Lam. spp *squarrosa* (Willd.) Gugler) in West Central Utah.

Jensen, Scott L; Jones, Covy. Plant Materials Development, Cultural Practices for *Agoseris* and *Lupinus*. Great Basin Native Plant Selection and Increase Project Annual Meeting, Salt Lake City, UT. February 14-15, 2009.

Publications:

Jensen, Scott L.; Monsen, Stephen B.; Fosse, Pat. 2008. Spatial and temporal seed dispersal of squarrose knapweed (*Centaurea virgata* Lam. ssp. *squarrosa* (Willd.) Gugler) in west central Utah, a case study. In: Kitchen, Stanley G.; Pendleton, Rosemary L.; Monaco, Thomas A.; Vernon, Jason, comps. 2008. Proceedings-Shrublands under fire: disturbance and recovery in a changing world; 2006 June 6-8; Cedar City, UT. Proc. RMRS-P-52. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 69-72.

Whitaker, Alison; Jensen, Scott L. 2008. Effects of Fire and Restoration Seeding on Establishment of Squarrose Knapweed (*Centaurea virgat*a Lam. spp. *squarrosa*). In: Kitchen, Stanley G.; Pendleton, Rosemary L.; Monaco, Thomas A.; Vernon, Jason, comps. 2008. Proceedings-Shrublands under fire: disturbance and recovery in a changing world; 2006 June 6-8; Cedar City, UT. Proc. RMRS-P-52. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 77-79

Davies, Mary Ann; Jensen, Scott. Hands beat machines for collecting native seed. USDA Forest Service, Missoula Technology and Development Center, Missoula, MT. http://www.fs.fed.us/t-d/pubs/htmlpubs/htm08242353/index.htm

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

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

Principal Investigators and Contact Information:

Covy Jones, Wildlife Biologist II
Utah Division of Wildlife Resources, Great Basin Research Center 494 West 100 South, Ephraim, UT 84627
435.283.4441, fax: 435.283.2034

Alison Whittaker, Wildlife Biologist III
Utah Division of Wildlife Resources, Great Basin Research Center 494 West 100 South, Ephraim, UT 84627
435.283.4441, fax: 435.283.2034

Project Description:
We are working on developing cultural practices for several forb and grass species for the Great Basin. We are also working on improvement of germination techniques through mechanical, chemical, and thermal scarification methods. Forging relationships with new growers continues to be a priority allowing us to increase seed availability from small collections to larger quantities and provide seed for larger production fields and landscape scale restoration projects. We continue to find new methods to deal with disease and pestilence issues that have become apparent in agricultural settings.

Project Status:
Wildland Seed Collections
We have bulked up our collections of gray hawksbeard (*Crepis intermedia*) and tapertip hawksbeard (*Crepis acuminata*). We were also able to start new collections of Hooker's balsamroot (*Balsamorhiza hookeri*). Native Seed Co. provided us with 20 pounds of gooseberryleaf globemallow (*Sphaeralcea grossularifolia*) seed from the Panaca, Nevada area and they donated 8 pounds tapertip hawksbeard that was collected on the west slope of the Pequop summit.

Common Gardens
We maintained common garden sites in Ephraim and Fountain Green. The direct seeded hawksbeard (*C. acuminata* and *C. intermedia*) trials planted fall 2007 came up well in spring 2008. However, the crop was decimated by what appeared to be flea beetles and all plants were lost. There was an interim between when Therese Meyer left and Covy Jones started which made it too late to take data on the globemallow (*Sphaeralcea* spp.), and cushion buckwheat (*Eriogonum ovalifolium*). We did however transplant a new common garden of arrowleaf balsamroot (*Balsamorhiza sagittata*). Work was also initiated with several desired grass species. Multiple accessions of muttongrass (*Poa fendleriana*), Sandberg bluegrass (*Poa secunda*), and Indian ricegrass (*Achnatherum hymenoides*) were transplanted at Fountain Green in June 2008.

Species Status:
Sphaeralcea spp.
We noticed that several of the globemallow plants were infected by a fungus that was later identified as a rust. The rust disease issue will be evaluated this coming year to determine which accessions are more resistant. Two new globemallow common gardens will be transplanted, one at Snow Field station and the other at the Desert Experimental Range (50 miles west of Milford, UT). The data from these common garden sites combined with the data collected from the Fountain Green common gardens will allow for further progression toward selected class releases for *Sphaeralcea* spp. in the Great Basin.

Hedysarum boreale
Preliminary testing was done on Utah Sweetvetch (*Hedysarum boreale*) this year to evaluate the effect of native rhizobia vs. the commercially available rhizobia. The commercial inoculum seemed to infect a higher percentage of plants. A follow up study is now in progress to see which inoculum is better suited to increase leafy growth, root development, and seed production.

Eriogonum ovalifolium
We determined that eight of the accessions from five geographic areas are superior. Mapping the selections onto Omernik ecoregion maps showed the ecological distribution. The accessions came from Nevada and Utah, between elevations 4400 and 6400 feet elevation. Only two of the accessions, Drum Mt. and Newcastle, were in the same Level 4 ecoregion. A more practical approach would be to group to Level 3 ecoregions, then all 8 sites are grouped into 4 ecoregions. A focus in 2009 will be to collect more wildland seed from these sites, and to produce seed in increase fields with adequate isolation distance from other *E. ovalifolium*. Once established we will evaluate mechanical harvesting methods in order to provide seed for growers along with seed harvesting information.

Balsamorhiza spp
Arrowleaf balsamroot has posed problems primarily because of the time it takes to establish. In addition, seed predation on this species can damage up to 30% of total seed harvest. In 2008 we began work with Hooker's balsamroot. This species is reported to establish quicker and would be more enticing for growers. We will continue working with this species in 2009 by establishing cultivated plots in Fountain Green and harvesting seed from multiple wildland sources through out the Great Basin.

Perideridia bolanderi
One Nevada accession has outshined the other collections in plant vigor and seed production. We will harvest more seed from this more vigorous accession from Nevada and an increase field will be planted. There were 12 *P. bolanderi* accessions started in 2007, which were grown in plugs in the greenhouse for a trial in Fountain Green. The *P. bolanderi* were dormant before we could transplant them this year. They overwintered in plugs beneath straw and will be planted out spring 2009.

Seed Scarification Studies:
Sphaeralcea spp.
We had success in 2007 using acid scarification to reduce dormancy in globemallows. However, concentrated sulfuric acid is not easy to acquire and handling the acid poses some risk. This is why treating large quantities of seed with this method is not our first choice. A more practical method of scarification is pouring boiling water over the globemallow seed. This melts away the waxy cuticle and allows the seed to imbibe and germinate. Preliminary studies using this method were conducted

fall 2008 and showed promise. We will continue research studies in 2009 to optimize water temperature and exposure time so that maximum germination is obtained with minimum embryo death.

Lupinus spp.
Mechanical, thermal, and chemical scarification methods continue to be explored for hard-seeded lupine species. *L. prunophilus* has shown good response to chemical scarification while *L. argeneus* has done best with mechanical scarification. Scarification methods are currently being re-tested, then, a linear regression model will be built to find optimal treatments. In 2009 we will use the results of the previous studies to find the optimal scarification technique for hard-seeded lupine species across several accessions. This will allow us to use a more complex statistical model to define the best scarification methods that are applicable for each species over a broad geographic area.

Cultivation Trials:
Lupinus spp.
We collected and analyzed data comparing two direct seeding methods for four lupine species in order to evaluate stand establishment. Increased germination was noted in the plots covered with insulate fabric. We suspect that the insulate fabric plays an important role in moisture retention and increased soil temperature and that these two factors are responsible for increased germination. Weed control methods were also evaluated between planting methods in man hours spent controlling weeds inside the plots. In 2009 we expect to collect yield data and continue to collect data on weed control.

N-sulate fabric
In fall 2009 we will conduct randomized, replicated studies to determine the effectiveness of the insulated fabric for several species and various accessions within those species.

Growers
Contacts were made with two new growers, one in Elko, Nevada, and one near Provo, Utah. The Nevada grower has recently acquired about 47 acres in a sandy soil type just outside of Elko Nevada. About 10 acres were in good planting condition. She has plenty of water to establish and grow native plants. The grower has planted 5 acres and 24 different species. Three of the species that we are currently working with were planted at the farm and are listed below (Table 1).

Table 1. Species planted at Elko, NV.

Species	**Common name**	**Acreage seeded**
Sphaeralcea coccinea	Scarlet globemallow	0.14
Sphaeralcea grossularifolia	Gooseberryleaf globemallow	0.58
Crepis intermedia	Limestone hawksbeard	0.37

The Utah farm comprises over 700 acres just north of Vernon on a clay loam soil type. The grower has had experience growing grass sod and several penstemon species. Twenty-two species were planted on 10 acres of land in fall 2008. The grower would like to expand as he determines which species do well on the farm. Five of the species that we are currently working with were planted at the Bell farm and are listed below (Table 2).

Table 2. Species planted at Vernon, UT.

Species	Common name	Acreage Seeded
Balsamorhiza hookeri	Hooker's balsamroot	0.10
Crepis acuminata	Tapertip hawksbeard	0.57
Crepis intermedia	Limestone hawksbeard	0.32
Sphaeralcea coccinea	Scarlet globemallow	0.45
Sphaeralcea grossulariifolia	Gooseberryleaf globemallow	0.96

Presentations:

Jones, Covy and Scott Jensen. Methods for cultivation of Great Basin native *Lupinus* spp. Wildland Shrub Symposium. Bozeman, MT. June 17-19, 2008.

Vernon, Jason. Development of project plans, seed procurement, seed storage, seed mixing, planning and on-site restoration measures. Colorado Division of Wildlife Utah Field Tour: Habitat Management and Restoration. Ephraim, UT. June 30, 2008.

Meyer, Therese. Progress report for Great Basin Research Center Native Forb Project. Presented at Great Basin Native Plant Selection and Increase Project Annual Meeting. Salt Lake City, UT. February 13-14, 2008.

Management Applications:

Land Managers

The plantings we did last year will increase the availability and seed quantity of several forb species. This will be coming online within the next 1-3 years. Land managers and seed purchasers need to keep this in mind when planning future seeding projects and putting out seed bid sheets.

Seed Producers

We are now able to provide seed producers with new information on scarification of globemallow and lupine species to facilitate stand establishment from seed.

Products:

Green House

We automated the greenhouse watering system to provide a more even water distribution and a more consistent watering cycle. This will provide a more efficient way to establish plants from seed.

Q-Plug

We changed to a synthetic potting media known as a Q-plug. The media consists of peat moss and a tackifier and allows us to transplant species with a taproot that would not adhere to a typical soil mix.

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

Project Location: Prineville, OR

Principal Investigators and Contact Information:

Berta Youtie
Eastern Oregon Stewardship Services (EOSS)
P.O. Box 606, Prineville, OR 97754
541.447.8166 or 541.447.6228
byoutie@crestviewcable.com, berta.youtie@oregonstate.edu

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 in the Columbia Basin were visited and accessed for their capacity to grow forbs. We discussed possible forb species to grow and what guarantee companies might need in order to grow seed where protocols are still unknown. After reporting back to Nancy Shaw and Stan Young, contract agreements are being developed with growers, in some cases pending stand establishment. Where seed stocks from the Great Basin were not immediately available, we spent the 2008 field season collecting large quantities of seed to transfer to contracted growers. We also collected seed for the GBNBSIP and USDI BLM Seeds of Success programs.

Results

Six native seed growers were contracted to grow 7 forb species (Table 1). Thirty-five seed lots from 15 species were collected by EOSS (Table 2). Seed lot weights varied between less than a pound to over 20 pounds. A workshop, “Developing a Successful Native Plant Program” initially scheduled for September 2008 was held April 1 and 2, 2009. The workshop highlighted partnership and collaboration, available native plant materials, and success stories from UT, NV, ID, OR &WA. It will included a field demonstration on selecting and calibrating drills for seeding native seed mixes and a field tour of the forb seed production research at the Oregon State University Malheur Experiment Station.

Management Applications:
Increased communication 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. BLM and USFS Districts may increase efficiency in developing native seed selection and increase programs.

Products:
Table 1. Forb species under contract for seed production in Oregon and Washington.

Species under Contract	Code
Eriogonum heracleiodes	ERHE2
Eriogonum umbellatum	ERUM
Dalea ornatum	DAOR
Astragalus filipes	ASFI
Penstemon cyaneus	PECY
Penstemon deustus	PEDE
Lomatium triternatum	LOTR

Table 2. Seed lots collected in the 2008 field season by Eastern Oregon Stewardship Services.

SOS Number	Site/Species	Site Details	Collection Date	No. of Plants
RMRS-1053	ERHE 17	Stinking Water Pass	7/24-31/2008	1500
RMRS-1054	ERHE 18	Castle Rock	7/26/2008	1000's
RMRS-1056	PEDE 18	Jordon Craters	7/17/2008	100
RMRS-1057	BASA 13	Leslie Gulch	6/13/2008	60
RMRS-1058	CHDO 01	Silver City RD	7/18/2008	50
RMRS-1059	LODI 29	Silver City RD	7/18/2008	200
RMRS-1060	LODI 96	NAMORF	6/16/2008	30
RMRS-1061	LODI 77	Hwy 20 Foley Rd	7/10/2008	---
RMRS-1062	ERUM 05	Stinking Water Pass	7/31/2008	500
RMRS-1063	LOTR 05	Leslie Gulch	6/13/2008	50
RMRS-1064	PEDE 41	Frenchglen	7/7/2008	50
RMRS-1065	PEDE 46	Hwy 20 mp 163/164	8/8/2008	50
RMRS-1066	LOTR 39	Castle Rock	7/19/2008	250
RMRS-1067	LOTR 59	Frenchglen	7/7/2008	50
RMRS-1068	DAOR 07	Chalk Basin	6/27/2008	0

Table 2 continued.

SOS Number	Site/Species	Site Details	Collection Date	No. of Plants
RMRS-1069	PESP 70	N of Twin Springs	7/19/2008	50
RMRS-1070	PESP 69	Sunset Valley Ln	7/25/2008	100
RMRS-1071	MACA 03	Hwy 27 N of Hwy 20	8/8/2008	250
RMRS-1072	PEDE 48	Stinking Water Pass	8/5/2008	150
RMRS-1073	LOTR 70	Steens Mountain	7/14/2008	140
RMRS-1074	LONU 04	Hwy 20 mp 163/164	7/12/2008	50
RMRS-1075	LONU 05	Stinking Water Pass	7/12/2008	40
RMRC-1076	LONU 06	Castle Rock	7/20/2008	100
RMRS-1077	LOGR 36	S of Twin Springs	6/14/2008	30
RMRS-1078	CHDO 10	N of Twin Springs	7/19/2008	50
RMRS-1079	EROV 69	Stinking Water Pass	8/5/2008	70
RMRS-1080	CHDO 10	Rock Creek	7/17/2008	100
RMRS-1081	DAOR 04	Round Mt Succor CK	6/13/2008	100
RMRS-1082	DAOR 05	Twin Springs RD	6/20/2008	350
RMRS-1083	DAOR 06	Rock Creek RD	7/18/2008	100
RMRS-1084	ASFI 02	Sunset Valley Ln	7/25/2008	100
RMRS-1085	ACTH 09	Oxbow Reservoir	6/22/2008	300
RMRS-1086	LOTR 69	Jordon Craters	6/28/2009	70
RMRS-1087	ACTH 08	Hwy 95 ODOT	6/27/2008	1000's
RMRS-1088	DAOR 3	Jeans Harper Site	6/14/2008	400
RMRS-1089	ERUM ?	Brothers	8/7/08	1000

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

Project Location: Utah Crop Improvement Association, Utah State University

Principle Investigators and Contact Information:

Stanford Young, Utah Crop Improvement Association
Utah State University, Logan, UT 84322-4855
435.797.2082, fax: 435.797.0642
sayoung@mendel.usu.edu

Michael Bouck, Utah Crop Improvement Association
Utah State University, Logan, UT 84322-4855
435.797.2101, fax: 435.797.0642
michaelb@mendel.usu.edu

Project Description:
This project is funded through a Research Joint Venture Agreement 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. Seed was distributed using the Buy-back option, a mechanism for obtaining a portion of the seed increased by private growers back to the UCIA for redistribution to the original and additional seed growers for further seed increase.

Project Status:
A synopsis of the Buy-back Program follows (Jan. 1, 2008-Dec. 31, 2008). Table 1 lists new (2008) seed distributions and their field status. Table 2 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 2002-2007. This list includes the previous AOSCA program, which is now being administered by the UCIA. It is expected that in 2009 several additional forbs and grasses will be included in the program. Table 3 lists the standardized market price for contract negotiations for each species included in the program, updated at the beginning of 2009. However, some of the species planted in the fall of 2008 do not have a market record, and more investigation and negotiation is underway to complete monetary details of buy-back contracts.

Great Basin Native Plant Selection and Increase Project (GBNPSIP) and Utah Crop Improvement Association (UCIA) Stock Seed Buy-back Program

Project Synopsis

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

The purpose of the UCIA Stock Seed Buy-back Program, funded through the GBNPSIP, is: a) to facilitate development of a seed market for specific germplasm accessions and formal germplasm releases developed through GBNPSIP; these include all germplasms prior to 2003 and certain others assigned through 2008 (see Tables 1 and 2); b) to reward initial seed growers financially for the risks they have assumed to participate in the program; c) to document germplasm identity through the seed increase process by utilizing seed certification protocols; and d) to increase stock seed available for potential secondary seed growers. This program is administered through the Utah Crop Improvement Association.

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

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

Notes:

1. Seed quantity and quality (lbs PLS) of original stock seed provided to the seed grower will be determined on a case by case basis in order to determine the amount of seed that must be returned to the UCIA from the first harvestable crop by the seed grower.

2. When the original seed grower sells to the UCIA and/or buys back seed (as in points 3 and 4 above) the amount of seed (lbs PLS) will typically be verified through the applicable state seed certification agency. Some instances may require special negotiation.

3. In one instance (basin wildrye tetraploid pool from the geographic Great Basin, planted in 2007 and replanted in 2008), the UCIA has negotiated a forward contract with establishment cost payment. This pre-payment will be credited towards eventual seed purchase at an agreed upon price.

Table 1. 2008 Utah Crop Improvement Association (UCIA) forb and grass seed acquisition, distribution and field planting status for species germplasms included in the Great Basin Native Plant Selection and Increase Project, UCIA Stock Seed Buy-back Program

Kind & Variety / Germplasm	Lot / Source	Origin	Seed acquisition and production	Generation	Added to Inventory	Date	Distributed from Inventory	Date	State distributed to	Field Status
FORBS & SHRUBS					bulk (lb)		bulk (lb)			Seeded:
Elymus elymoides	Lot 81, GBR118	Little Sahara Site	*1*2	G0	2.5	10/10/08	2.5	10/10/08	ID	Fall 2008
Eriogonum heracleoides	ERHE2	Pooled	*1*2	G0	52.5	12/5/08	52.5	12/5/08	WA	Fall 2008
Leymus cinereus	LECI	Pooled	*1*2*3	G1	10.00	9/9/08	10.00	9/9/08	WA	Fall 2008
Eriogonum umbellatum	ERUM	Pooled	*1*2	G0	34.09	9/17/08	34.09	9/17/08	OR	Fall 2008
Penstemon deustus	PEDE	Pooled	*1*2	G0/G1?	14.8	9/8/08	14.8	9/8/08	OR	Fall 2008
Dalea ornata	DAOR	Pooled	*1*2	G0	1.14	9/10/08	1.14	9/10/08	WA	Fall 2008
Astragalus filipes	ASFI	Brothers	*1*2	G1	8	9/28/08	8	9/28/08	WA	Fall 2008
Lomatium triternatum	LOTR	Pooled	*1*2	G0/G1	9.05	9/24/08	9.05	9/24/08	ID	Fall 2008
Agoseris heterophylla	AGHE2	Pioche	*1*2	G1	1.5	11/12/08	1.5	11/12/08	UT	Fall 2008
Balsamorhiza hookerl	BAHO	Elko	*1*2	G0	0.33	11/12/08	0.33	11/12/08	UT	Fall 2008
Crepis acuminata	CRAC	Warm Springs	*1*2	G0	1.38	11/12/08	1.38	11/12/08	UT	Fail 2008
Crepis intermedia	CRIN4	Pequop Summit	*1*2	G0	5.74	11/12/08	5.74	11/12/08	UT	Fall 2008
Heliomeris multiflora var. *nevadensis*	HEMUN	Pioche	*1*2	G1	0.11	11/12/08	0.11	11/12/08	UT	Fall 2008
Lupinus prunophilus	LUPR2	Eurerka	*1*2	G0	0.94	11/12/08	0.94	11/12/08	UT	Fall 2008
Penstemon pachyphyllus	PEPA6	Warm Springs	*1*2	G0	1.17	11/12/08	1.17	11/12/08	UT	Fall 2008
Sphaeralcea coccinea	SPCO	Pooled	*1*2	G0	4.4	11/12/08	4.4	11/12/08	UT	Fail 2008
Lomatium nudicaule	LONU2	Pequop Summit	*1*2	G0	0.96	11/12/08	0.96	11/12/08	UT	Fall 2008
Achnatherum thurberianum	ACTH7	Jordan Valley	*1*2	G0	1.133	11/12/08	1.133	11/12/06	UT	Fall 2008
Penstemon cyaneus	PECY3	Richfield	*1*2	G0	0.51	11/12/08	0.51	11/12/08	UT	Fall 2008
Penstemon deustus	PEDE35	Huntington. OR	*1*2	G1	0.504	11/12/08	0.504	11/12/08	UT	Fall 2008
Eriogonum heracleoides	ERHE11	Adams Idaho	*1*2	G0	0.299	11/12/08	0.299	11/12/08	UT	Fall 2008
Achillea millifolium	ACHMI 01	Eagle Idaho	*1*2	G0	0.125	11/12/08	0.125	11/12/08	UT	Fall 2008
Lomatium dissectum	LODI 70 2005	Gooding Idaho	*1*2	G0	7.51	11/12/08	7.51	11/12/08	UT	Fall 2008
Penstemon acuminatus	PEAC Pooled	SR Plain	*1*2	G0	2.55	11/12/08	2.55	11/12/08	UT	Fall 2008
Lupinus prunophilus	LUPR2	Eurerka	*1*2	G0	0.94	11/6/08	0.94	11/6/08	NV	Fall 2008
Agoseris heterophylla	AGHE2	Orovada	*1*2	G2	6.61	11/6/08	6.61	11/6/08	NV	Fall 2008
Lomatium nudicaule	LONU2	Pequop Summit	*1*2	G0	0.68	11/6/08	0.68	11/6/08	NV	Fall 2008
Heliomeris multiflora var. *nevadensis*	HEMUN	Pioche	*1*2	G1	0.22	11/6/08	0.22	11/6/08	NV	Fall 2008
Frasera albomarginata	FRAL5	Newcastle	*1*2	G0	0.124	11/6/08	0.124	11/6708	NV	Fall 2008
Sphaeralcea coccinea	SPCO	Pooled	*1*2	G0	1.57	11/6/08	1.57	11/6/08	NV	Fall 2008
Crepis intermedia	CRIN4	Pequop Summit	*1*2	G0	1.79	11/6/08	1.79	11/6/08	NV	Fall 2008
Eriogonum umbellatum	ERUM	Pooled	*1*2	G0	0.61	11/6/08	0.61	11/6/08	NV	Fall 2008
Lomatium dissectum	LODI 70 2005	Gooding Idaho	*1*2	G0	6.04	11/6/08	6.04	11/6/08	NV	Fall 2008
Penstemon acuminatus	PEAC Pooled	SR Plain	*1*2	G0	4.62	11/6/08	4.62	11/6/08	NV	Fall 2008
				Total (lb)	184.4		184.4			

*1 Currently under Stock Seed Increase contract with grower/cooperators.
*2 Seed acquired at no charge from GBRI Cooperators.
*3 Forward contract with establishment cost payment.

Table 2.2008 Update. Utah Crop Improvement Association (UCIA) forb and grass seed acquisition, distribution, inventory, and field planting status for species germplasms included in the Great Basin Native Rant Selection and Increase Project, UCIA Stock Seed Buyback Program. Previous AOSCA program is now being administered by UCIA.

Kind & Variety/ Germplasm	Lot/ Source	Origin	Seed acquisition and production status	Generation	Added to Inventory	Date	Distributed from Inventory	Date	Inventory 12/31/2007	State Distributed to	Field Status	Seed Harvested
FORBS & SHRUBS					bulk		bulk		bulk			
Achillea millefolium	NSW4-1-EMY1-1	Landmark Seed WA	*3	G2	6.5lb	9/15/04	0.6lb	4/25/05	0	WY	Seeded Fall 07	no
Western Yarrow	NSW4-1-EMY1-1	Landmark Seed WA	*3	G2			5.8lb	9/14/05	0	WA	Established	2006-2008
Eagle Site	NWS-1-YAR-FDN	Landmark Seed WA	*3	G2	13lb	9/20/05	13lb	5/30/07	0	OR	Seedling	Established
Balsamoriza hookeri	BAHO B1-02	Wild collected USFS	*1*2	G0	271g	Fall 02	126g	Fall 02	0.0	ID	Taken out 2006	Yes
Hooker Balsamroot	BAHO B1-02	Wild collected USFS	*1*2	G0	n/a	Fall 02	145g	Fall 02		CO		2007-2008
	BAHO JS-1	BAHO B1-02-ID	*1*2	G1	181g	9/13/06	0		181g			
Balsamorhiza sagittata Arrowleaf Balsamroot	BASA U32-02	Wild collected USFS	*1*2	G0	735g	4/15/04	541g	4/16/04	194g	UT	Seeded 2004	No
Crepis acuminata	CRAC U11-02	Wild collected USFS	*2	G0	50g	Fall 02	50g	Fall 02	0.0	ID	Est.2002, out 2005	2005
Tapertip hawksbeard	CRAC U10-02	Wild collected USFS	*1*2	G0	160g	4/15/04	148g	Fall 02	12g	UT	Unsuccessful	No
Eriogonum heracleoides Wyeth Buckwheat	ERIHER1-BSE-03	Wild collected USFS	*1*2	G0	43g	4/15/04	22.5g	4/16/04	20.5g	UT	Unsuccessful	No
Eriogonum umbelatum Sulfurflower Buckwheat	Unknown	Wild collected USFS		G0		2004		2004		ID	Seeded 2004	No
Lomatium dissectium	LODI B7-02	Wild collected USFS	*2	G0	39g	Fall 02	39g	Fall 02	0.0	NV	Unsuccessful	No
	LODI B14-02	WC	*2	G0	96g	Fall 02	96g	Fall 02	0.0	OR	Taken out 2004	2004
Giant Lomatium	LODI PS-04	LODI B14-02-OR	*3	G1	60g	11/30/04	0		60g *4			
	LODI11-B7-03	Wild collected USFS	*1*2	G0	91g	4/15/04	72.1g	4/16/04	18.9	UT	Unsuccessful	No
	LOMDIS18-BSE-03	Wild collected USFS	*1*2	G0	488g	4/15/04	188g	4/16/04	300g	UT	Unsuccessful	No
	LOMDIS18-BSE-03	Wild collected USFS	*1*2	G0			453g	10/3/05	0.0	WA		
Northern Basin and Range	pooled LODI 11,77,41,78,76	Wild collected USFS	*1*2	G0	907g	10/31/06	907g	11/22/06	0.0	UT	Seeding 2007	No
Lomatium triternatum	LOTRT B2-02	Wild collected USFS	*2	G0	446g	Fall 02	171g	Fall 02	0.0	ID	Est2002, out 2004	Yes
Ternate lomatium	LOTRT B2-02	Wild collected USFS	*2	G0	446g	Fall 02	275g	Fall 02	0.0	OR	Unsuccessful	No
Penstemon acuminatus	PEAC2 B4-02	Wild collected USFS	*1*	G0	102g	Fall 02	102g	Fall 02	0.0	ID	Established	No
Sharpleaf Penstemon	PEAC2 B1-01	Wild collected USFS	2	G0	37g	Fall 02	37g	Fall 02	0.0	NV	Unsuccessful	No
Penstemon cyaneus	PECY2 B6-02	Wild collected USFS	*2	G0	968g	Fall 02	83g	Fall 02	0.0	ID	Est 2002 out 2006	2004-2006
	PECY2 B6-02	Wild collected USFS	*2	G0			685g	Fall 02		CO	Established	2004-2008
Blue Penstemon	PPI-04-1	PECY2 B6-O2-ID	*1*	G1	3lb	1/6/05	3lb	9/16/05	0.0	ID	Seeded 2005	No
	2004.0448	PECY2 B6-02-CO	3	G1	16lb	2/2/05	16lb	2/2/05	0.0	CO	Seeded 2004	2006-2008
	2006.0413	PECY2 B6-02-CO	*1*	G1	5lb	12/5/06	5lb	3/1/07		WY, ID	Seeded 2007	No
	Unknown	PECY1 B6-02	3	G1						ID	Established	2006-2008
Penstemon deustus	PEDE B11-02	Wild collected USFS	*1*	G0	150g	Fall 02	150g	Fall 02	0.0	ID	Established	2005-2008
Hotrock Penstemon	PEDE B10-02	Wild collected USFS	2	G0	123g	Fall 02	123g	Fall 02	0.0	OR	Est. 2002, out 2004	2004

Table 2. cont. 2008 Update. Utah Crop Improvement Association (UCIA) forb and grass seed acquisition, distribution, inventory and field planting status for species germplasms included in the Great Basin Native Plant Selection and Increase Project, UCIA Stock Seed Buyback Program. Previous AOSCA program is now being administered by UCIA.

Kind&Variety/ Germplasm	Lot/ Source	Origin	Seed acquisition and production status	Generation	Added to Inventory	Date	Distributed from Inventory	Date	Inventory 12/31/2007	State distributed to	Field Status	Seed Harvested
FORBS&SHRUBS					bulk		bulk		bulk			
Penstemon pachyphyilus	PEPA2 U6-99	Wild collected USFS	*1*2	G0	1020g	Fall 02	340g	Fall 02	0.0	OR	Est.2002, out 2005	2004-2005
Thickleaf Penstemon	PEPA2 U6-99	Wild collected USFS	*1*2	G0			340g	Fall 02		OR	Est.2002, out 2004	2004
	PEPA2 U6-99	Wild collected USFS	*1*2	G0			340g	Fall 02		NV	unsuccessful	no
	PEPA2 U6-99	Wild collected USFS	*1*2	G0			340g	Fall 02		NV	unsuccessful	no
	PEPA PS-04	PEPA2 U6-99- OR	*3	G1	345g	11/30/04	0		345g*4			
	A5-4-P1	PEPA2 U6-99-OR	*3	G1	50lb	6/7/05	4.6lb	Fall 05	38lb	UT	unsuccessful	no
	A5-4-P1	PEPA2 U6-99-OR	*3	G1			7.3lb	Fall 05		ID	established	no
Pentemon palmerii	CPP KL-05-1, GBRI 16	Wild collected UCIA		F	133lb	3/2/06	2.14lb	3/14/06	88.46lb	WY	established	no
Palmer Penstemon	CPP KL-05-1, GBRI 16	Wild collected UCIA		F			9.7lb	3/14/06		ID	established	no
Cedar	CPP KL-05-1, GBRI 16	Wild collected UCIA		F			32.2lb	11/2/06		CO	established	no
	CPP KL-05-2, GBRI 26	Wild collected UCIA		F	4lb	3/24/06						
	CPP KL-05-3. G8RI 36	Wild collected UCIA		F	10lb	3/24/06						
Penstemon speciosus	PENSPE1-BSE-03	Wild collected USFS	*1*2	G0	92g	4/15/04	82g	4/16/04	0.0	UT	unsuccessful	no
Sagebrush Penstemon	PENSPE1-BSE-03	Wild collected USFS	*1*2	G0	N/A	4/15/04	10g	4/16/04		UT	Established 2005	2006-2008
	PEN SPE KV-06	PENSPE1-BSE-03	*1*3	G1	1360	12/6/06			1360g			
	PEN SPE KV-07	PENSPE1-BSE-03	*1*3	G1	*5	12/6/06						
Northern Basin and Range	PEN SPE NBR USFS-07	Pooled NBR	*1*3	G0	3052g	11/8/07	3052g	11/8/07	0.0	UT	not seeded	no
Sphlaeralcea parvifolia	SPGR U19-02	Wild collected USFS	*2	G0	150g	Fall 02	150g	Fall 02	0.0	OR	Est. 2002, out 2004	yes
	SPGR U13-01	Wild collected USFS	*2	G0	150g	Fall 02	150g	Fall 02	0.0	OR	unsuccessful	no
Small Flower Globemallow	SPPA U14-02	Wild collected USFS	*1*2	G0	150g	Fall 02	150g	Fall 02	0.0	CO	established	2004-2008
	S04-2-4	SPPA UI4-02-CO	*3	G1	1.44lb	8/19/04	0		1.44lb			
	SPGR PS-04	SPGR U19-O2-OR	*3	G1	130g	11/30/04	0		130g*4			
				subtotal (lb)	262.3		119.99		132.3			

Kind & Variety/ Germplasm	Lot/ Source	Origin	Seed acquisition and production status	Generation	Added to Inventory	Date	Distributed from inventory	Date	Inventory 12/31/2007	State distributed to	Field Status	Seed Harvested
GRASS					bulk lbs		bulk lbs		bulk lbs			
Sandberg Bluegrass												
	557-215-31A	Rainier Seed WA	*3	G2	304.0	11/4/03	50.0	9/15/03	0.0	UT	not seeded	no
Mountain Home Site	557-215-31A	Rainier Seed WA	*3	G2			135.0	2003-2005		ID	taken out 2006	2005-2006
	557-215-31A	Rainier Seed WA	*3	G2			121.0	2003-2005		WA	Est. 2003. out 2006	2003-2006
	557-215-31A	Rainier Seed WA	*3	G2			1.5	4/25/05		WY	Seeded 2007	no
	016-215-611A	Rainier Seed WA	*3	G2	112.0	8/9/06	28.0	10/3/06	84.0	WA	Seeded 2007	2008
	Poa Sec 01-BSE-O6	Wild collected USFS	*1	G0	6.5	9/10/06	6.5	9/11/06	0.0	WA	seeded 4 acres 2006	2008
Thurber's Needlegrass												
	SSF-TH-05	Seedyco ID	*1*2	G1	1.0	1/5/06			1.0			
Orchard Idaho	2005.0394-1	SW Seed CO	*3	G1	13.0	1/5/06	13.0	4/17/06	0.0	WA	seeded 2006	2007
	AchThu-BSE1-06	Wild collected USFS	*1	G0	2.5	9/10/06	2.5	9/11/06	0.0	WA	seed sent back	no
	Unknown	Wild collected USFS		G0						ID	taken out	no
Basin Wildrye NBR-Utah sites	UDWR	Wild collected USFS	*2*6	G1	17.0	8/15/07	17.0	8/15/07	0.0	WA	taken out	no
				subtotal (lb)	456.0		374.5		85.0			
				Total (lb)	718.3		494.5		217.3			

* 1 Currently under Stock Seed Increase contract with grower/cooperators
*2 Seed acquired at no charge from GBRI Cooperators
*3 Cost of seed reimbursed to UCIA through USFS joint venture buy-back program agreement
*4 Seed not certified, can be used for demonstration plots
*5 Seed harvested and added to Inventory but not conditioned

Table 3. Standardized Market Price for Contract Negotiation, Great Basin Native Plant Selection and Increase Project – Utah Crop Improvement Association Buyback Program

Scientific Name	Common Name	January 2009 Suggested Market Price ($)
Forbs		
Achillea millefolium	Western yarrow	**12.00**
Balsamorhiza hookeri	Hooker's balsamroot	**28.00**
Balsamorhiza sagittata	Arrowleaf balsamroot	**28.00**
Crepis acuminata	Taper-tip hawksbeard	**140.00**
Lomatium dissectum	Giant lomatium (parsley or biscuitroot)	**80.00**
Lomatium triternatum	Nineleaf lomatium	**80.00**
Penstemon acuminatus	Sharpleaf penstemon	**75.00**
Penstemon cyaneus	Blue penstemon	**70.00**
Penstemon deustus	Hot-rock penstemon	**40.00**
Penstemon pachyphyllus	Thickleaf penstemon	**75.00**
Penstemon palmeri	Palmer penstemon	**18.00**
Sphaeralcea parviflora	Small-flower globemallow	**60.00**
Linum perenne	Blue Flax	**12.00**
Grasses		
Achnatherum thurberianum	Thurber needlegrass	**45.00**
Elymus elymoides	Bottlebrush squirreltail	**25.00**
Poa secunda	Sandberg bluegrass	**9.00**
Leymus cinereus	Basin Wildrye	**10.00**

Publication:

Young, S.A., 2008. Verification of germplasm source and status by seed certifying agencies as native plants are collected and cultivated. Multifunctional Grasslands in a Changing World, 2008 IGC/IRC Conference, Vol. II, p. 470 Abstract and Poster Presentation

Presentations:

Young, S. A. and D. Ogle, 2008*. "Reclamation Seed Availability Issues." Tri-State Interagency Plant Materials Plant Materials Committee Meeting, May 20, 2008, Utah Botanical Center, Kaysville, UT. PowerPoint Presentation and Discussion. *NRCS Plant Materials Specialist, Boise, ID

Young, S. A., 2008. "Native Species Seed Availability (Or Not)." Great Basin Native Plant Selection and Increase Project Annual Meeting, Feb. 13-14, 2008, SLC, UT. PowerPoint Presentation.

Young, S.A., 2008. "UCIA/Uncompahgre Plateau Native Seed Increase and Commercial Production Proposal." Upper Colorado Plateau Native Plant Program Stakeholders Meeting, Feb. 6-7, 2008, Green River, UT. Flow Chart Presentation and Discussion.

Management Applications:
For most of the species being studied by GBNPSIP cooperators, wildland seed collection is insufficient to provide for reclamation planting needs. Thus, accessions consisting of limited quantities of seed obtained from defined wildland stands, or pooled from defined geographic areas, must be increased in commercial fields or nurseries in order to be available in the marketplace in sufficient quantities to supply reclamation projects of the scope called for in the Great Basin. The UCIA Buy-Back project provides a bridge between small-quantity initial accessions and commercial marketplace productions by working with specialized growers who are willing to provide land, time and expertise to produce increased amounts of stock seed from the former, and with UCIA facilitation, make 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.

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

Project Location: Utah State University, Logan, Utah

Principal Investigators and Contact Information:

Heidi A. Kratsch
Utah State University
4820 Old Main Hill
Logan, UT 84322-4820
435.797.8124, 435.797.3376
heidi.kratsch@usu.edu

Douglas Johnson
USDA-ARS Forage and Range Research Lab
Utah State University
Logan, UT 84322-6300
435.797.3067
Doug.Johnson@ars.usda.gov

Jack Staub
USDA-ARS Forage and Range Research Lab
Utah State University
Logan, UT 84322-6300
435.797.2249
Jack.Staub@ars.usda.gov

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.

Methods:
Common garden trials are in progress at four sites across Utah: North Logan, Kaysville, Kanab, and St. George. Three or more accessions of each species from geographically diverse habitats are included at each site in replicated trials. Data generated will provide information about the range of adaptability for each species.

Species currently in common garden trials:
Cercocarpus ledifolius (Curl-leaf Mountain Mahogany)
Purshia mexicana (Cliffrose)
Fallugia paradoxa (Apache Plume)
Agastache urticifolia (Horsemint)
Monardella odoratissima (Mountain Beebalm)
Stanleya pinnata (Prince's Plume)
Penstemon eatonii (Firecracker Penstemon)
Geranium viscosissimum (Sticky Geranium)
Arenaria macradenia (Showy Sandwort)
Astragalus filipes (Basalt Milkvetch)
Dalea searlsiae (Searl's Prairie Clover)
Dalea ornata (Western Prairie Clover)

Results:
- Preliminary results indicate that *Stanleya pinnata* survival is linked to seed source; plants from seed collected at southern locations did not overwinter at the two northern sites.
- *Penstemon eatonii* survival appears to be unrelated to seed source; most plants survived at all four sites.
- *Purshia mexicana* survival shows some sensitivity to seed source, but data are too preliminary to draw definitive conclusions.

Future Plans:
Festuca spp. (Fine Fescue) will be added to current trials to evaluate performance as an ornamental grass in various markets across the region. *Shepherdia rotundifolia* and *Sphaeralcea* spp. will also be included once production issues have been resolved. Appropriate plant materials will be shared with other established trial programs across the intermountain region.

Presentations:
<u>Oral</u>
Kratsch, H.A., D. Johnson, and J. Staub. 2009. Evaluating intraspecies diversity of Intermountain West native plants. Intermountain Native Plant Summit V. March 26, 2009; Boise, ID.

<u>Poster</u>
Hunter, G., R. Kjelgren, H. Kratsch, D. Hole, and L. Schultz. 2009. Water use of Eriogonum corymbosum in an irrigated field study. Intermountain Native Plant Summit V. March 24-26, 2009; Boise, ID.

Sriladda, C., H. Kratsch, and R. Kjelgren. 2009. Potential for domestication of *Shepherdia rotundifolia* (roundleaf buffaloberry) for urban landscapes. Intermountain Native Plant Summit V. March 24-26, 2009; Boise, ID.

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:
Common garden trials are in progress at four sites across Utah: Greenville Farm on the campus of Utah State University, the Utah Botanical Center in Kaysville, behind the Kane County Extension office in Kanab and at Tonaquint Gardens in St. George.

"Water-Wise Starts with You." Interpretive sign for USU ornamental research and demonstration gardens. Designed in collaboration with Barbara Middleton (Environment & Society Dept.) and the Natural Resources Interpretation class at Utah State University.

Project Title: Pollinator and Seed Predator Studies

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

Principal Investigator and Contact Information:

James H. Cane
USDA-ARS Bee Biology and Systematics Lab
Utah State University, Logan, UT 84322-5310, USA
435.797.3879, fax: 435.797.0461
Jim.Cane@ars.usda.gov

Project Description:
Native bees and/or honey bees are needed to pollinate most 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 honeybees 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 laboratory, 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 laboratory's common garden. Practical management protocols and materials are being developed to sustainably manage pollinators on-farm. Pollination information is being disseminated to collaborators and growers.

Anticipating that seed from some of these perennial forb species will be used for post-fire restoration, we 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:
Most ground-nesting wild bees will survive the direct heat of wildfire to pollinate persisting wildflowers. In the laboratory, I developed and ran controlled experiments that mimicked soil heating by wildfire so as to evaluate the thermal tolerances of each life stage of non-social bees. Eggs, larvae, pupae and adults all survived temperatures up to 42°C. Some died at 27-min durations

at 44^{o}C, and all died at any duration hotter than 48^{o}C. In duff-free soils (where ground-dwelling bees nest), published research reports these burn temperatures extend down only 5-10 cm. My collaborator's exhaustive survey of published nesting biologies of 430 species of ground-nesting bees found that less than 5% nested this shallowly. Thus, the prevalent ground-nesting bee communities of the basins of the Intermountain West are predicted to survive the direct heating of wildfire.

The wet winter of 2008 allowed me to begin evaluating consequences of wildfire in sagebrush steppe and juniper woodlands for wild bee communities. Fates of native bee communities after fire are largely unknown, although logical predictions are possible (e.g. species nesting above-ground in flammable deadwood may fare poorly). I developed efficient and seemingly effective protocols to sample bee and wildflower communities paired in and out of large burns in the eastern Great Basin, sampling bees at *Sphaeralcea*, *Astragalus filipes*, *Balsamorhiza* and *Penstemon*.

At all ten burns, native ground-nesting bee communities were largely unscathed and actively pollinating their recovering floral hosts. Where bee and plant communities were impoverished before the burn (e.g. Salt Creek Fire, Utah), they remained so afterward. In one fire (Dairy Creek outside of Etna UT), surviving *A. filipes* were stunted and vegetative the year after fire; around the perimeter, *A. filipes* bloomed and was avidly visited by the expected native bees. Where fire killed off the forb community at one fire site, wild bees were nonetheless emerging as predicted. In this last case, reseeding with the right flowering annual would enable at least some of the native bee community to persist to pollinate perennial forbs that first flower several years after seeding.

Pollinators, particularly bees, will be needed for seed production for most of the native forbs chosen for this project from the Great Basin flora. In 2008, we repeated our studies of breeding biologies on established plants of *Lomatium dissectum* and *Sphaeralcea* growing in our 20' x 20' common garden plots, as 2007 studies yielded ambiguous or unsatisfactory results (or misidentified seed in the case of *Sphaeralcea*). Pollinators proved to be essential for the selected wildflower species. For *L. dissectum*, no seed results on racemes bagged to exclude pollinators. Manual self-pollination yielded as much seed as manual outcrossing, so the species is self-fertile. Manual pollinations of common garden plants were not as productive as wild populations accessible to the small-bodied specialist bees of the genus *Andrena* that we have found associated with this species across five states. Because the flowers are strongly protogynous, bees are strongly beneficial for seed set. At our common garden, we did notice small sweat bees avidly visiting flowers of *Lomatium dissectum* for pollen, so we are hopeful that these ubiquitous, often common floral generalists may serve to pollinate these flowers on some farms.

The three globemallows, *Sphaeralcea grossularifolia*, *S. cocinnea* and *S. munroana* responded similarly to our manual pollination treatments in our greenhouse, using potted plants. Few capsules and little seed resulted from either autogamy or self-pollen. When outcrossed, however, we obtained 8-10 times more capsules and 5-9 times more seed per capsule that formed. These globemallows are at best weakly self-fertile.

These rates of outcross capsule and seed production were equivalent to our samples for openly-visited flowers in Tom Monaco's plots in Logan. Those plants were avidly visited by diverse wild bees, including the two specialists in the genus *Diadasia* that must have colonized the site since planting. In 2006, we found these specialists to be present in every sampled wild patch of globemallow across Nevada and into eastern Oregon, southern Idaho and northwestern Utah. This year I found that these specialist *Diadasia* bees even had colonized, and were nesting amid, rows of globemallow growing at the Malheur Experiment Station in eastern Oregon, despite the Station's agricultural setting.

Publications

Cane, J.H. 2008. Pollinating bees crucial to farming wildflower seed for U.S. habitat restoration. pp. 48-64 *in* Bees in Agricultural Ecosystems (eds. R.R. James and T. Pitts-Singer). Oxford Univ. Press, U.K.

Cane, J.H. 2008. Breeding biologies, pollinating bees and seed production of *Cleome lutea* and *C. serrulata* (Cleomaceae). Plant Species Biology. 23 (3):152-158.

Presentations

Cane, J.H. 2008. Pollinating Great Basin forbs for seed to rehabilitate western rangelands Department of Entomology, Univ. Calif. Davis. CA. Invited.

Management Applications:

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

Products:

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 for pollination of sweetvetch (now 2000 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).

2008 Summary

- Fernleaf biscuitroot was confirmed through a second year of more rigorous experiment to be fully self-fertile but requires pollinators to move pollen between flowers. Across a five-state region, it is pollinated by small ground-nesting floral specialists and sometimes floral generalists, the latter likely to be available on-farm.
- Globemallows (three species) were found to be self-incompatible, requiring native bees to transfer pollen between individual plants. Mallow-specialists of the bee genus *Diadasia* are ubiquitous at field populations, effective in pollen deposition on stigmas, and apparently quick to colonize seedings, even in some agricultural settings.

- Any and all life stages of most ground-nesting wild bees will escape injury from wildfire. In relatively mild burns of intact sage-steppe plant communities, preliminary standardized samples of bloom and bees indicate excellent prospects for survival. 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, perhaps, something that blooms reliably the year after seeding.
- Species of three *Osmia* bee species and one *Hoplitis* bee that effectively pollinate northern sweetvetch and threadstem milkvetch have been acquired from the wild and are being propagated at the USDA-ARS Logan labs for evaluation and later distribution to seed growers.

Project Title: Insect Pests of Grass and Forb Seed Production

Project: Colorado State University Extension, Grand Junction CO

Principal Investigators and Contact Information:

Bob Hammon
Tri River Area Extension
P.O. Box 20,000-5028, Grand Junction CO 81502-5028
970.244.1838 (office), fax: 970.244.1700
bob.hammon@mesacounty.us

Project Description:
The goal of this project is to document insects affecting field collections and production fields of native plant seed. Insect collections from seed increase fields in UT and ID are forwarded to the laboratory in Grand Junction, CO for identification. In addition seed production fields near Hotchkiss, CO that are associated with the Uncompahgre Plateau Project are being monitored for insect pests.

Several new insects were found attacking seed production plots and collection sites in 2008.

An unidentified leaf miner was discovered attacking *Hedysarum boreale* production near Hotchkiss CO in 2008. The damage occurred early in the season, between initial growth and flowering. Damage was widespread in the field, with severe damage to some plants. By the time damage was reported, the mines had been evacuated and the pest could not be identified. This is the only reported incidence of this insect, but it is probably widespread.

A second leafminer, *Coptodisca cercocarpella* Braun was discovered attacking curlleaf mountain mahogany, *Cercocarpus ledifolius*, near Grand Junction CO. This discovery represented the first report of the moth since its original description in 1925, from a collection in Logan Canyon, UT. Growers who plant seed increase orchards or collect seed of this species should be aware of the moth's damage potential.

An ebony bug, tentatively identified as *Corimelaena* (*Parapora*) *extensa* Uhler (Hemiptera: Cormimelaenidae) was collected from mature seed pods of *Penstemon deustus* near Idaho City ID. It had previously been recorded feeding on mullein, tobacco and mints. The damage potential of this native insect is unknown. The mature bug is about 3.5 mm in length. It can be abundant on plants.

Presentations:

Hammond, B. 2008. Managing Pests Affecting Native Plant Seed Production. Western Forest Insects Working Conference, April 8/9, 2008 Boulder CO.

Management Applications:

Pest identification, scouting procedures, and management options for native insect pests recorded from *Hedysarum boreale*, *Spheralcea* spp., *Lupinus* spp. and *Penstemon* spp. are presented on the Western Colorado Insects Seed Production web site. The site is updated as new pests are identified.

Products:

The Western Colorado Insects Seed Production web site, http://wci.colostate.edu, contains up to date information on insects affecting native plant seed production. The site also contains a listing of pesticides registered for use in grass, forb and woody plant seed production.

Project Title: Impact of Great Basin Habitat Alterations on Pollinator Diversity

Project: Brigham Young University, Provo, UT

Principal Investigators and Contact Information:

Val Jo Anderson
Department of Plant and Animal Science
275A WIDB
Brigham Young University
801.422.3527
Provo, UT 84602
Val_Anderson@byu.edu

Project Description:
This project compares the traditional post-fire outcome (namely cheatgrass, or crested wheatgrass) in Great Basin habitat on native bee diversity compared to intact and contiguous stands of sagebrush and pinyon/juniper.

In 2006 and 2007, pollinator sampling was conducted using flight-intercept Malaise traps. A total of three traps were randomly located in each habitat type of cheatgrass, crested wheatgrass, sagebrush, and pinyon/juniper. All habitat types were contiguous with each other at near the same elevation on near level sites. This was replicated at three different sites in the eastern Great Basin. A total of 36 traps were employed and operated continually from the first of April to the first of October for two years. Samples were collected biweekly and the sample contents sorted in the lab.

Bees were sorted and diversity compared between habitat types and compared against the composition of blooming plants sampled biweekly concurrent with sample retrieval. Other pollinator guilds such as butterflies, bee flies, and flower flies were sorted and prepped for analysis in 2008. This report provides some results of the bee diversity analysis conducted in 2008.

Both bee abundance and species richness were evaluated. As expected, both metrics were significantly different based on habitat type ($p<0.01$). Significant differences in richness were also found between site ($p<0.01$) and years ($p=0.05$), and a significant interaction between site and year for bee abundance ($p=0.04$).

The most remarkable finding was the superior abundance (Fig. 1) and richness (Fig. 2) found in pinyon/juniper habitat. Crested wheatgrass had the lowest scores and sagebrush was comparable to cheatgrass even though both were far below pinyon/juniper. Results can be explained in part due to a similar trend in blooming plants. Pinyon/juniper habitat supported a greater abundance of nectar and pollen producing plants and, in most cases, greater species richness as well. Total abundance of bees and blooming plants over time are strikingly similar (Fig. 3). Future plans include evaluating data for other pollinator groups.

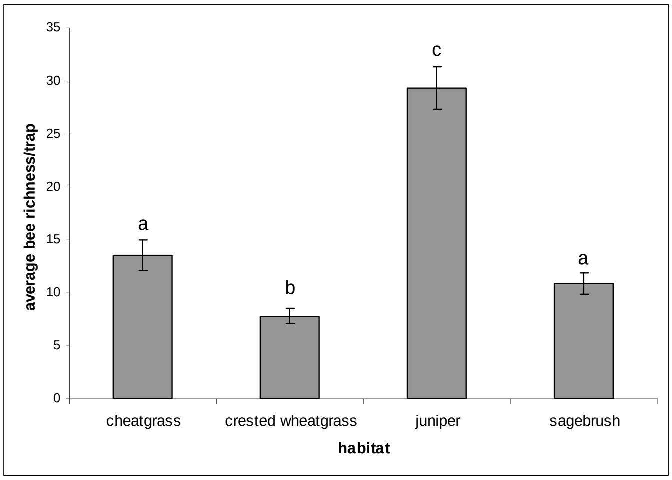


Figure 1. Bee richness per trap by habitat.

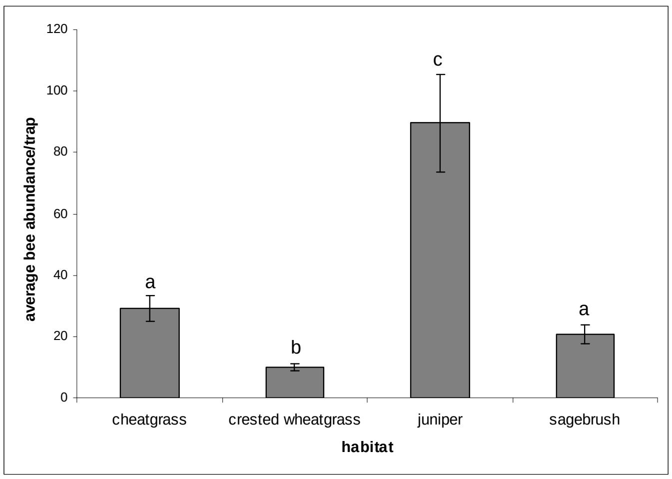


Figure 2. Bee abundance per trap by habitat.

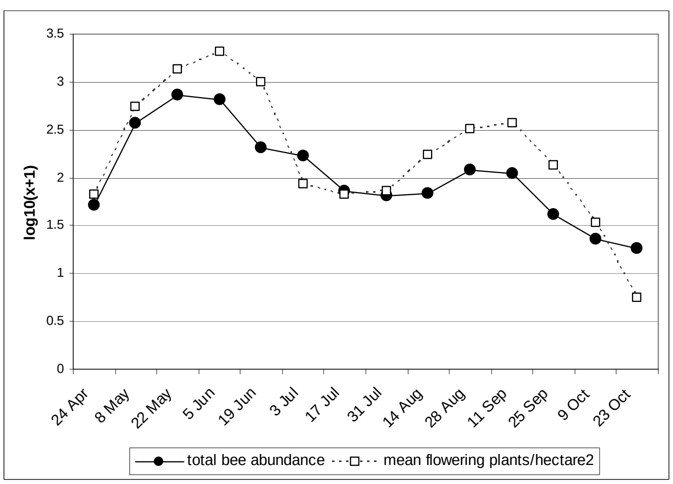


Figure 3. Bee abundance in relation to flowering plants.

Publication:

Johnson, R. L. 2008. Impacts of Habitat Alterations and Predispersal Seed Predation on the Reproductive Success of Great Basin Forbs. Provo, UT: Brigham Young University**.** Dissertation.

Management Applications:

These results demonstrate the importance that native forbs play in supporting a diverse and abundant bee population. A stable pollinator population in turn supports a stable plant population. Revegetation plans which focus on site recovery with aggressive wheatgrasses neglect to recognize impacts to native bee populations. As rangelands become more fragmented, the ability of bees to recolonize reseeded areas may be diminished especially if a suite of native forbs is not re-established. A degree of habitat value should be assessed for pinyon/juniper stands for the benefit of native bees. In the case of this study, the pinyon/juniper habitat had the lowest overall plant cover, but at the same time had the highest abundance and diversity of blooming plants. This dichotomy is due to the abundance of diminutive forbs, which contribute little to overall cover but much in the way of food sources for pollinators. Evaluations of sagebrush communities may consider native forb density as a metric for assessing habitat value, especially relative to pollinators.

Project Title: Impacts of Predispersal Seed Predation on Seed Production of *Wyethia amplexicaulis*, *Agoseris glauca*, and *Crepis acuminata*

Project: Brigham Young University, Provo, UT

Principal Investigators and Contact Information:

Val Jo Anderson
Department of Plant and Animal Science
275A WIDB
Brigham Young University
801.422.3527
Provo, UT 84602
Val_Anderson@byu.edu

Project Description:
Seed damage caused by insects can significantly impact total seed production in plant populations. Predispersal seed damage was investigated in wild populations of *Wyethia amplexicaulis*, *Agoseris glauca*, and *Crepis acuminata* from multiple locations in central Utah during 2006-2007. This report provides a summary of the final analysis from rearing trials conducted to determine percent seed damage and associated seed predator/host relationships. Though rearing trials were conducted in the laboratory, results are considered in situ because capitula were recovered during the pupation phase of identified pests. The exception to this may be the moth *Phycitodes albatella* that was, in most instances, reared as larvae. In this case seed damage results are considered underestimated since the majority of moth larvae died pre-pupation. In all other cases, the seed predators are flies, which were present as pupa or pupating larvae. Total seed predators and seed damage found in wild populations of *A. glauca* and *C. acuminata* are provided in Table 1 and in Table 2 for *W. amplexicaulis*.

Capitula of *A. glauca* averaged 38.3 seeds of which an average of 8.1% was damaged by seed predators. The distribution of total seed damage per capitulum is displayed in Figure 1. A presumably undescribed species of fruit fly in the genus *Campiglossa* was the primary seed predator in *A. glauca.* A secondary, unknown dipteran was also discovered during rearing trials. Percent seed damage was highly dependent upon site ($p<0.01$) with an overall low of 0.8% seed damage during one year at one location and a high of 38.6% at another.

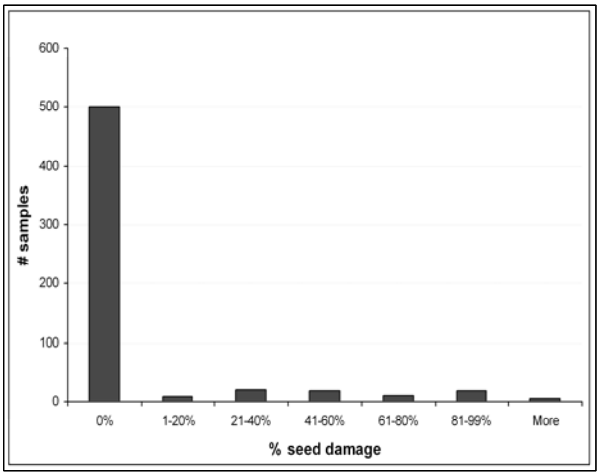
C. acuminata produced an average of 9 seeds per capitulum with an average percent seed damage of 12.4. The distribution of total seed damage per capitulum is displayed in Figure 2. The same *Campiglossa* spp. that infected *A. glauca* also predated seeds of *C. acuminata*. The moth *Phycitodes albatella* (Pyralidae) was the more common and damaging seed predator in *C. acuminata*. Percent seed damage was influenced by a site x year interaction ($p<0.01$) with an average range of damage between 0.7% and 22.2%.

Table 1. Total seed predators and seed damage in wild populations of *A. glauca* and *C. acuminata.*

	site	plants *n*	reared capitula *n*	total seed *n*	seed/ capitula mean, min, max	% seed damaged	% flower head infestation	% plant infestation	reared seed predators	#
2006										
Agoseris glauca	Manti Ridge	80	80	2823	35, 19, 62	4.6%	5.0%	5.0%	*Campiglossa* sp.	11
	Teat Mountain	80	88	3371	38, 12, 64	20.9%	38.6%	39.8%	*Campiglossa* sp.	25
									Diptera unkown	14
	Willow Creek	80	80	3372	42, 30, 66	5.2%	10.0%	10.0%	*Campiglossa* sp.	12
Crepis acuminata	Sheep Creek	20	345	2669	8, 5, 10	10.7%	50.0%	78.9%	*Campiglossa* sp.	4
									Phycitodes albatella	13
	Rock Canyon Overlook	19	357	3441	10, 5, 13	8.5%	37.3%	68.4%	*Campiglossa* sp.	2
									Phycitodes albatella	4
	West Mountain	20	380	3395	9, 6, 12	22.2%	80.3%	100.0%	*Campiglossa* sp.	14
									Phycitodes albatella	30
2007										
Agoseris glauca	Manti Ridge	76	94	3035	32,14,53	6.1%	6.4%	7.9%	*Campiglossa* sp.	20
	Teat Mountain	84	108	4291	40,22,70	11.3%	20.4%	23.8%	*Campiglossa* sp.	43
									Diptera unkown	4
	Willow Creek	80	125	5170	41,18,73	0.5%	0.8%	1.3%	*Campiglossa* sp.	4
Crepis acuminata	Sheep Creek	20	594	4339	8,4,13	12.0%	11.3%	85.0%	*Campiglossa* sp.	5
									Phycitodes albatella	48
	Rock Canyon Overlook	20	519	5365	10,7,14	20.4%	20.2%	95.0%	*Campiglossa* sp.	25
	West Mountain	20	664	6112	9,3,11	0.7%	0.9%	25.0%	*Campiglossa* sp.	1
									Phycitodes albatella	3

Table 2. Total seed predators and seed damage found in wild populations of *W. amplexicaulis*.

site	plants *n*	reared capitula *n*	total seed *n*	seed/ capitula mean, min, max	% seed damaged	% flower head infestation	% plant infestation	reared seed predators	#
2006									
Manti Ridge	18	104	7744	92, 38, 184	46.9%	100%	100.0%	*Neotephritis finalis*	305
								Trupanea nigricornis	21
								Melanagromyza sp.	1
								Lepidoptera sp.	0
Payson Canyon	20	65	6012	95, 37 , 157	32.7%	98.4%	100.0%	*Neotephritis finalis*	183
								Trupanea nigricornis	1
								Melanagromyza sp.	0
								Lepidoptera sp.	19
Squaw Peak	20	194	12063	62,25,174	44.8%	95.9%	100.0%	*Neotephritis finalis*	542
								Trupanea nigricornis	34
								Melanagromyza sp.	3
								Lepidoptera sp.	0
2007									
Manti Ridge	20	102	6124	60,20,103	38.3%	94.0%	100.0%	*Neotephritis finalis*	438
								Trupanea nigricornis	25
								Melanagromyza sp.	6
								Lepidoptera sp.	0
Payson Canyon	20	81	7226	89,20,148	40.4%	94.0%	100.0%	*Neotephritis finalis*	387
								Trupanea nigricornis	87
								Melanagromyza sp.	2
								Lepidoptera sp.	4
Squaw Peak	20	120	7412	62,20,116	30.6%	93.0%	100.0%	*Neotephritis finalis*	401
								Trupanea nigricornis	18
								Melanagromyza sp.	3
								Lepidoptera sp.	1



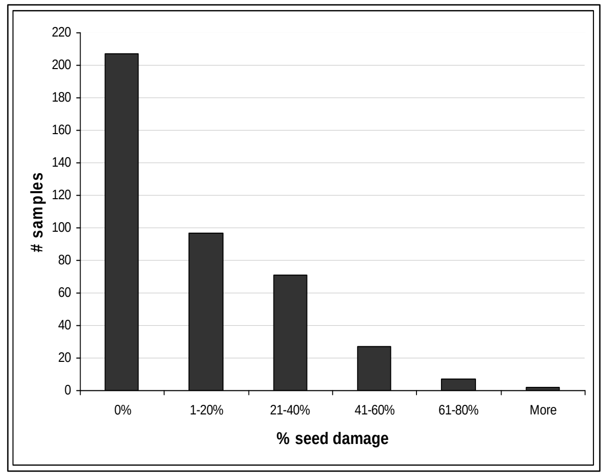
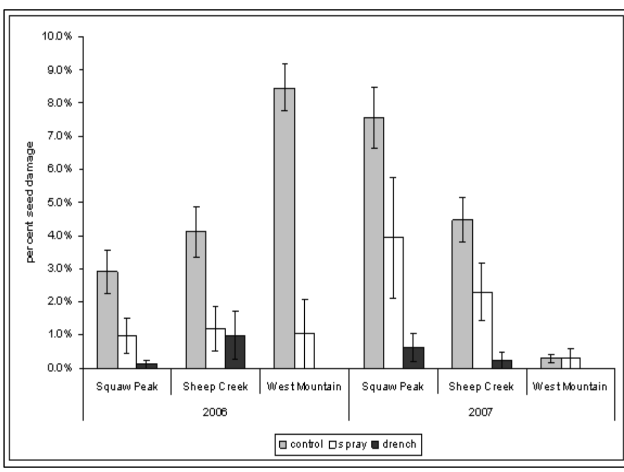


Figure 1. Distribution of damage by capitulum for *Agoseris glauca*.

Figure 2. Distribution of damage by capitulum for *Crepis acuminata*.

An evaluation of foliar application verses soil drench using the systemic pesticide imidacloprid for enhancing seed production in wild populations of *A. glauca* and *C. acuminata* was examined over years 2006 and 2007. A significant interaction was found between treatment, site and year for *C. acuminata* ($p<0.01$) (Fig. 3) and between site and treatment for *A. glauca* ($p<0.01$) (Fig. 4). In most instances, a soil drench was superior in performance to foliar spray. Application of imidacloprid as a foliar spray decreased seed damage in most cases compared to the control.



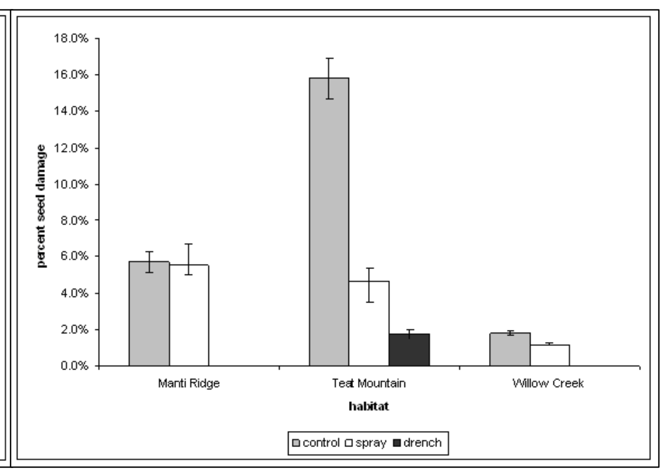
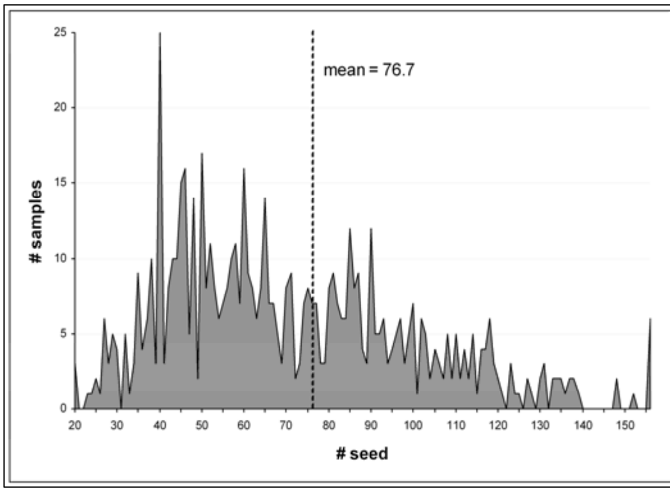


Figure 3. Effects of foliar application verses soil drench with imidacloprid on *Agoseris glauca.*

Figure 4. Effects of foliar application and soil drench with imidacloprid on *Crepis acuminata.*

The number of seeds per *W. amplexicaulis* capitulum is highly variable (Fig. 5) with an average of 76.6. That variability represents the diversity of seed production in primary terminal buds verses lateral secondary buds. Percent seed damage was also highly variable (Fig. 6) with an overall average of 39.0. Differences in seed damage was a function of year and site ($p<0.01$). Seed damage across site and year ranged from a low of 32.7% to a high of 46.9%. The primary seed predator was the fruit fly *Neotephritis finalis*, the secondary pest was also a fruit fly *(Trupanea nigricornis)*.



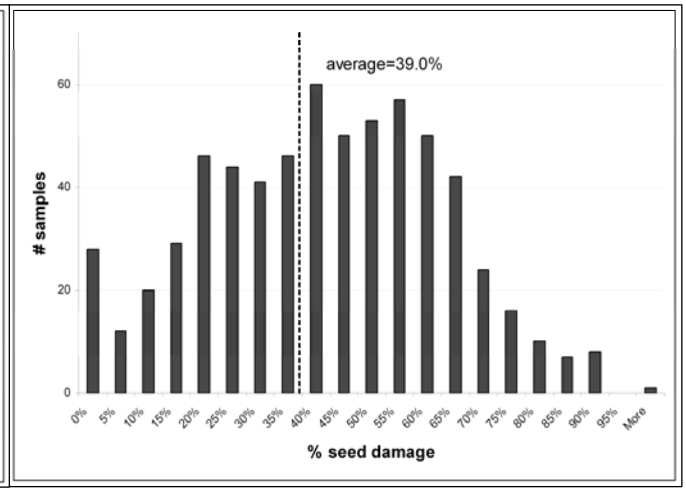


Figure 5. Distribution of seed number per *Wyethia amplexicaulis* capitula.

Figure 6. Distribution of seed samples with seed damage from *Wyethia amplexicaulis* capitula.

A significant amount of parasitoidism was observed in the seed predator *N. finalis*. An unidentified wasp in the genus *Pteromlaus* (Pteromalidae) was responsible for parasitoidism rates as high as 23.0%, but significance was highly dependent upon site and year ($p<0.01$) (Table 3). The parasitoid *Zaglyptonotus mississippiensis* (Torymidae) was also reared and extends the known range of this species substantially. Though parasitoidism can provide some pest control, consideration of these two wasps as biological control agents is problematic since they emerge from fly pupa after the seed damage has already occurred. They would not provide any improvement in seed production during the immediate season, but rather the following year.

Table 3. Occurrence and parasitoidism of *Pteromalus* sp. and *Zaglyptonotus mississippiensis* (Torymidae) on seed predator was the fruit fly, *Neotephritis finalis*, a seed predator of *Wyethia amplexicaulis*.

2006						
site	*Pteromalus* sp.			*Z. mississippiensis*		
	reared	% SUM frequency	% parasitoidism	reared	% SUM frequency	% parasitoidism
Manti Ridge	45	88.0%	12.6%	6	12.0%	1.7%
Payson Canyon	25	63.0%	11.2%	15	38.0%	6.7%
Squaw Peak	174	97.0%	23.0%	5	3.0%	1.0%
2007						
site	*Pteromalus* sp.			*Z. mississippiensis*		
	reared	% SUM frequency	% parasitoidism	reared	% SUM frequency	% parasitoidism
Manti Ridge	99	78.0%	17.5%	28	22.0%	5.0%
Payson Canyon	8	38.0%	2.0%	13	62.0%	3.2%
Squaw Peak	10	34.0%	2.3%	19	66.0%	4.4%

Publications:

Johnson, R. L. 2008. Impacts of Habitat Alterations and Predispersal Seed Predation on the Reproductive Success of Great Basin Forbs. Provo, UT: Brigham Young University**.** Dissertation.

Management Applications:

Even though overall seed damage for both *A. glauca* and *C. acuminata* was relatively low, the potential for severe seed loss is evident in some wild populations where seed damage reached 22.3 to 38.6%. The potential for certain years or sites having significant seed yield losses warrants evaluation of pest management practices. Pest management could apply to managing wild populations as sources for wild seed collections or in cultivated fields where pest problems could greatly exceed levels found in wild populations. Observed seed damage as high as 46.9% in *W. amplexicaulis* reveals an immediate benefit that could be gained with pest control in some stands targeted for seed collection. Because its primary seed predator is a common pest of many large seeded plants in the Asteraceae (i.e. *Balsamorhiza, Helianthella*), the same pest problems and losses in seed yields should be cautiously expected.

Project Title: Native Forb Seed Production in Response to Irrigation in 2008

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

Principal Investigators and Contact Information:

Clinton C. Shock
Oregon State University Malheur Experiment Station
595 Onion Ave., Ontario, OR 97914
541.889.2174, fax: 541.889.7831
clinton.shock@oregonstate.edu

Erik B. Feibert
Oregon State University Malheur Experiment Station
595 Onion Ave., Ontario, OR 97914
541.889.2174, fax: 541.889.7831

Lamont D. Saunders
Oregon State University Malheur Experiment Station
595 Onion Ave., Ontario, OR 97914
541.889.2174, fax: 541.889.7831

Nancy Shaw
U.S. Forest Service, Rocky Mountain Research Station
322 E. Front Street, Suite 401, Boise, ID 83702
208.373.4360, fax: 208.373.4391

Project Description:
Native wildflower seed is needed to restore rangelands of the Intermountain West. Commercial seed production is necessary to provide the quantity of seed needed for restoration efforts. A major limitation to economically viable commercial production of native wildflower (forb) seed is stable and consistent seed productivity over years. Variations in spring rainfall and soil moisture result in highly unpredictable water stress at flowering, seed set, and seed development, which for other seed crops is known to compromise seed yield and quality.

Another limitation for seed production is that native wildflower plants are often not competitive with crop weeds in cultivated fields. Both sprinkler and furrow irrigation could promote seed production, but risk further encouraging weeds. Also sprinkler and furrow irrigation can lead to the loss of plant stand and seed production due to fungal pathogens. By burying drip tapes at 12-inch depth, and avoiding wetting of the soil surface, we hope to assure flowering and seed set without encouraging weeds or opportunistic diseases. This trial tested the effect of three irrigation intensities on the seed yield of thirteen native forb species.

Materials and Methods

Plant Establishment

Seed of the seven Intermountain West forb species (Table 1) was received in late November in 2004 from the Rocky Mountain Research Station (Boise, ID). The plan was to plant the seed in the fall of 2004, but due to excessive rainfall in October, the ground preparation was not completed and planting was postponed to early 2005. To ensure germination the seed was submitted to a cold stratification treatment. The seed was soaked overnight in distilled water on January 26, 2004. After seeds were soaked, the water was drained and the seed soaked for 20 minutes in a 10 percent by volume solution of 13 percent bleach in distilled water. The water was drained and the seed placed in a thin layer in plastic containers. The plastic containers had lids with holes drilled to allow air movement. The seed containers were placed in a cooler set at approximately 34°F. Every few days the seed was mixed and, if necessary, distilled water added to maintain moist seed. In late February, seed of *Lomatium grayi* and *L. triternatum* had started sprouting.

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

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

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

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

Table 1. Forb species planted at the Malheur Experiment Station, Ontario, OR (USDA, NRCS. 2009).

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

Irrigation for Seed Production

In April, 2006, the field was divided into plots 30 ft long. Each plot contained 4 rows each of *E. umbellatum, P. acuminatus, P. speciosus, P. deustus, L. dissectum, L. triternatum, and L. grayi*. The experimental design was a randomized complete block with four replicates. The 3 irrigation treatments were: a non irrigated check, 1 inch per irrigation, and 2 inches per irrigation. Each treatment received four irrigations that were applied approximately every 2 weeks starting with flowering of the forbs. The amount of water applied to each treatment was measured by a water meter and recorded after each irrigation to ensure correct water applications (Table 4).

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

Irrigation dates can be found in Table 3 and irrigation amounts in Table 4. In 2007, irrigation treatments were inadvertently continued after the four irrigations were applied, as in 2006. Irrigation treatments for all species were continued until the last irrigation on June 24 in 2007.

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

Flowering, Harvesting, and Seed Cleaning

Flowering dates for each species are found in Table 2. The *Eriogonum umbellatum* and *Penstemon* spp. plots produced seed in 2006, probably because they had emerged in the spring of 2005. The plant stand for *P. deustus* was too poor to result in reliable seed yield estimates. Replanting of P. *deustus* in the fall of 2006 did not result in adequate plant stand in the spring of 2007. Each year, the middle two rows of each plot were harvested when seed of each species was mature (Table 2) using the methods listed on Table 3.

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

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

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

Cultural Practices in 2006

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

Cultural Practices in 2007

Penstemon acuminatus and *P. speciosus* were sprayed with Aza-Direct® at 0.0062 lb ai/acre on May 14 and May 29 for lygus bug (*Lygus* sp.) control. All plots of the three *Sphaeralcea* species were flailed on November 8, 2007.

Cultural Practices in 2008

On November 9, 2007 and on April 15, 2008, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Capture 2EC at 0.1lb ai/acre was sprayed on all plots of *Penstemon acuminatus* and *P. speciosus* on May 20 for lygus bug control.

Table 2. Native forb seed harvest and cleaning by species, Malheur Experiment Station, Oregon State University, Ontario, OR.

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

[a] Wintersteiger Nurserymaster small plot combine with dry bean concave.
[b] Wintersteiger Nurserymaster small plot combine with alfalfa seed concave. For the *Sphaeralcea* species, flailing in the fall of 2007 resulted in more compact growth and one combine harvest in 2008.
[c]Clipper seed cleaner.
[d]Specialized seed threshing machine at USDA Lucky Peak Nursery. In 2007 and 2008, an adjustable hand-driven corn grinder was used to thresh seed.
[e]Hard seed pods were broken by rubbing against a ribbed rubber mat.
[f]Harvested by hand in 2007 due to poor seed set.

Table 3. Native forb flowering, irrigation, and seed harvest dates by species in 2006, 2007, and 2008, Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	flowering start	flowering peak	flowering end	irrigation start	irrigation end	harvest
				2006		
Eriogonum umbellatum	19-May		20-Jul	19-May	30-Jun	3-Aug
Penstemon acuminatus	2-May	10-May	19-May	19-May	30-Jun	7-Jul
Penstemon deustus	10-May	19-May	30-May	19-May	30-Jun	4-Aug
Penstemon speciosus	10-May	19-May	30-May	19-May	30-Jun	13-Jul
Lomatium dissectum				19-May	30-Jun	
Lomatium triternatum				19-May	30-Jun	
Lomatium grayi				19-May	30-Jun	
Sphaeralcea parvifolia						
Sphaeralcea grossulariifolia						
Sphaeralcea coccinea						
Dalea searlsiae						
Dalea ornata						
				2007		
Eriogonum umbellatum	25-May		25-Jul	2-May	24-Jun	31-Jul
Penstemon acuminatus	19-Apr		25-May	19-Apr	24-Jun	9-Jul
Penstemon deustus	5-May	25-May	25-Jun	19-Apr	24-Jun	
Penstemon speciosus	5-May	25-May	25-Jun	19-Apr	24-Jun	23-Jul
Lomatium dissectum				5-Apr	24-Jun	
Lomatium triternatum	25-Apr		1-Jun	5-Apr	24-Jun	29-Jun, 16-Jul
Lomatium grayi	5-Apr		10-May	5-Apr	24-Jun	30-May, 29-Jun
Sphaeralcea parvifolia	5-May	25-May		16-May	24-Jun	20-Jun, 10-Jul, 13-Aug
Sphaeralcea grossulariifolia	5-May	25-May		16-May	24-Jun	20-Jun, 10-Jul, 13-Aug
Sphaeralcea coccinea	5-May	25-May		16-May	24-Jun	20-Jun, 10-Jul, 13-Aug
Dalea searlsiae						20-Jun, 10-Jul
Dalea ornata						20-Jun, 10-Jul
				2008		
Eriogonum umbellatum	5-Jun	19-Jun	20-Jul	15-May	24-Jun	24-Jul
Penstemon acuminatus	29-Apr		5-Jun	29-Apr	11-Jun	11-Jul
Penstemon deustus	5-May		20-Jun	29-Apr	11-Jun	
Penstemon speciosus	5-May		20-Jun	29-Apr	11-Jun	17-Jul
Lomatium dissectum				10-Apr	29-May	
Lomatium triternatum	25-Apr		5-Jun	10-Apr	29-May	3-Jul
Lomatium grayi	25-Mar		15-May	10-Apr	29-May	30-May, 19-Jun
Sphaeralcea parvifolia	5-May		15-Jun	15-May	24-Jun	21-Jul
Sphaeralcea grossulariifolia	5-May		15-Jun	15-May	24-Jun	21-Jul
Sphaeralcea coccinea	5-May		15-Jun	15-May	24-Jun	21-Jul
Dalea searlsiae		19-Jun				
Dalea ornata		19-Jun				

Results and Discussion

The soil volumetric water content responded to the irrigation treatments (Figures 1 to 5).

– Flowering and Seed Set

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

Penstemon acuminatus and *P. speciosus* had poor seed set in 2007 partly due to a heavy lygus bug infestation that was not adequately controlled by the applied insecticides. In the Treasure Valley, the first hatch of lygus bugs occurs when 250 degree days (52 ^{o}F base) are accumulated. Data collected by an AgriMet weather station adjacent to the field indicate that the first lygus bug hatch occurred on May 14 in 2006, on May 1 in 2007, and on May 18 in 2008. *Penstemon acuminatus* and *P. speciosus* start flowering in early May. The earlier lygus bug hatch in 2007 probably resulted in harmful levels of lygus bugs being present during a larger part of the *Penstemon* spp. flowering period than in 2006 or 2008. Poor seed set for *P. acuminatus* and *P. speciosus* was also related to poor vegetative growth in 2007 compared to 2006 and 2008.

The three *Sphaeralcea* species (globemallow) showed a long flowering period (early May through September) in 2007. Multiple harvests were necessary because the seed falls out of the capsules once they are mature. The flailing of the three *Sphaeralcea* species in the fall of 2007 resulted in a more concentrated flowering in 2008, which allowed one mechanical harvest.

– Seed Yields

In 2006, seed yield of *Eriogonum umbellatum* increased with increasing water applied up to 8 inches, the highest amount tested (Table 5, Figure 6). In 2007 and 2008, seed yield showed a quadratic response to irrigation rate (Table 5, Figures 7 and 8). Seed yields were maximized by 8.1 inches and 7.2 inches of water applied in 2007 and 2008, respectively. Averaged over the three years, seed yield of *Eriogonum umbellatum* increased with increasing water applied up to 8 inches, the highest amount tested (Figure 9).

There was no significant difference in seed yield between irrigation treatments for *Penstemon acuminatus* in 2006 (Table 5). Precipitation from March through June was 6.4 inches in 2006. The 64-year average precipitation from March through June is 3.6 inches. The wet weather in 2006 could have attenuated the effects of the irrigation treatments. In 2007 and 2008, seed yield showed a quadratic response to irrigation rate (Table 5, Figures 10 and 11). Seed yields were maximized by 4.0 and 8.5 inches of water applied in 2007 and 2008, respectively.

In 2006, 2007, and 2008, seed yield of *Penstemon speciosus* showed a quadratic response to irrigation rate (Table 5, Figures 12 - 14). Seed yields were maximized by 4.3, 4.2, and 5.0 inches of water applied in 2006, 2007, and 2008, respectively. Averaged over the three years, seed yield of *Penstemon speciosus* was maximized by 4.8 inches of water applied (Figure 15).

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

Of the three *Lomatium* species, *L. grayi* had the most vigorous vegetative growth in 2007 and 2008. *L. dissectum* had very poor vegetative growth in 2006, 2007, and 2008. *L. dissectum* only produced very small amounts of flowers in 2008. *Lomatium grayi* and *L. triternatum* showed a trend for increasing seed yield with increasing irrigation rate in 2007. The highest irrigation rate resulted in significantly higher seed yield than the non-irrigated check. Seed yields of *L. grayi* and *L. triternatum* were substantially higher in 2008. In 2008, seed yields of *L. grayi* and *L. triternatum* showed a quadratic response to irrigation rate (Table 5, Figures 16 and 17). Seed yields were maximized by 8.4 and 6.9 inches of water applied in 2008 for *L. triternatum* and *L. grayi*, respectively. Averaged over the two years, seed yield of *L. triternatum* and *L. grayi* were maximized by 8.5 and 7.1 inches of water applied, respectively.

In 2007 and 2008, there was no significant difference in seed yield among irrigation treatments for the three *Sphaeralcea* species, with *S. parvifolia* having the highest seed yield. Seed yields for the three *Sphaeralcea* species were lower in 2008 than 2007.

In 2007, there was no significant difference in seed yield among irrigation treatments for the two *Dalea* species, with *D. ornata* having the highest seed yield. Emergence for the two *Dalea* species was poor with plots having poor and uneven stand. The stand of the three *Dalea* species declined and was too poor for seed harvest in 2008. The three *Dalea* species were replanted in the fall of 2008.

<u>Conclusions</u>

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

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

Literature Cited:

Shock, C.C., E.B.G. Feibert, L.D. Saunders, N. Shaw, and A. DeBolt. 2007. Seed Production of Native Forbs Shows Little Response to Irrigation in a Wet Year. Oregon State University Agricultural Experiment Station Special Report 1075:13-20.

USDA, NRCS. 2009. The PLANTS Database (http://plants.usda.gov, 13 March 2009). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Table 4. Irrigation treatments and actual amounts of water applied to native forbs in 2006, 2007, and 2008. Malheur Experiment Station, Oregon State University, Ontario, OR.

			Actual amount of water applied				
		Irrigation rates	*Lomatium* spp.	*Penstemon deustus, P. speciosus*	*Penstemon acuminatus* spp.	*Eriogonum umbellatum*	*Sphaeralcea* spp. *Dalea spp.*
	Date		inches per irrigation				
2006	19 May	2	2.23	2.23	2.23	2.23	
	19 May	1	1.31	1.31	1.31	1.31	
	2 Jun	2	2.16	2.16	2.16	2.16	
	2 Jun	1	1.23	1.23	1.23	1.23	
	20 Jun	2	2.04	2.04	2.04	2.04	
	20 Jun	1	1.23	1.23	1.23	1.23	
	30 Jun	2	2.26	2.26	2.26	2.26	
	30 Jun	1	1.12	1.12	1.12	1.12	
	total	2	8.69	8.69	8.69	8.69	
	total	1	4.89	4.89	4.89	4.89	
2007	5 Apr	2	2.00				
	5 Apr	1	1.28				
	19 Apr	2	2.78	2.78			
	19 Apr	1	1.34	1.34			
	2 May	2	2.70	2.70	2.70	2.70	
	2 May	1	1.40	1.40	1.40	1.40	
	16 May	2	2.62	2.62	2.62	2.62	2.62
	16 May	1	1.42	1.42	1.42	1.42	1.42
	30 May	2	2.49	2.49	2.49	2.49	2.49
	30 May	1	1.22	1.22	1.22	1.22	1.22
	10 Jun	2	2.46	2.46	2.46	2.46	2.46
	10 Jun	1	1.09	1.09	1.09	1.09	1.09
	24 Jun	2	2.59	2.59	2.59	2.59	2.59
	24 Jun	1	1.41	1.41	1.41	1.41	1.41
	total	2	17.6	15.6	12.9	12.9	10.2
	total	1	9.2	7.9	6.5	6.5	5.1
2008	10-Apr	2	2.34				
	10-Apr	1	1.81				
	29-Apr	2	2.02	2.02	2.02		
	29-Apr	1	1.02	1.02	1.02		
	15-May	2	2.09	2.09	2.09	2.09	2.09
	15-May	1	1.10	1.10	1.10	1.10	1.10
	29-May	2	2.15	2.15	2.15	2.15	2.15
	29-May	1	1.48	1.48	1.48	1.48	1.48
	11-Jun	2		2.06	2.06	2.06	2.06
	11-Jun	1		1.16	1.16	1.16	1.16
	24-Jun	2				2.10	2.10
	24-Jun	1				1.00	1.00
	total	2	8.59	8.31	8.31	8.38	8.38
	total	1	5.41	4.75	4.75	4.74	4.74

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

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

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

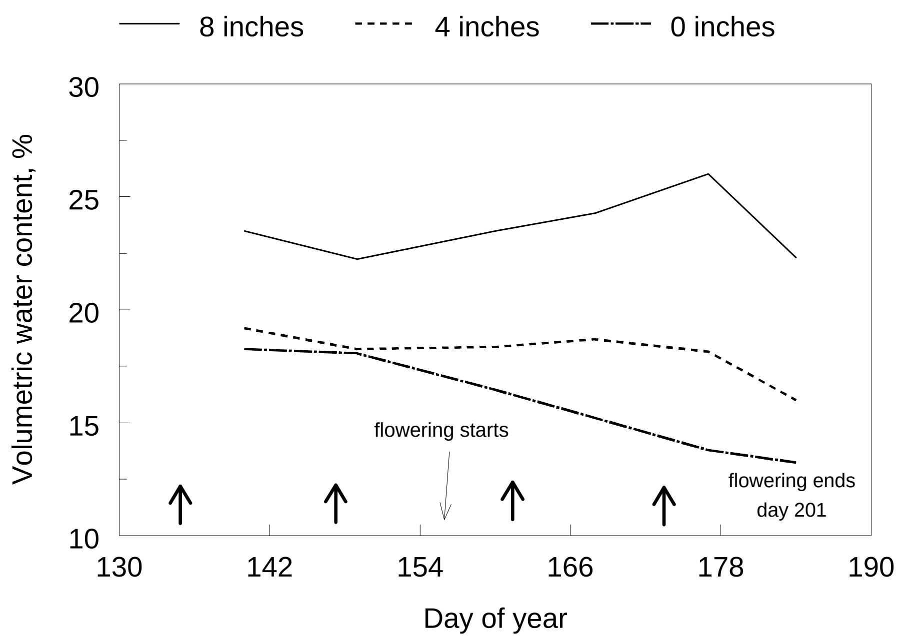


Figure 1. Soil volumetric water content for *Eriogonum umbellatum* over time in 2008. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on May 15 and ended on June 24. Arrows denote irrigations. *E. umbellatum* was harvested on July 24 (day 205). Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

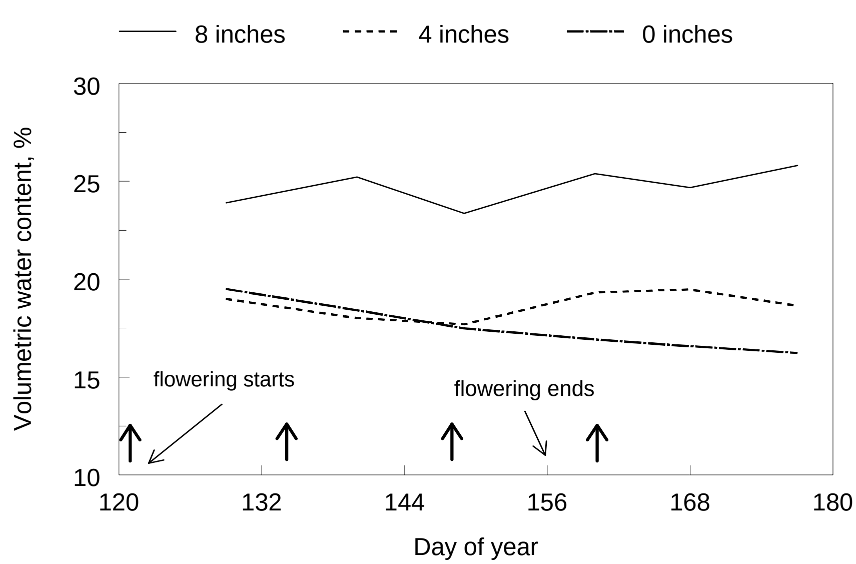


Figure 2. Soil volumetric water content for *Penstemon acuminatus* over time in 2008. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 29 and ended on June 11. Arrows denote irrigations. *P. acuminatus* was harvested on July 11 (day 192). Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

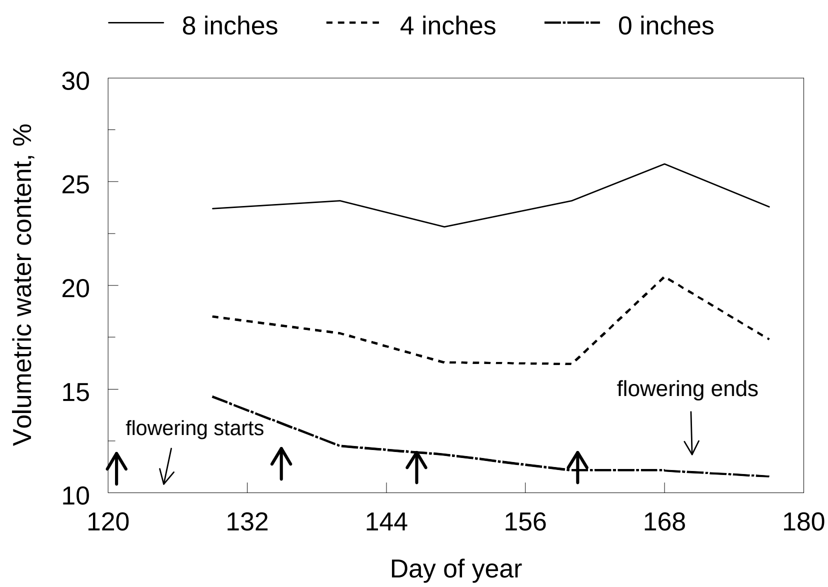


Figure 3. Soil volumetric water content for *Penstemon speciosus* over time in 2008. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 29 and ended on June 11. Arrows denote irrigations. *P. speciosus* was harvested on July 17 (day 198). Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

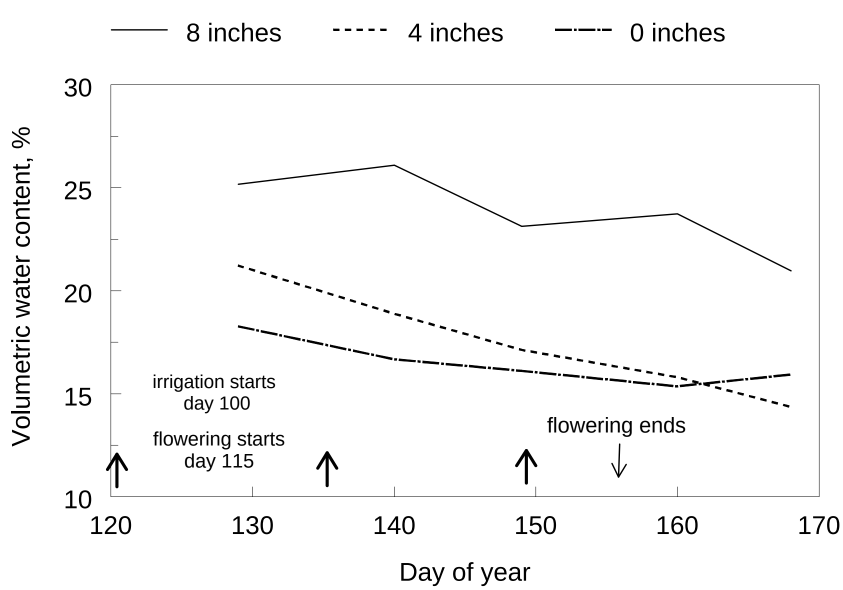


Figure 4. Soil volumetric water content for *Lomatium triternatum* over time in 2008. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 10 and ended on May 29. Arrows denote irrigations. *L. triternatum* was harvested on July 3 (day 184). Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

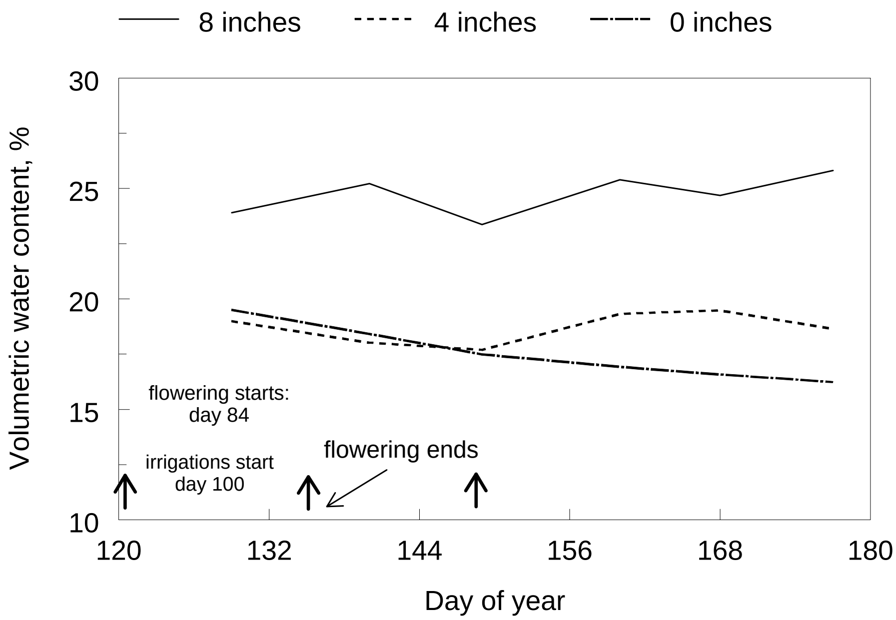


Figure 5. Soil volumetric water content for *Lomatium grayi* over time in 2008. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Irrigations started on April 10 and ended on May 29. Arrows denote irrigations. *L. grayi* was harvested on May 30 (day 151) and June 19 (day 170). Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

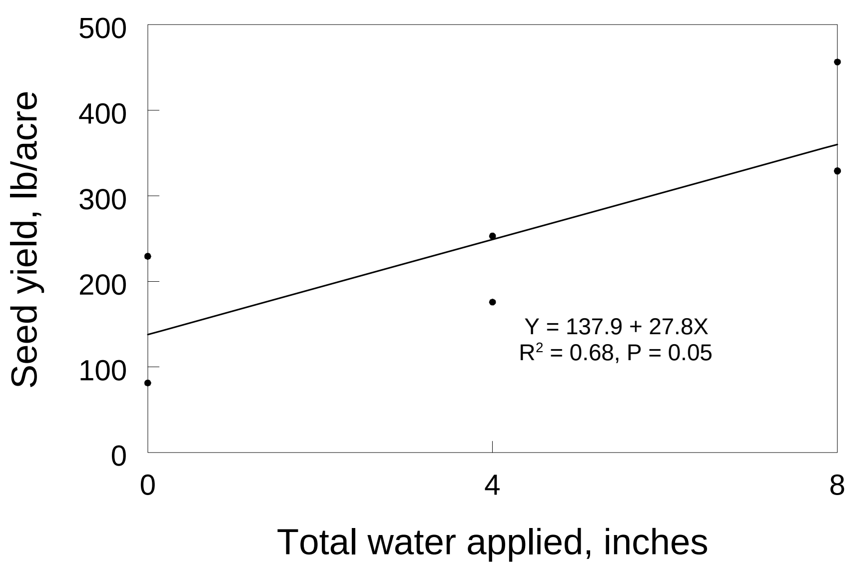


Figure 6. *Eriogonum umbellatum* seed yield response to irrigation water applied in 2006. Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

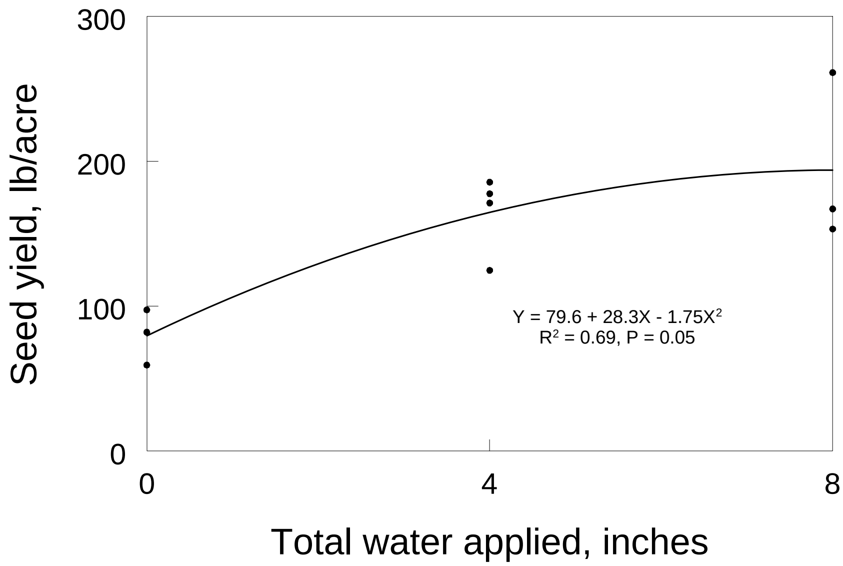


Figure 7. *Eriogonum umbellatum* seed yield response to irrigation water applied in 2007. Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

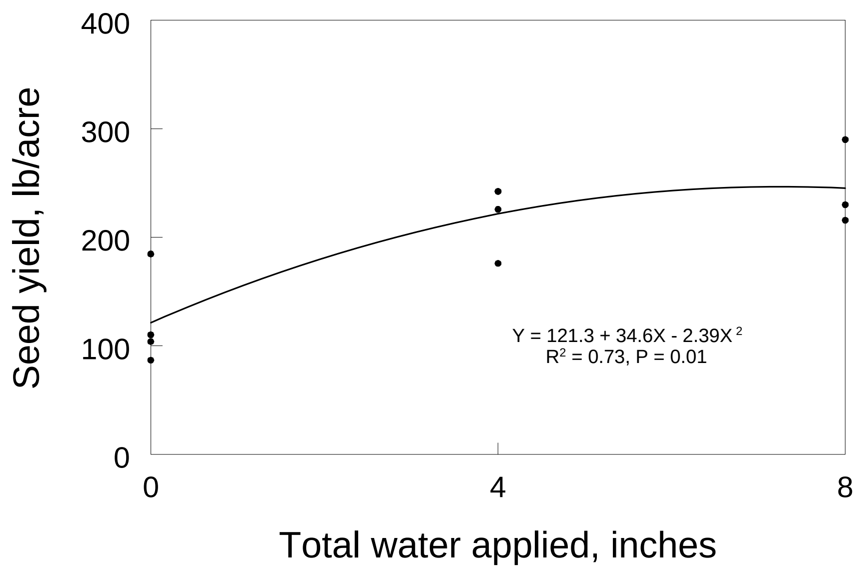


Figure 8. *Eriogonum umbellatum* seed yield response to irrigation water applied in 2008. Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

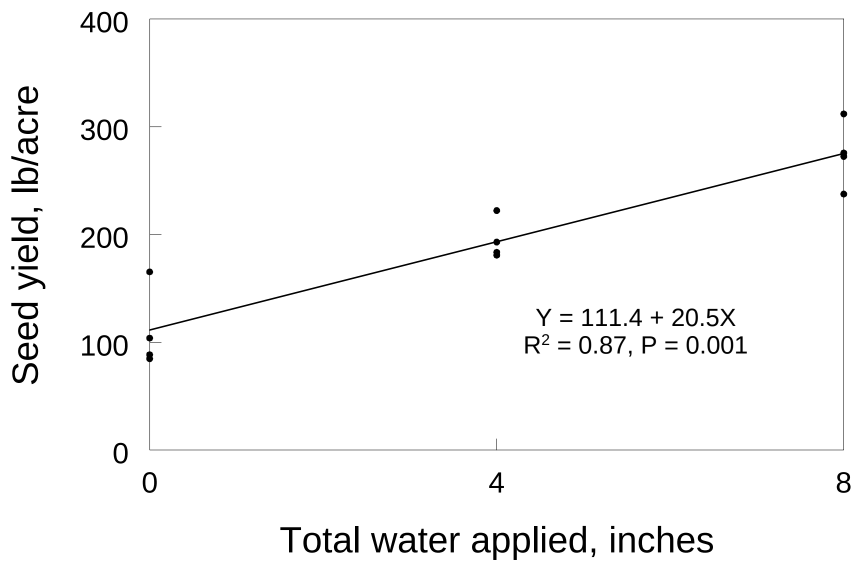


Figure 9. Average annual *Eriogonum umbellatum* seed yield response to irrigation water applied averaged over three years. Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

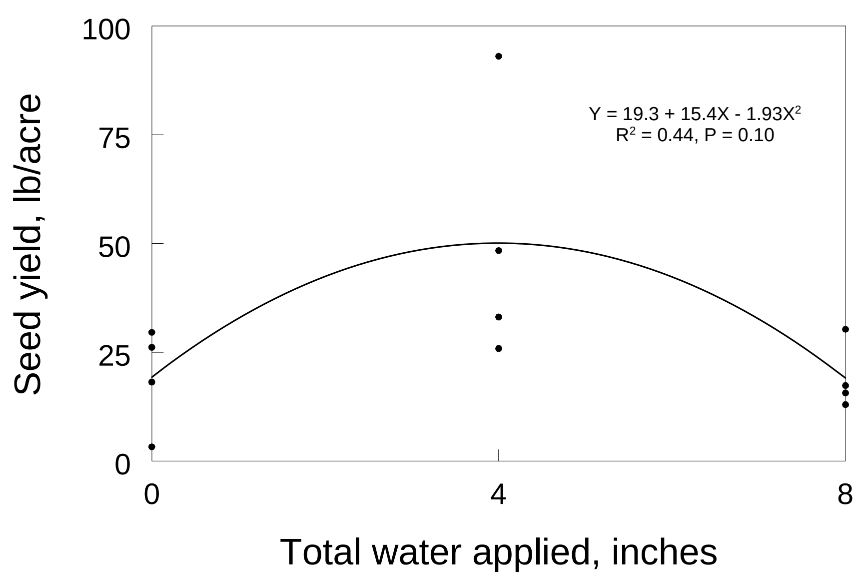


Figure 10. *Penstemon acuminatus* seed yield response to irrigation water applied in 2007. Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

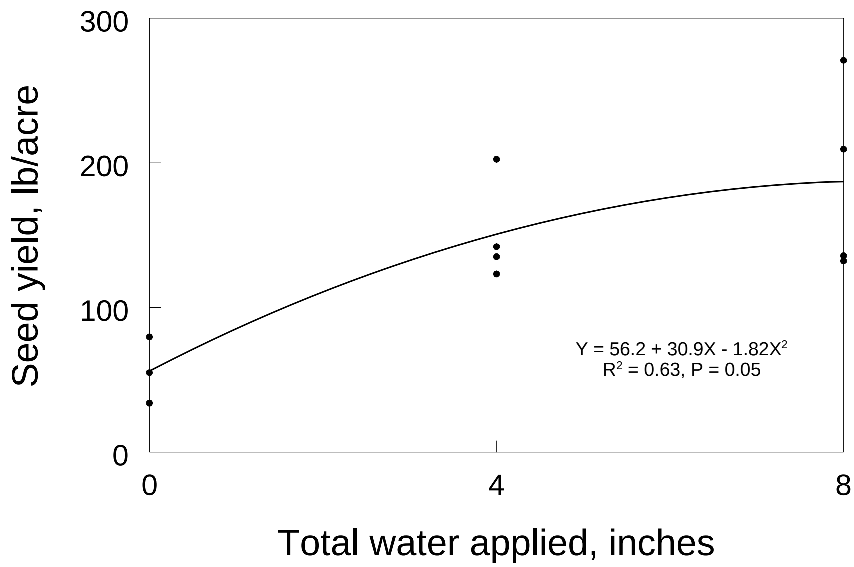


Figure 11. *Penstemon acuminatus* seed yield response to irrigation water applied in 2008. Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

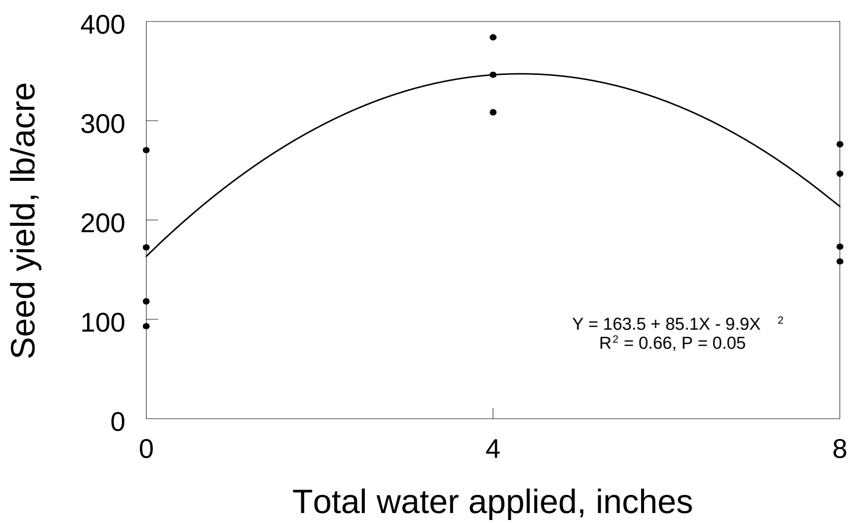


Figure 12. *Penstemon speciosus* seed yield response to irrigation water applied in 2006. Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

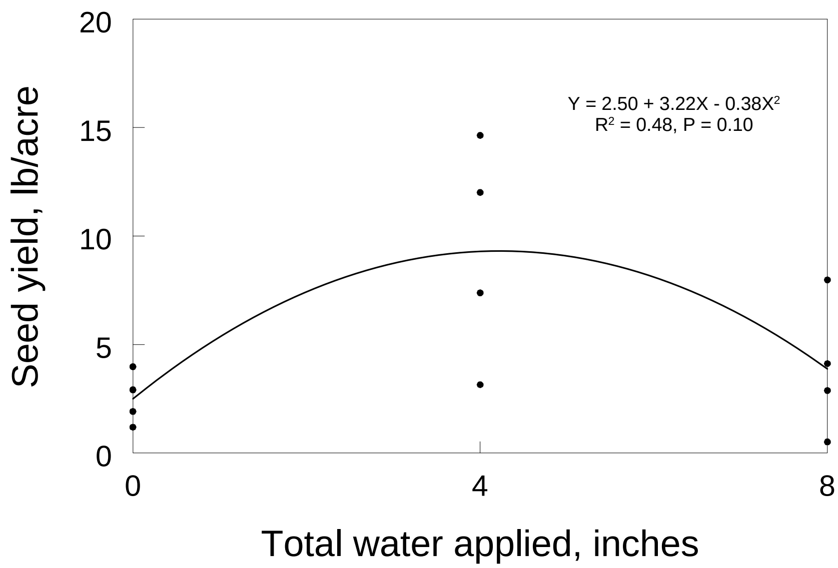


Figure 13. *Penstemon speciosus* seed yield response to irrigation water applied in 2007. Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

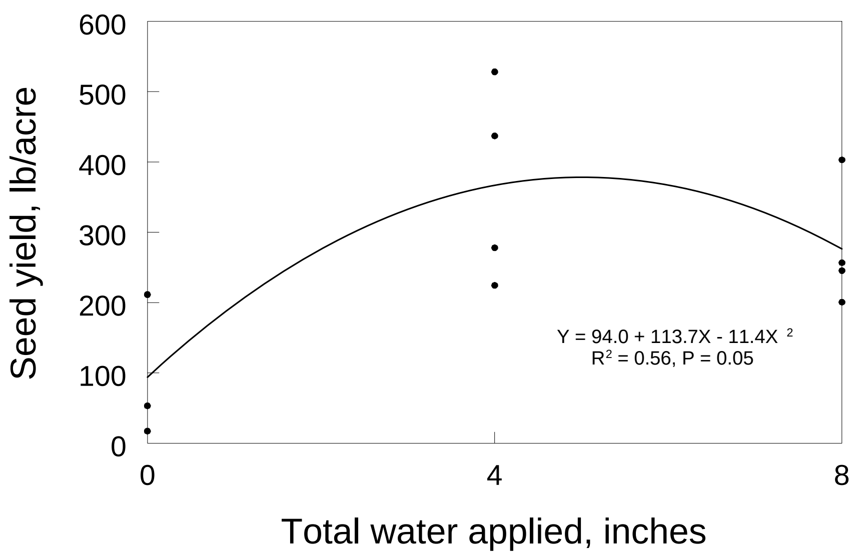


Figure 14. *Penstemon speciosus* seed yield response to irrigation water applied in 2008. Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

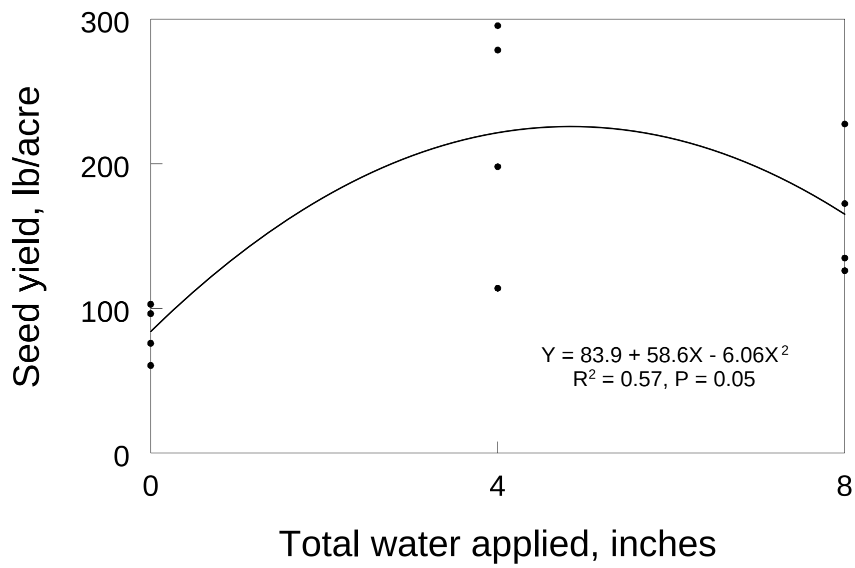


Figure 15. Average annual *Penstemon speciosus* seed yield response to irrigation water applied averaged over three years. Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

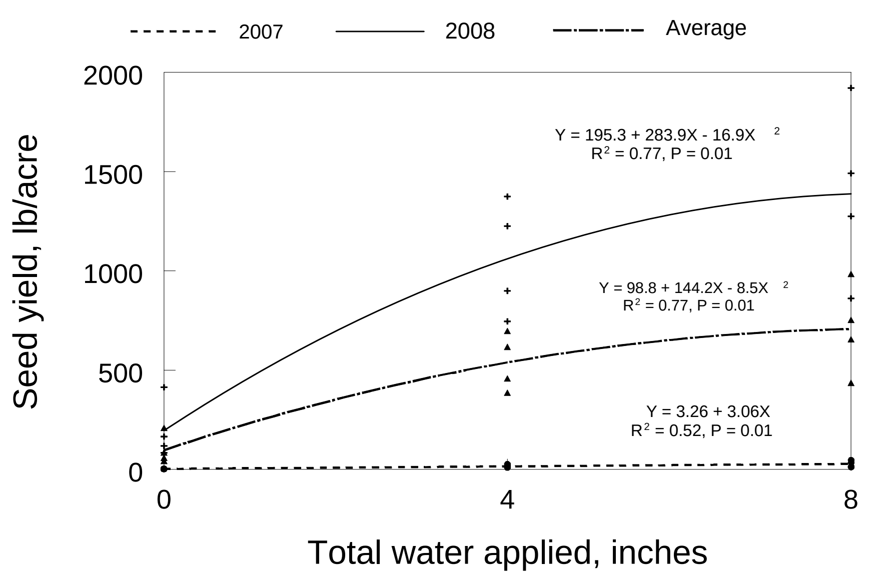


Figure 16. Annual and two year average *Lomatium triternatum* seed yield response to irrigation water applied. Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

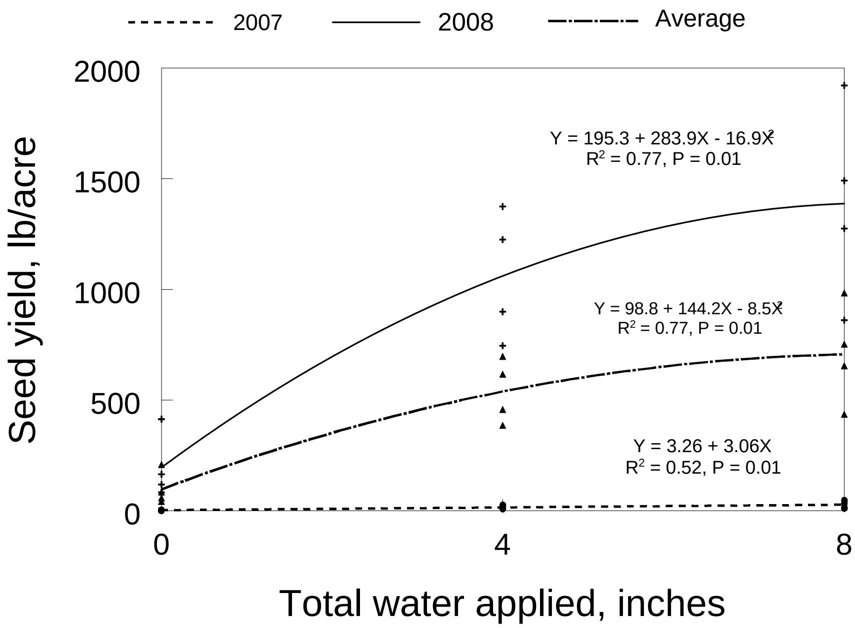


Figure 17. Annual and two year average *Lomatium grayi* seed yield response to irrigation water applied. Malheur Experiment Station, Oregon State University, Ontario, OR, 2008.

Publications:

Shock, C.C., E.B.G. Feibert, L.D. Saunders, and N. Shaw. 2008. Subsurface drip irrigation for native wildflower seed production. Oregon State University Agricultural Experiment Station, Special Report 1087:183-196. http://www.cropinfo.net/AnnualReports/2007/ForbIrrigation2007.html

Shock, C.C., E.B.G. Feibert, and L.D. Saunders. 2008. Scarification of basalt milkvetch (*Astragalus filipes*) seed for improved emergence. Oregon State University Agricultural Experiment Station, Special Report 1087:204-205. http://www.cropinfo.net/AnnualReports/2007/BasaltMilkvetchEmergence2007.html

Presentations:

Shock, C.C., E.B.G. Feibert, L.D. Saunders, and J. Ishida 2008. Native forb seed production in response to SDI in 2007. Great Basin Native Plant Selection & Increase Project Annual Meeting, Salt Lake, UT.

Sampangi, R.K., S.K. Mohan, C.C. Shock, E.B.G. Feibert, and D.A. Glawe. 2008. Powdery mildew of onion caused by *Leveillula taurica* and the possible epidemiological role of alternative hosts in Idaho and Oregon. Am. Phytopathalogical Soc. July 26-30, 2008. Minneapolis, MN.

Shock, C.C., E.B.G. Feibert, L.D. Saunders, E.P. Eldredge, L.B. Jensen, N.L. Shaw, S.K. Mohan, R.K. Sampangi, and H.R. Pappu. 2008. Progress on micro-irrigation in Oregon 2008. Regional working group W1128: Reducing Barriers to Adoption of Microirrigation. Portland, OR. October 22-24. PowerPoint presentation and a written report.

Management Applications:
The report above describes practices that can be immediately implemented by seed growers.

Products:
Seed produced from these plantings was used to establish commercial seed production fields.

A field tour for growers was conducted in May 2008.

A tour of the seed production trials was incorporated into the annual Malheur Experiment Station Field Day activities on July 9, 2008.

Project Title: Growth Characteristics of Five Great Basin Forbs and Interactions between Forbs and Grasses

Project: Rocky Mountain Research Station, Boise, ID

Principal Investigators and Contact Information:

Hilary Parkinson
Montana State University
Land Resources and Environmental Science
P.O. Box 173120
Bozeman, Montana 59717-3120
406.599.3459
parkinsonh@gmail.com

Catherine Zabinski
Montana State University
Land Resources and Environmental Science
P.O. Box 173120
Bozeman, MT 59717-3120
406.994.4227
cathyz@montana.edu

Project Description:

Objectives

The lack of information on Great Basin forb growth, and competitive interactions between forbs and both native and exotic grasses limit the ability of managers to knowledgably select mixtures that limit reductions in growth from interspecific competition. Greenhouse and field experiments were conducted to address the following objectives for a group of forbs selected for restoration in the Great Basin:

1. Measure differences in forb biomass, relative growth rates, root to mass ratios.
2. Assess the impact of native grasses on forb seedling growth by comparing forb biomass and relative growth rates when growing with two different native grasses to growth alone, and growth with the invasive annual cheatgrass (*Bromus tectorum* L.).
3. Measure how forb seedling biomass and survival respond to increasing densities of cheatgrass, and whether forbs differ in their response to cheatgrass.

Methods

In the greenhouse experiment, five forbs--sulfur-flower buckwheat *(Eriogonum umbellatum* Torr.), biscuitroot (*Lomatium* sp.), hoary tansyaster (*Machaeranthera canescens* (Pursh) A. Gray), royal penstemon (*Penstemon speciosus* Douglas ex Lindl.), and Munro's globemallow (*Sphaeralcea munroana* (Douglas) Spach)--were grown for 12 weeks in containers 45 cm deep and 15 cm wide (11.5 liters) in a mix of 1/3 top soil (silt loam), 1/3 washed concrete sand, and 1/3 peat moss. After 6, 9 and 12 weeks of growth, root and shoot material of six replicates per species were harvested to

obtain biomass, relative growth rates of root and shoot material, and root mass ratios. Additionally, differences in root morphology were observed and recorded.
In the same experiment, forbs were grown with a grass neighbor--either squirreltail (*Elymus elymoides* (Raf.) Swezey), Sandberg bluegrass (*Poa secunda* J. Presl), or cheatgrass to compare the effect of grasses on forb seedlings to growth alone.

In the field experiment, four forbs--sulfur-flower buckwheat, Gray's biscuitroot (*Lomatium grayi* (J.M. Coult. & Rose) J.M. Coult. & Rose), royal penstemon and yarrow (*Achillea millefolium* L.) were seeded in fall 2006 at two locations in the Snake River Plain of southern Idaho, both within 30 miles of Boise, ID: the Lucky Peak Nursery (43.5829, -115.9938, 975 m, 361 mm average annual precipitation) and the Orchard Research Site (43.3276, -116.0077, 973 m, 292 mm annual precipitation). To test the effects of cheatgrass density on forb seedling survival and growth, five cheatgrass densities: 0 (control), 45, 90, 180 and 360 plants m^{-2} were randomly assigned to main plots. In single-species subplots, forb seed was planted 30-cm apart in two rows of four spots (8 forb plants per 1.35 m^{-2} subplot). The treatments, cheatgrass seeding levels and forb species, were repeated in three complete blocks at Lucky Peak and Orchard. Cheatgrass density was recorded as the number of plants within a 30-cm diameter frame (0.071 m^{-2}) centered on three randomly selected forbs per subplot. Forb response was measured using forb shoot biomass clipped at ground level and dried to a constant biomass. All forbs were clipped in late July except biscuitroot, which was collected as it senesced to prevent the loss of plant material. Forb biomass for the Orchard site is for buckwheat and yarrow only. Small mammals, primarily ground squirrels, began consuming cheatgrass in mid spring, and consumed all the penstemon and biscuitroot by early summer. For details see Parkinson (2008).

Results and Discussion

Forb Growth (when growing alone)

Biomass: There were large differences among forbs in biomass in the greenhouse and field experiment (Table 1, average biomass of forbs in the field experiment is from the control plots, plants growing without cheatgrass). In both experiments, the biomass of biscuitroot was 2-3 orders of magnitude smaller than that of the other forbs (Table 1). This is partially explained by its shorter period of growth. Biscuitroot entered dormancy after 9 weeks of growth in the greenhouse and after 12 weeks of growth in the field. In the greenhouse, the biomass differed significantly among all forbs (Table 1). For the four species that did not enter dormancy after 12 weeks of growth, Munro globemallow produced the greatest biomass, while buckwheat produced the least (Table 1). In the field experiment at the Lucky Peak site, biscuitroot shoot biomass was only a fraction of the size of the other forbs, similar to the greenhouse results. By contrast, buckwheat and penstemon biomass were similar. Yarrow biomass was more than five times greater than that of either of these species. At Orchard, the shoot biomass of both yarrow and buckwheat were 10 to 15 times smaller than plants of the same species at Lucky Peak. This is likely due to differences in annual precipitation between the sites. Orchard averages 50 mm less per year than Lucky Peak, and precipitation was below average at Orchard in 2007 (Parkinson 2008). At both sites, yarrow was more than four times the size of buckwheat.

Root growth and morphology: Forbs exhibited large differences in the allocation of biomass to roots versus shoots (Table 1, based on growth in the greenhouse-root biomass was not collected in the field experiment). Biscuitroot had the largest root:mass ratio (RMR) at 0.83. The RMR of penstemon was similar to that of buckwheat, tanseyaster and globemallow at week 6; but after 12 weeks of growth, its RMR was 0.48, 45% greater than for the other three species (Table 1).

In the greenhouse, forb roots exhibited two main growth forms. The roots of biscuitroot, buckwheat, and tansyaster were oriented primarily vertically and lateral branching was absent, or nearly absent, with roots not growing beyond the shoot canopy. In contrast, the roots of penstemon and globemallow had a minimum of three main divisions in the root immediately below the soil surface; these extended laterally more than vertically until they reached the container walls. Soil pits were excavated at both field sites to observe root growth. Yarrow roots grew laterally beyond the shoot crown, and were strongly conical, while roots of Gray's biscuitroot were tap-rooted with no lateral branching, similar to biscuitroot root production in the greenhouse.

Phenology: Emergence among yarrow, sulfur-flower buckwheat, Gray's biscuitroot, and showy penstemon differed by up to 8 weeks in the field. Biscuitroot emerged in late February at both sites, with no additional emergents appearing after mid-April. Buckwheat emergence began in late March, with the most seedlings emerging by mid-April at both sites. Yarrow and penstemon began to emerge in early April. By mid-April, half of the yarrow had emerged at Lucky Peak, and slightly more at Orchard. Penstemon had an unusually low emergence at Lucky Peak, all of which germinated by mid-April, but at Orchard, less than half had emerged by mid-April, with all emerging by mid-May.

Plants in arid environments like the Great Basin are considered most vulnerable to competition as seedlings, and forb seedlings whose growth is stunted in the spring by competition from other plants are less likely to survive the dry, hot summer (Cline *et al.* 1977, Aguirre & Johnson 1991, Dyer & Rice 1999). The differences in forb phenology, root morphology and biomass suggest mixtures that are likely to enhance resource partitioning spatially or temporally, as well as combinations likely to increase inter-specific competition. The early germination, and vertically orientated root growth of biscuitroot and buckwheat contrast with the later germinating and lateral root growth of yarrow, penstemon and globemallow. The smaller biomass of buckwheat and biscuitroot also suggests these two are less likely to pre-empt resources and reduce the growth of the later germinating species. In contrast, both yarrow and Munro's globemallow obtained a high biomass relative to the other forbs, and have similar root morphologies. These two are more likely to overlap in resource use, increasing inter-specific competition if seeded together. However, as seed availability increases, it may be worth it to risk some reductions in biomass or survival from inter-specific competition between these larger species in order to maximize biomass in the first growing season, thereby sequestering more resources and potentially reducing invasibility by cheatgrass (James *et al.* 2008).

Impacts of Native Grasses on Forb Growth

Effects of grasses on forb biomass: The effect of a grass neighbor on forb biomass varied depending on whether the grass was native or exotic. When growing with a native grass, the biomass of all four forbs was no different than when growing alone (Figure 1). In contrast, the biomass of all forbs was greatly reduced when growing with cheatgrass. Reductions ranged from 65% (globemallow) to 92% (penstemon).

The uniform response in biomass of all the forbs to cheatgrass and the absence of a response to native grasses is likely attributable to large differences in the biomass of cheatgrass relative to the native grasses. Averaged across all forb neighbors, cheatgrass obtained a biomass of 24 g (±0.52) after 12 weeks of growth. This was more than three times the biomass of squirreltail (7.3 g ±0.54) and more than 12 times that of Sandberg bluegrass (1.8 g ±0.22). While an unusually high seeding density and recruitment of native grasses relative to forbs would likely reduce forb seedling biomass, concerns about inter-specific competition from native grasses during the early stages of growth is clearly less important than competition from cheatgrass.

Effects of grasses on forb relative growth rates (RGR): Compared to biomass, the RGR of forb seedlings was more affected by having a native grass neighbor (Figure 2). The effect of a grass neighbor on forb RGR depended on the identity of both the grass neighbor and the forb. The RGR of two forbs, penstemon and globemallow, was reduced by 28% and 19%, respectively, when growing with squirreltail compared to growth alone. The native grasses did not affect the RGR of the other two forbs, tansyaster and buckwheat, relative to growth alone. However, the RGR of buckwheat was greater when growing with Sandberg bluegrass than with squirreltail. Consistent with the analysis using biomass, cheatgrass reduced the RGR of all the forbs. Reductions ranged from 36% for globemallow to 79% for penstemon.

While growth with squirreltail did not change the biomasses of globemallow or penstemon after 12 weeks, the reductions in RGR mean that at some point in the future, these forbs will be significantly smaller than a cohort growing alone. Potential impacts of reduced size could be delay in reproductive maturity, reduced seed set or seed quality. However, these side-effects may be offset by the potential for squirreltail to reduce the invasibility of cheatgrass (Booth *et al.* 2003, Beckstead & Augspurger 2004, James *et al.* 2008).

Competitive interactions with squirreltail did not correspond to forb size, as the biomass of both the largest and second smallest forbs were reduced while the biomass of the other forbs was not affected. There are a variety of explanations: the absence of a response in buckwheat may be due to its small biomass relative to that of penstemon and globemallow (Figure 1), meaning there was no competition for a limiting resource between buckwheat and squirreltail. And while tansyaster was roughly twice the size of penstemon, the absence of a response in the RGR of tansyaster may be due to greater resource use efficiency compared to penstemon. However, the root morphology of both buckwheat and tansyaster was distinctly different from that of penstemon and globemallow. The roots of buckwheat and tansyaster were nearly tap-rooted, oriented vertically, and with minimal lateral branching. The roots of penstemon and globemallow had a minimum of three divergent branches immediately below the soil surface and the roots grew more laterally (Parkinson, 2008). This means that the root zones of penstemon and globemallow had much greater overlap with the grasses than did the root zones of buckwheat and tansyaster. Although based on a small sample size, this data suggests that contrasting root morphologies of buckwheat and tansyaster versus the native grass reduced inter-specific competition. Therefore, when composing species mixtures, contrasting root morphologies may be an additional trait to consider to increase diversity and reduce inter-specific competition among desirable species.

– Effects of Cheatgrass on Forb Seedling Survival and Growth

Effect on Survival: At Lucky Peak, mortality increased for only two of the forbs, yarrow and biscuitroot, but only at the two highest cheatgrass seeding levels (Parkinson 2008). Assuming that the biscuitroot plants that senesced early (prior to late May) actually died rather than entered dormancy early, then seedling mortality of these two species was near 100% when growing with cheatgrass at densities greater than 360 plants m^{-2} (no yarrow were alive at the highest seedling level by mid-May, and 15 of 16 biscuitroot in the highest seeding level senesced prior to May 26th). Survival was approximately 50% lower in plots seeded with 180 cheatgrass plants m^{-2} compared to the control. In contrast to these two forbs, the total number of buckwheat and penstemon plants was not different among cheatgrass seeding levels at Lucky Peak. However, there was an unusually small sample size of penstemon plants at Lucky Peak, limiting the statistical power of analysis of these results. At Orchard, the field site with high herbivory levels, total number of forbs did not differ among cheatgrass seeding levels for any of the forbs.

Effect on biomass: At Lucky Peak, scatter plots of forb biomass versus cheatgrass density show the biomass of all forbs except biscuitroot declined abruptly as cheatgrass densities increased from 0 to 100 plants m^{-2} (Figure 3). Not until densities were greater than 200 cheatgrass plants m^{-2} were there large reductions in biscuitroot biomass (biomass was reduced by 82% at densities >200 plants m^{-2} compared to the control). The majority of buckwheat plants were reduced by 90-99% at densities greater than 85 cheatgrass plants m^{-2}. For yarrow, the biomass of plants in plots with cheatgrass densities greater than 70 plants m^{-2} was reduced by 90-99% compared to the biomass of plants growing in the control plots. The biomass of all penstemon growing with cheatgrass was reduced by 90-99% compared to plants in the control, even where densities were as low as 14 or 28 cheatgrass plants m^{-2}.

Direct comparisons between sites are difficult based on the reductions in cheatgrass biomass and loss of biscuitroot and penstemon from herbivory at Orchard. Additionally, lower than average precipitation levels reduced the biomass of the remaining forbs. Buckwheat and yarrow plants in the control plots were more than 10 times smaller at Orchard than at Lucky Peak. Despite reductions in biomass of both forbs and cheatgrass, which we would expect to reduce competitive interactions, trends for buckwheat and yarrow were similar at both sites, large reduction in biomass occurred at densities less than 100 plant m^{-2} (Figure 4).

Revegetation will typically occur in the first year following a major disturbance such as wildfire when cheatgrass densities are typically at their lowest (or following some sort of cheatgrass control). While actual emergence will vary based on site history and seasonal climactic patterns, research suggests that cheatgrass densities can be as low as 10 plants m^{-2} during the first growing season following a fire, but can increase to 10,000 plants m^{-2} within 3 years (Young & Evans 1985). Assuming these low levels, and that seeding projects are not postponed, this research suggests that mortality from cheatgrass competition should be low. While mortality for two of the forbs (biscuitroot and yarrow) was 50% and close to 100% in plots seeded at 180 and 360 cheatgrass plants m^{-2} respectively, cheatgrass did not reduce survival of any of the forbs in plots seeded with 45 or 90 plants m^{-2}.

However, if densities are closer to 40 or 60 plants m^{-2} rather than 10 plants m^{-2} in the first year following fire, some forbs may grow better than others with cheatgrass. The rate of decrease of forb biomass with increasing cheatgrass density varied between forb species based on significant differences in the slopes of ln transformed biomass versus cheatgrass density (Parkinson 2008). Biscuitroot biomass declined more slowly with increasing cheatgrass density than the other three forbs, and buckwheat responded better than yarrow at Lucky Peak. This suggests that smaller forbs are less affected by cheatgrass than larger forbs. However, biscuitroot and buckwheat also had the

earliest germination, 4-8 weeks earlier than yarrow and penstemon. Germinating earlier when water is more available could allow the development of a larger root system before competitive interactions with cheatgrass increased. Additionally, both biscuitroot and buckwheat have roots that are tap-rooted, or more vertically oriented, contrasting with cheatgrass, potentially reducing competition via spatial resource partitioning. The roots of penstemon and yarrow were more fibrous and conical similar to cheatgrass, increasing resource overlap.
Future studies will be needed to determine the mechanism allowing some forbs to respond better than others, but based on these results, the most important trait could be smaller biomass, early phenology, contrasting root morphology, or rather a combination of these.

Publications:

Parkinson, H.; Zabinski, C.; Shaw, N. 2009. Effects of native grasses and cheatgrass on the growth of five Great Basin forbs. Boise, ID: USDA Forest Service, Rocky Mountain Research Station. Technical Note. In review.

Parkinson, H.; Zabinski, C.; Shaw, N. 2009. Growth characteristics of six forbs selected for restoration in the Great Basin. Boise, ID: USDA Forest Service, Rocky Mountain Research Station. Technical Note. In review.

Parkinson, H.; Zabinski, C.; Shaw, N. 2009. The response of four Great Basin forbs to increasing densities of cheatgrass. Boise, ID: USDA Forest Service, Rocky Mountain Research Station. Technical Note. In review.

Parkinson, H. 2008. Impacts of native grasses and cheatgrass on Great Basin forb development. Thesis. Bozeman: Montana State University, Bozeman. 75 p. Thesis.

Presentations:

Parkinson, H.; Zabinski, C.; Shaw, N.; Cox, R. 2008. Assessing the effects of grass competition on Great Basin forbs. Society for Range Management and American Forage and Grassland Council 2008 Joint Annual Meeting, Lexington, KY. Poster.

Parkinson, H.; Zabinski, C.; Shaw, N. 2007. Reseeding native forbs in the Great Basin: A study of the growth patterns of five forbs and interactions with grass neighbors". Ecological Society of America and Society for Ecological Restoration Joint Meeting, San Jose, CA. Poster.

Management Applications:

The differences found in forb seedling biomass, phenology and root morphology suggest seeding mixtures that will enhance resource partitioning spatially or temporally among forbs. Future studies can test this more explicitly. Assuming there is not an unusually high seeding rate and establishment of native grasses relative to forbs, the forb-native grass interactions observed in the greenhouse study suggest that negative interactions are not likely among the forb seedlings and Sandberg bluegrass, but are more likely to occur between squirreltail and penstemon, and squirreltail and globemallow.

The differences observed in root morphologies in the greenhouse may have contributed to the ability of some to avoid competition from squirreltail. Both buckwheat and tansyaster are nearly tap-rooted. The roots are oriented vertically with minimal lateral branching. By contrast, the roots of penstemon and globemallow are more fibrous with a minimum of three divergent branches immediately below the soil surface and roots that grow laterally (Parkinson, 2008). This results in greater overlap between the root zones of penstemon and globemallow with squirreltail than with the root zones of buckwheat and tansyaster. Contrasting root morphologies may be an additional trait to consider when composing species mixtures to increase diversity and reduce inter-specific competition among desirable species.

This research emphasizes that to increase survival and establishment of forbs, seeding must be done promptly following a disturbance such as fire when densities are expected to be at their lowest, or only after some control treatment has been done. If forbs can become established when cheatgrass densities are low, the same forbs that respond poorly in the first year of competition may be important in creating communities resistant to invasion by cheatgrass as increases in competitive interactions means greater overlap of resource use. Forbs with shallower, more fibrous roots, or greater biomass may respond poorly as seedlings, such as yarrow relative to biscuitroot or buckwheat, but may be capable of resisting cheatgrass invasion in subsequent years, given a year to establish. To test this, forb communities could be established in research plots for one or more years prior to seeding with cheatgrass.

Products:
Two manuscripts will be submitted to peer-reviewed journals to summarize the results of this research.

Table 1. Summary of data obtained in greenhouse and field experiment. All forbs except the globemallow grown in the greenhouse experiment were collected in southern Idaho.

Common name	Common yarrow	Sulfur-flower buckwheat	Gray's biscuitroot[1]	Hoary aster	Royal Penstemon	Munro's globemallow[2]
Species	*Achillea millefolium*	*Eriogonum umbellatum*	*Lomatium grayi*	*Machaeranthera canescens*	*Penstemon speciosus*	*Sphaeralcea munroana*
Family	Asteraceae	Polygon-aceae	Apiaceae	Asteraceae	Scrophulari-aceae	Malvaceae
Greenhouse						
Total biomass, 12 weeks	Field experiment only	0.46 ±0.12 a	0.08 ±0.003 b	3.38 ±0.5 c	1.49 ±0.33 d	24.09 ±2.02 e
Root mass ratio		0.23 ±0.02 a	0.83 ±0.01 b	0.29 ±0.01 a	0.48 ±0.02 c	0.24 ±0.02 a
Root RGR		0.48 ±0.03 a	[3]	0.48 ±0.04 a	0.72 ±0.03 b	0.53 ±0.03 a
Shoot RGR		0.38 ±0.03 ab	[3]	0.36 ±0.04 a	0.41 ±0.03 b	0.40 ±0.03 ab
Root morphology	Lateral branching (based on soil pits from field experiment)	Tap root-like (one long, thin root, & lateral branches small or absent)	Tap-rooted	Tap-rooted (with only small secondary roots off main root)	Fibrous rooted with lateral branching	Fibrous rooted with lateral branching
Field Experiment						
Shoot biomass						
Lucky Peak	16.6 ±2.94	3.94 ±0.72	0.04 ±0.005	Field experiment only	2.45 ±1.15	An insufficient number germinated for analysis at both sites
Orchard	1.62 ±0.18	0.25 ±0.03	All consumed by small mammals		All consumed by small mammals	
Emergence[4]	early to mid-April	late March	late February		mid-April	early April
Forb palatability to small mammals[5]	Very low.	Low.	Very High. All consumed by mid-May.		Very high. All consumed by mid-May.	The few that emerged were not eaten.

1. *Lomatium* seed for the the greenhouse experiment was collected at the same location as the *L. grayi*, but was likely *L. ambiguum*.

2. *Sphaeralcea munroana* was used in the greenhouse, and *S. grossulariafolia* in the field experiment. Less than five *S. grossulariafolia* germinated in total between both field sites; only relative emergence data is presented.

3. Relative growth rate was computed using biomass harvested at 6, 9, and 12 weeks of growth. Because this species became dormant after 9 weeks of growth, it was not appropriate to compute RGR or compare to the other species.

4. Based on emergence at the two field locations in 2007. Actual dates are likely to vary based on annual climate and elevation, but emergence dates relative to other forbs are expected to be the same.

5. Ground squirrels and badgers were observed at the Orchard Research Site despite electric fencing and chicken wire buried to a depth of >30cm to exclude them. Actual forb use by each of these two mammals was not determined.

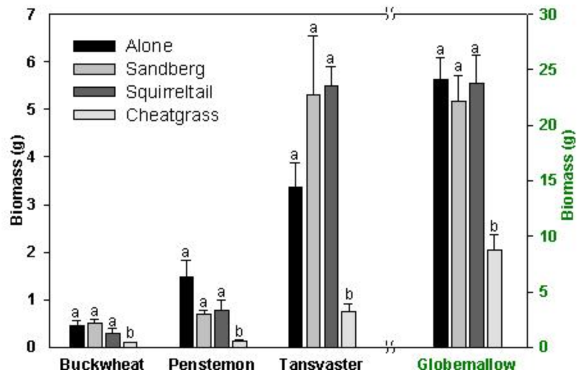


Figure 1. Forb biomass after 12 weeks of growth when growing alone and with a grass neighbor (±1 SE). Note the second y-axis on the right corresponds to the biomass of globemallow. Letters represent significant differences among neighbor treatments within a forb species based on the Tukey multiple comparisons test (p<0.05).

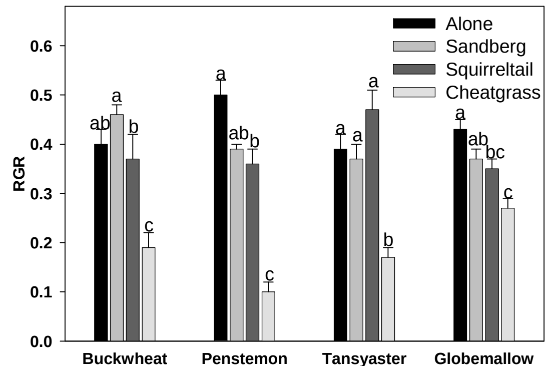


Figure 2. Relative growth rate of forbs when growing alone and with a native grass (±1 SE). Letters represent significant differences among neighbor treatments within a forb species based on the Tukey multiple comparisons test (p<005).

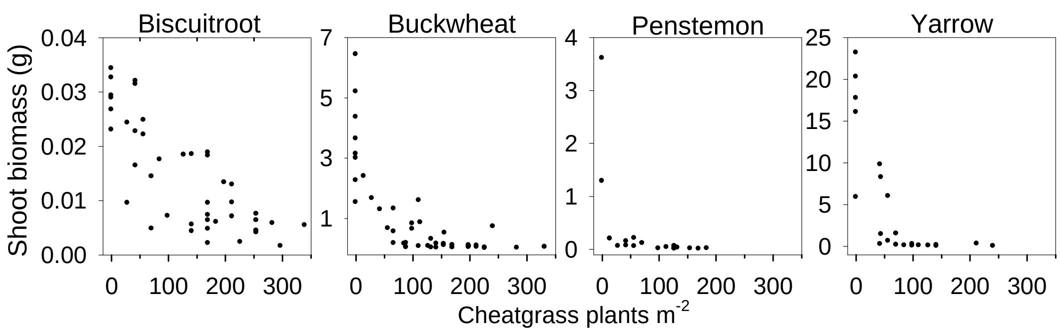


Figure 3. Forb biomass (g) by cheatgrass plants m^{-2} at Lucky Peak. Note different y-axis scales.

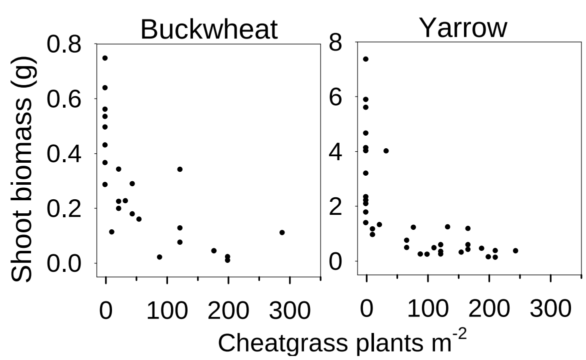


Figure 4. Forb biomass (g) by *B. tectorum* plants m^{-2} at Orchard. Note different y-axis scales.

Literature Cited:

Aguirre, L., and D. A. Johnson. 1991. Influence of temperature and cheatgrass competition on seedling development of two bunchgrasses. Journal of Range Management 44:347-354.

Beckstead, J., and C. K. Augspurger. 2004. An experimental test of resistance to cheatgrass invasion: limiting resources at different life stages. Biological Invasions 6:417-432.

Booth, M. S., M. M. Caldwell, and J. M. Stark. 2003. Overlapping resource use in three Great Basin species: implications for community invasibility and vegetation dynamics. Journal of Ecology 91:36-48.

Cline, J. F., D. W. Uresk, and W. H. Rickard. 1977. Comparison of soil-water used by a sagebrush-bunchgrass and a cheatgrass community. Journal of Range Management 30:199-201.

Dyer, A. R., and K. J. Rice. 1999. Effects of competition on resource availability and growth of a California bunchgrass. Ecology 80:2697-2710.

James, J. J., K. W. Davies, R. L. Sheley, and Z. T. Aanderud. 2008. Linking nitrogen partitioning and species abundance to invasion resistance in the Great Basin. Oecologia 156:637-648.

Parkinson, H. 2008. Impacts of native grasses and cheatgrass on Great Basin forb development. Montana State University.

Young, J.A., and R.A. Evans. 1985. Demography of *Bromus tectorum* in *Artemisia* communities, p. 489-501. In: D.J. White, ed. The population structure of vegetation. Dr. W. Junk Publishers. Dordrecht, Netherlands.

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

Project Location: USDA ARS, Burns, Oregon

Principal Investigators and Contact Information:

Jeremy James, Plant Physiologist
USDA-ARS, Eastern Oregon Agricultural Research Center
67826-A Hwy 205, Burns, OR 97720
541.573.8911, fax: 541.573-3042
jermey.james@oregonstate.edu

Project Description:

Objectives

Establishing and maintaining invasion resistant plant communities is a central goal of land managers. Invasion resistance is expected to be directly tied to the ability of the resident vegetation to sequester limiting resources (Stohlgren et al. 1999; Davis et al. 2000). While resource sequestration is known to be largely driven by the dominant species, less dominate species also may contribute to resource sequestration if they differ in pattern of resource uptake relative to dominate species (Grime 1987; Kahmen et al. 2006). For example, spatial and temporal variation in soil nitrogen (N) cycling is substantial in the Great Basin and even small increases in soil N availability can facilitate the establishment of invasive plants (Paschke et al. 2000). Communities with greater species or functional group diversity may partition N to a greater extent than communities with low diversity. As a result, communities with greater species or functional group diversity may be better able to respond to these fluctuating patterns of N supply and maintain lower levels of soil N through the growing season.

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

Methods

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

Nitrogen partitioning by time, depth and chemical form

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

Functional group removal plots

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

<u>Final results</u>

Nitrogen partitioning by time, depth and chemical form

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

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

Functional group removal plots

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

Conclusion

Understanding mechanisms of invasion resistance is critical for conservation biology and land management. While the particular resource or combination of resources facilitating annual grass invasion may change depending on timing and amount of water input and soil chemistry, these results suggest that the main mechanism of invasion resistance likely depends on how species abundance is distributed in the plant community. Namely, in systems where coexisting dominants differ in how they harvest resources it seems likely that resource partitioning will be a key mechanism contributing to invasion resistance. However, in systems where the bulk of community biomass is determined by one or two species it seems likely that invasion resistance will mainly be conferred by the resource acquisition traits of the dominant species. In terms of reseeding programs trying to maximize invasion resistance, these findings suggest it may be appropriate to identify and select perhaps only a subset of species that have a strong potential to obtain dominance in the community but are differentiated from each other in phenology and rooting structure. Species diverse plant communities are critically important for multiple ecosystem properties and processes but these results suggest invasion resistance may be achieved at relatively low levels of functional group diversity.

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

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

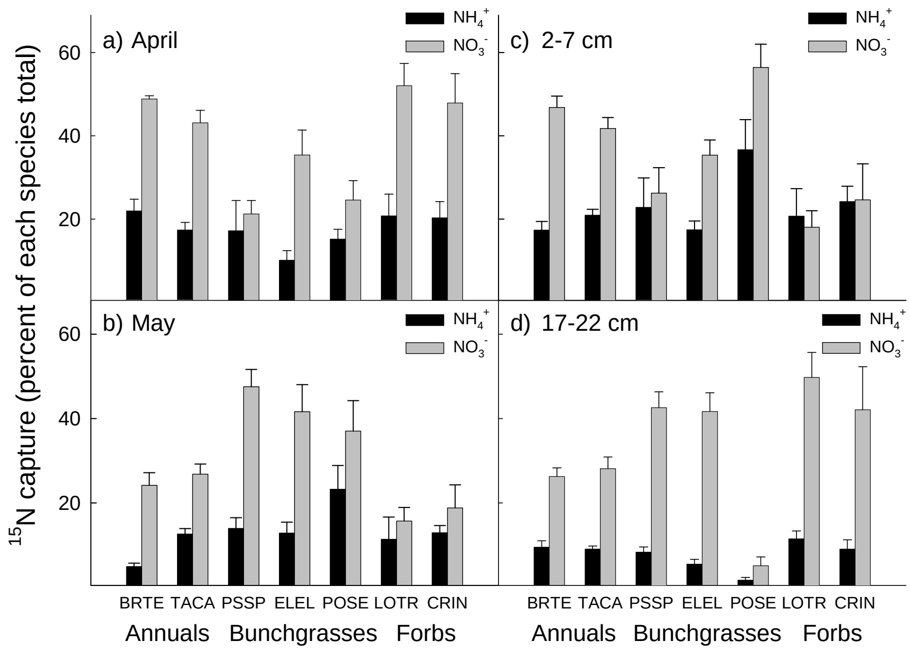


Figure 1. ^{15}N capture by the seven study species as influenced by the time, depth and form of ^{15}N tracer addition. Based on the ANOVA results, panels (a) and (b) show the simple effects of time and N form on species N capture while panels (c) and (d) show the simple effects of depth and N form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

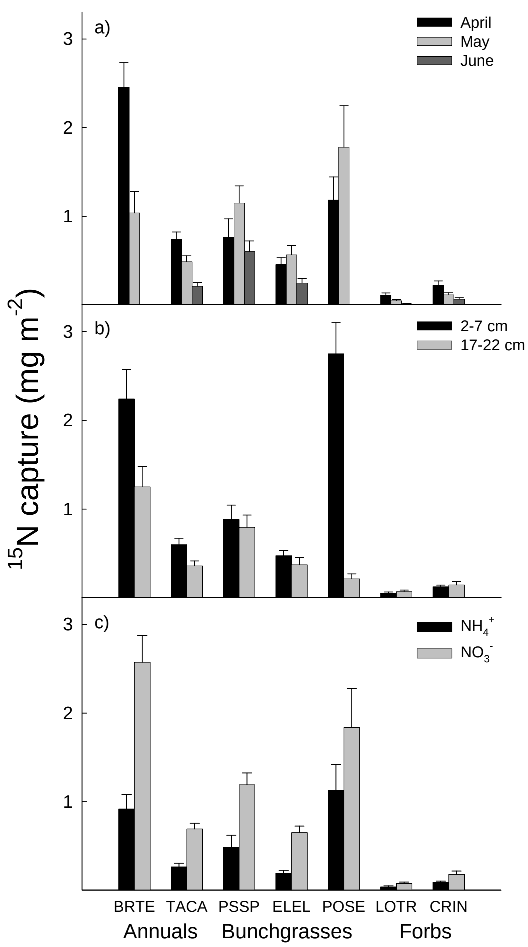


Figure 2. Total N capture by the seven study species as affected by the time (a) depth (b) and form (c) of ^{15}N injections. Values in (a) are averaged over the different depths and chemical form of tracer addition (mean ± SE, n = 20). Values in (b) are averaged over the different times and form of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

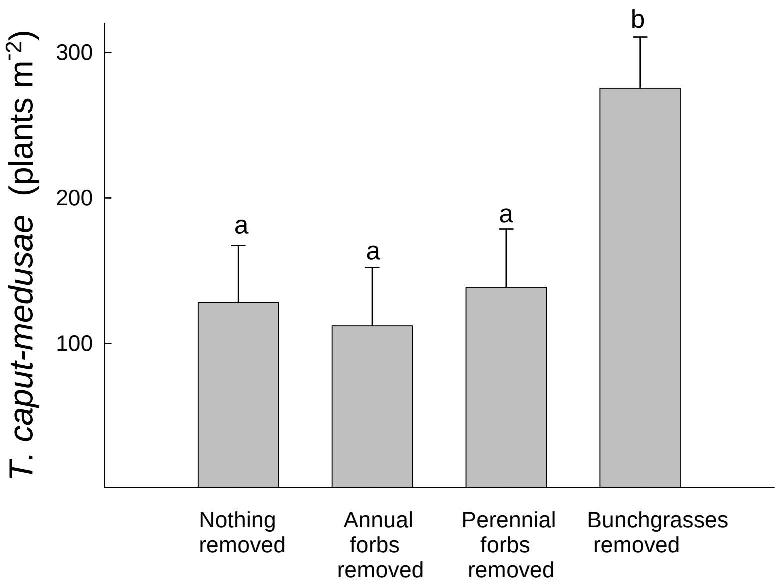


Figure 3. *Taeniatherum caput-medusae* densities in plots where functional groups had been removed at two sites (mean + SE, $n = 8$). Different letters indicate differences among treatments as determined by LS-means ($P < 0.05$).

Literature cited:

Davis MA, Grime JP, Thompson K (2000) Fluctuating resources in plant communities: a general theory of invasibility. J Ecol 88:528-534

Grime JP (1987) Dominant and subordinate components of plant communities-implications for succession, stability and diversity. In: Gray AJ, Edwards PJ, Crawley MJ (eds) Colonization, Succession and Stability. Blackwell, Oxford, pp 413-428

Kahmen A, Renker C, Unsicker SB, Buchmann N (2006) Niche complementarity for nitrogen: An explanation for the biodiversity and ecosystem functioning relationship. Ecology 87:1244-1255

McKane RB, Johnson LC, Shaver GR, Nadelhoffer KJ, Rastetter EB, Fry B, Giblin AE, Kielland K, Kwiatkowski BL, Laundre JA, Murray G (2002) Resource-based niches provide a basis for plant species diversity and dominance in arctic tundra. Nature 415:68-71

Nadelhoffer KJ, Fry B (1994) Nitrogen isotope studies in forest ecosystems. In: Lajtha K, Michener R (eds) Stable isotopes in ecology. Blackwell Scientific, Oxford, pp 22-44

Paschke MW, McLendon T, Redente EF (2000) Nitrogen availability and old-field succession in a shortgrass steppe. Ecosystems 3:144-158

SAS (1999) Statistical Software, version 8.0. SAS Institute Inc., Cary

Stohlgren TJ, Binkley D, Chong GW, Kalkhan MA, Schell LD, Bull KA, Otsuki Y, Newman G, Baskin M, Son Y (1999) Exotic species invade hot spots of native plant diversity. Ecol Monogr 69:25-46.

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

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

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

Contributed to development of a workshop and education material for Ecologically Based Management of Invasive Annual Grasses.

Publication:
James, J. J., Davies, K.W., Sheley, R. L. and Aanderud, Z. T. (2008) Linking nitrogen partitioning and species abundance to invasion resistance in the Great Basin. Oecologia 156:637-648

Presentations:
James, J. 2007. The potential for resource-based niches to contribute to invasion resistance in a semi-arid plant community. 60th Annual meeting Society for Range Management Paper No. 213. February 9-16, 2007

James, J. 2008. Nitrogen partitioning and invasion resistance in sage steppe communities. CSU Sonoma, CA.

James, J. 2009. The role of abundance and N capture traits for invasion resistance in the Great Basin. Oregon State University. Corvallis, OR.

Project Title: Forb and Shrub Establishment in Perennial Grass Stands

Project: Brigham Young University, Provo, UT

Principal Investigators and Contact Information:

Val Jo Anderson
Department of Plant and Animal Science
275A WIDB
Brigham Young University
801.422.3527
Provo, UT 84602
Val_Anderson@byu.edu

Project Description:
In restoration efforts, grasses, both introduced and native, tend to have higher establishment rates than either seeded forbs or shrubs. Subsequent interseeding of forbs and shrubs may be required to achieve desired levels of plant and community diversity. Understanding the resource use patterns of common grasses and subsequent responses of native forb and shrub seedings will be useful in pairing potential seed mixes to dominant grass matrixes. The following 6 species of grass were transplanted into 12 adjacent plots (3 x 4) each with 1m spacing between plots except Bozoisky and Vavilov which had 6 plots (3 x 2) per species. Each plot measured 3m x 3m with plants 0.5m apart to make a 7 x 7 plant matrix.

Common Name	Scientific Name
Alkali sacaton	*Sporobolus airoides*
Bluebunch wheatgrass	*Elymus spicatus*
Bozoisky Select Russian wildrye	*Elymus junceus (currently Psathyrostachys juncea)*
'Vavilov' Siberian wheatgrass	*Agropyron fragile (Agropyron sibericum or Agropyron cristatum ssp. fragile or Agropyon fragile ssp. sibericum)*
Salinas wildrye	*Leymus salinus*
Great Basin wildrye	*Elymus cinereus*

Alkali sacaton, bluebunch wheatgrass, salina wildrye and Great Basin wildrye were transplanted in the summer of 2005. Bozoisky Russian wildrye and Vavilov Siberian wheatgrass were transplanted the summer of 2006 from the fields at the BYU farm. Plots were kept weed free with Plateau, 2,4-D, and mechanical weed control as needed.

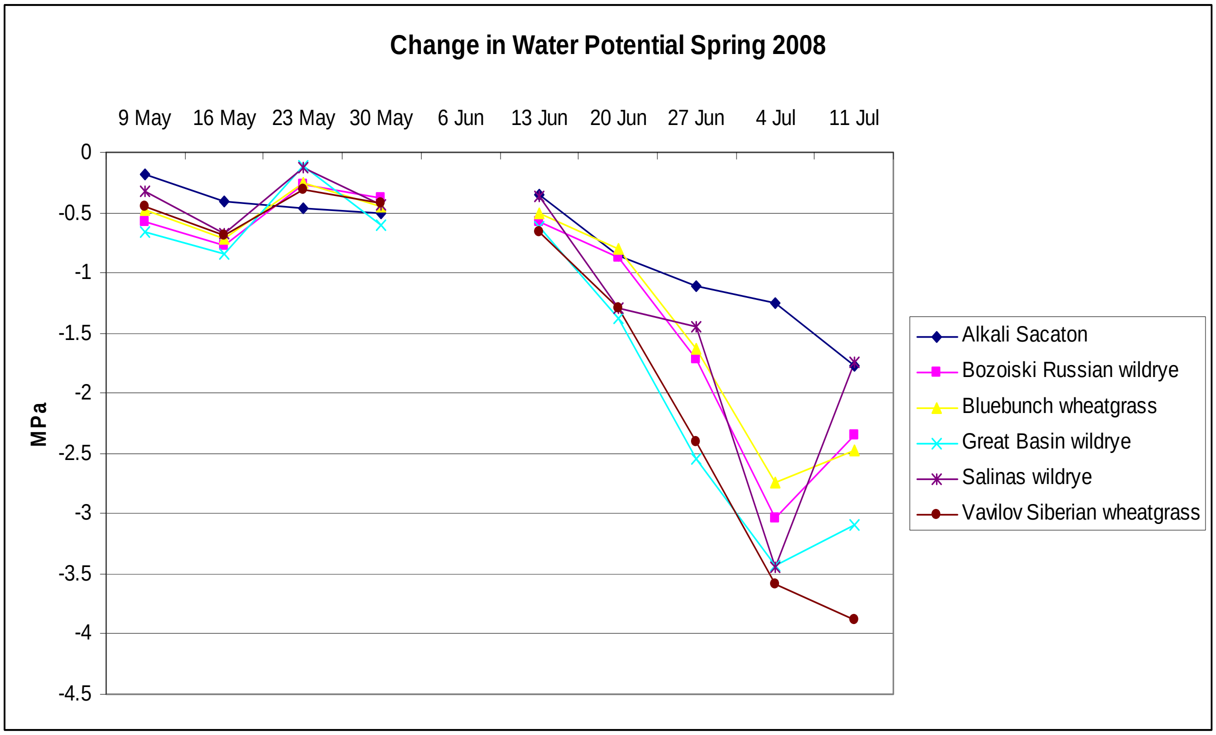
The following 4 species of forbs and 4 species of shrubs were planted in the interspaces of 6 plots per grass species in Nov 2007.

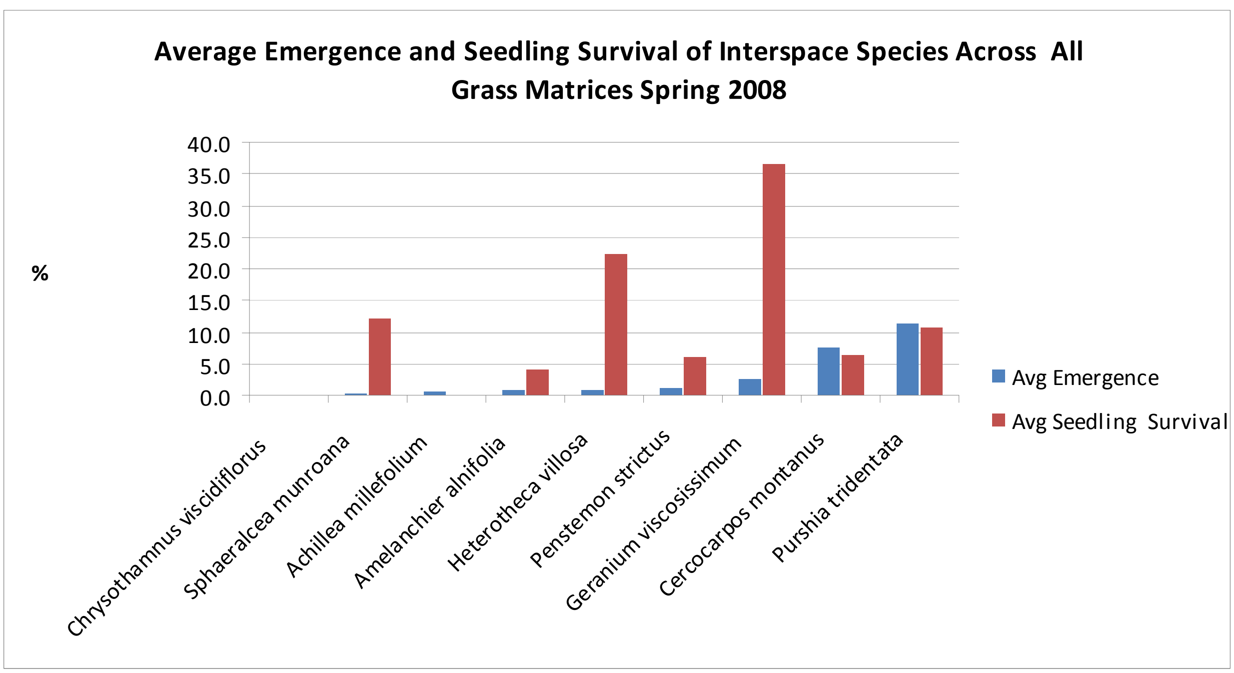
Common Name	Scientific Name	Source
Western Yarrow	*Achillea millefolium*	Washington Aug 2007
Hairy goldaster	*Heterotheca villosa*	Utah 2006
Rocky Mountain Penstemon	*Penstemon strictus*	Colorado Jun 2006
Munro's Globemallow	*Sphaeralcea munroana*	Utah Aug 2004
Serviceberry	*Amelanchier alnifolia*	Utah 2004
Birchleaf Mountain Mahogany	*Cercocarpus montanus*	Utah May 2006
Douglas rabbitbrush	*Chrysothamnus viscidiflorus*	Utah 2002
Antelope Bitterbrush	*Purshia tridentata*	Utah Aug 2007

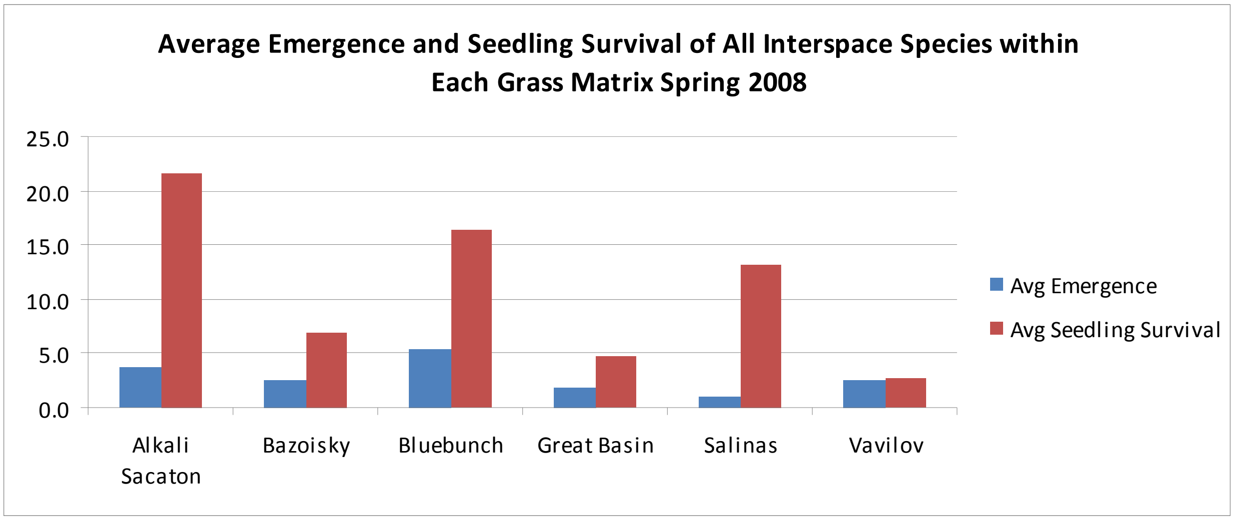
In each plot the edge plants were excluded and the inside 16 (4 x 4) interspaces were used. The 8 species were randomly assigned to 2 inner spaces per plot. Five caches of seeds were placed in each interspace with 10 seeds/cache for the bitterbrush, mountain mahogany, and serviceberry. Due to seed size and ease of handling, all other species were planted using 1 pinch between the thumb and forefinger per cache. Sticky geranium seed contaminated the western yarrow and data was collected for this species as well. Subsequent to the planting, several pinches of each species were counted in the lab to determine an average of the seed planted per cache. Tetrazolium tests were also conducted to determine the viability of each species. The following is a summary of the results.

Plants in the Interspaces	Species	Seeds/ cache	% Viability	Seeds/ pinch	Viable Seeds/ interspace
Achillea millefolium	Western Yarrow	1 pinch	**85**	**124.0**	527
Geranium viscosissimum	Sticky Geranium	planted with western yarrow	**93**	**9.6**	45
Heterotheca villosa	Hairy Golden Aster	1 pinch	**67**	**88.6**	295
Penstemon strictus	Rocky Mountain Penstemon	1 pinch	**55**	**58.1**	160
Sphaeralcea munroana	Munro's Globemallow	1 pinch	**90**	**28.9**	130
Amelanchier alnifolia	Serviceberry	10	**77**	**Counted**	38
Cercocarpus montanus	Birchleaf Mountain Mahogany	10	**42**	**Counted**	21
Chrysothamnus viscidiflorus	Douglas rabbitbrush	1 pinch	**15**	**62.5**	47
Purshia tridentata	Antelope Bitterbrush	10	**52**	**Counted**	26

In Spring 2008, density counts of the seedlings in the interspaces were conducted in May until emergence ceased. On July 31, the total emergence and seedling survival were recorded. In addition, pre-dawn water potential was measured once per week from May 9 to July 11 excluding the 1st week of June due to a heavy rainstorm. Plots were hand weeded as needed throughout the season to prevent confounding from weed competition. The following summarize our preliminary statistics.







In November 2008, the plots were weeded and the interspaces cleared and replanted using the same procedure as the previous year with one exception. The Douglas rabbitbrush which had 15% viability and 0% emergence was replaced with the sticky geranium seed cleaned from the western yarrow seed.

Overall, emergence was much lower than expected and we look forward to comparing it to this next season's data.

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

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

Principal Investigators and Contact Information:

Robert Karrfalt
USDA-FS National Tree Seed Laboratory
5675 Riggins Mill Road, Dry Branch, GA 31020
478.751.3551
rkarrfalt@fs.fed.us

Victor Vankus
USDA-FS National Tree Seed Laboratory
5675 Riggins Mill Road
Dry Branch, GA 31020
478.751.3551
vvankus@fs.fed.us

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

Project Status and Products:
Seed Moisture
The relative humidity at which a seed equilibrates can be measured and used to determine if the seed's moisture condition is appropriate for preserving its viability in storage. Traditionally this was done by oven drying methods and when possible with electronic meters that were calibrated by species with oven moisture content measurements on clean seed. Both methods presented a number of challenges and could be expensive. The relative humidity method can be done on any seed in any state of preparation from raw seed just off the plant to highly cleaned seed. A relatively inexpensive electronic hygrometer was adapted to do this moisture test. This method has been outlined in presentations made this past year. A handbook on seed drying and storage will be prepared in 2009. 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. A storage study on sagebrush has produced good first year data showing that seed equilibrated at 30% RH stores well at a range of temperatures and freezing

temperatures preserve some seed viability even at the relatively high ERH of 70%. A comparison of higher purity and low purity seed lots showed that low purity seed had to be equilibrated at 30% to preserve viability. Based on first year data, it seems that sagebrush seed is best stored at a high purity, equilibrated at 30% RH and frozen (figures 1, 2).

– Moisture evaluations with an electronic hygrometer that can be universally applied to any seed lot. The procedure is proving to be workable and convenient in the sagebrush seed storage study.

– Germination conditions were identified for *Agoseris glauca, Sphaeralcea coccinea,* and *Eriogonum umbellatum.* A minimal amount of work should lead to publication. *Lomatium dissectum, L. grayii, and L. triternatum* germination protocols can also be published in 2009. Rule submission to AOSA will occur in either 2009 or 2010 with adoption at the following annual meeting. *Penstemon* germination remains to be defined.

Agoseris glauca germinated well without chilling at temperatures from 5 to 20^{o}C with either 8 or 16 hours of light (figure 3).

Sphaeralcea coccinea germinated well only after the seed coat had been broken by clipping. Germination occurred equally well from constant 3^{o}C to alternating 20-30^{o}C (figure 4).

Eriogonum umbellatum germinated equally well, after 28 days of pre-germination chilling, at temperatures from constant 10^{o}C to alternating 20-30^{o}C. Longer pre-germination chilling may yet be found to be beneficial (figure 5).

Penstemon accuminata, P. deustus, and *P. speciosis* had 0 to 2% germination following 28 days of pre-germination chilling. Longer pre-germination chilling periods will be tried.

Presentations:

Karrfalt, R.P. Development of germination protocols, seed weight, purity, and seed conditioning/cleaning protocols for Great Basin grasses and forbs**.** Great Basin Native Plant Selection and Increase Project Annual Meeting, 2008 Feb 13-14, Salt Lake City, UT.

Publications:

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

Karrfalt, R.P. and N.L. Shaw. Ten steps to a successful native plant materials program. Submitted to Native Plant Journal.

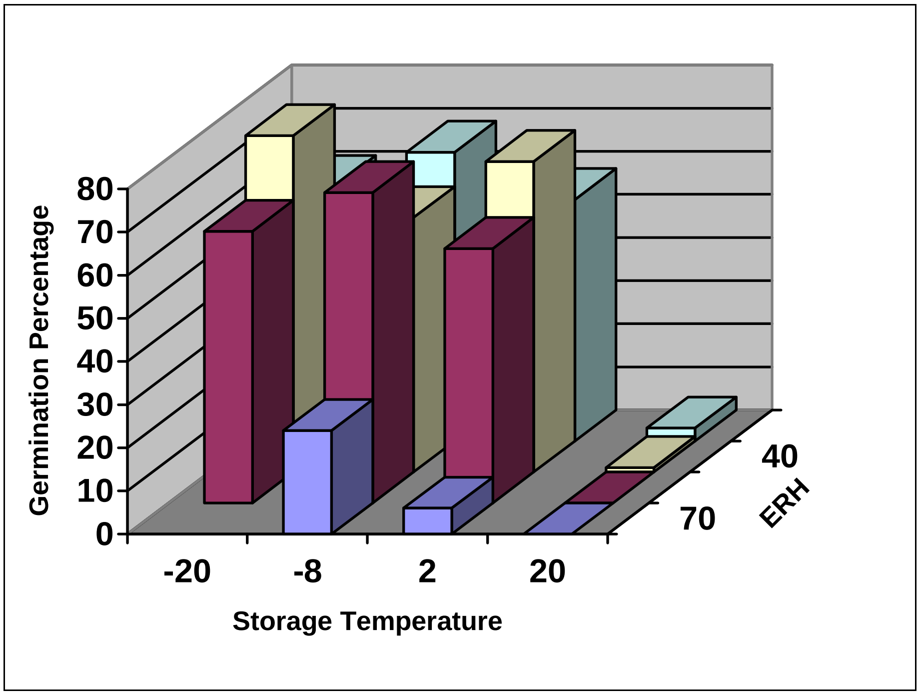


Figure 1. Germination of sagebrush seed storage, lot WP High Purity, after 15 months of storage at 15 ERH (equilibrium relative humidity) temperature combinations.

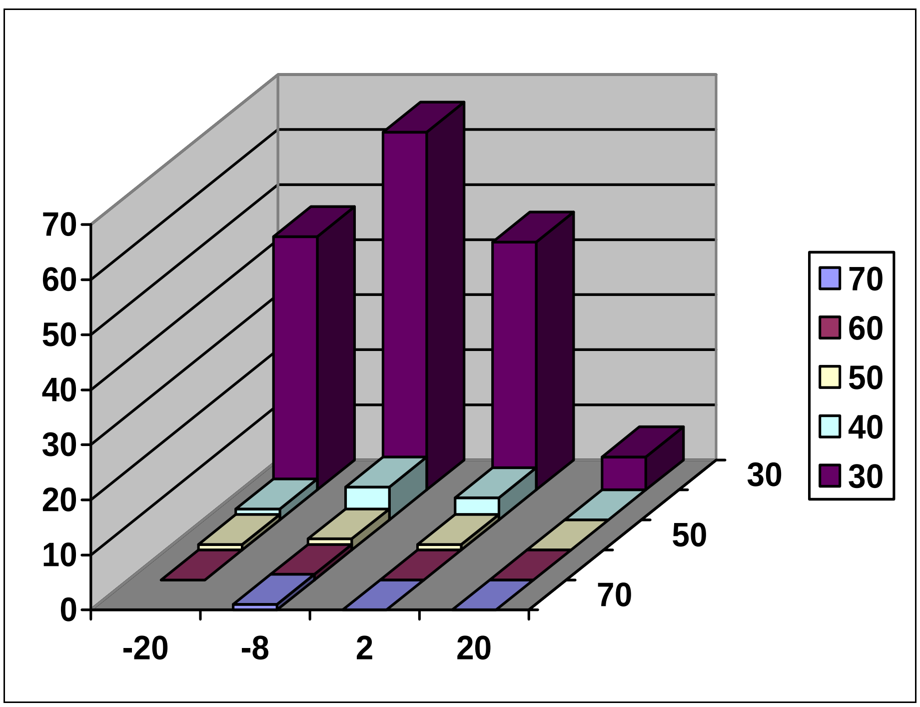


Figure 2. Germination of sagebrush seed storage, lot CA2 Low Purity, after 15 months of storage at 15 ERH (equilibrium relative humidity) temperature combinations.

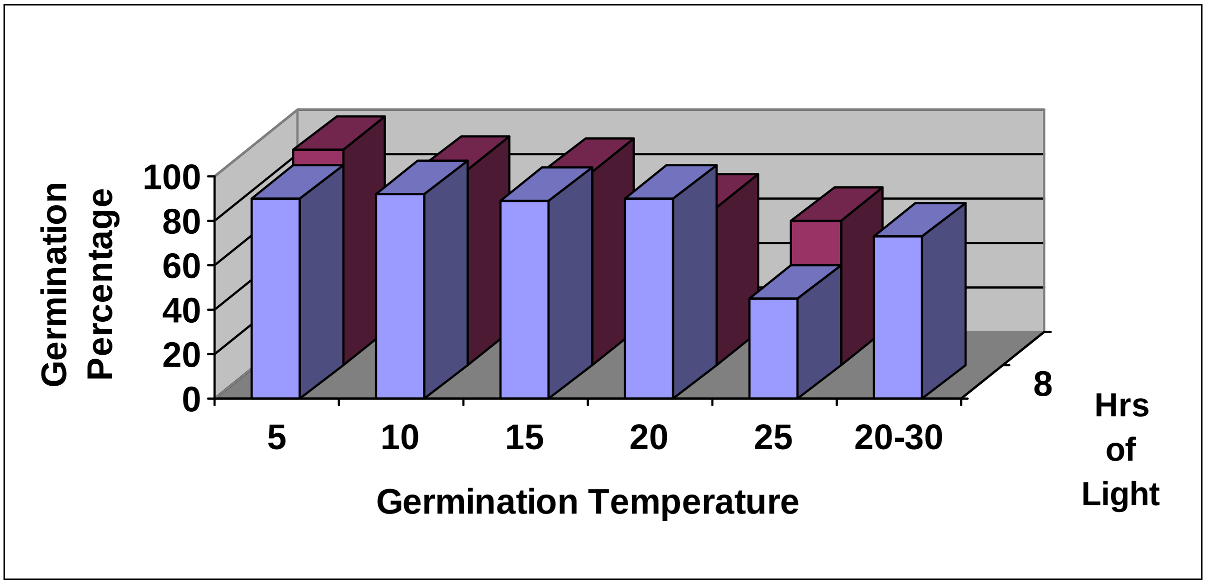


Figure 3. *Agoseris glauca* germination at 11 temperature-light combinations without pregermination chilling.

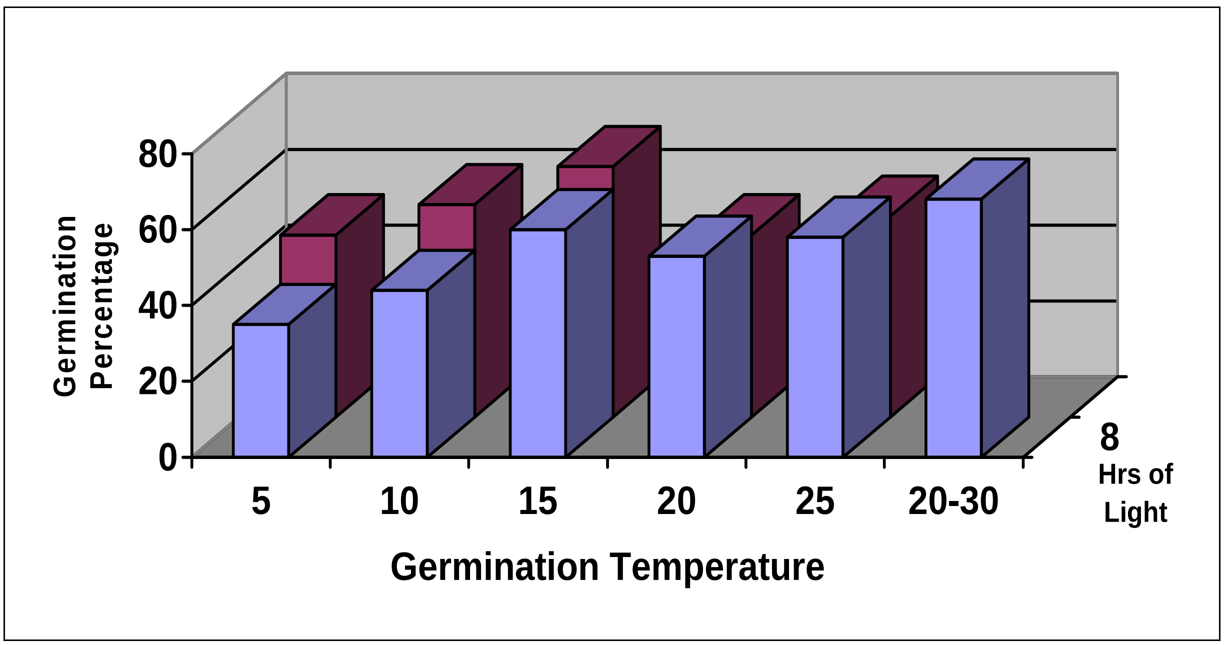


Figure 4. *Sphaeralcea coccinea* germination at 11 temperature-light combinations without pregermination chilling but with seed coat opened by clipping.

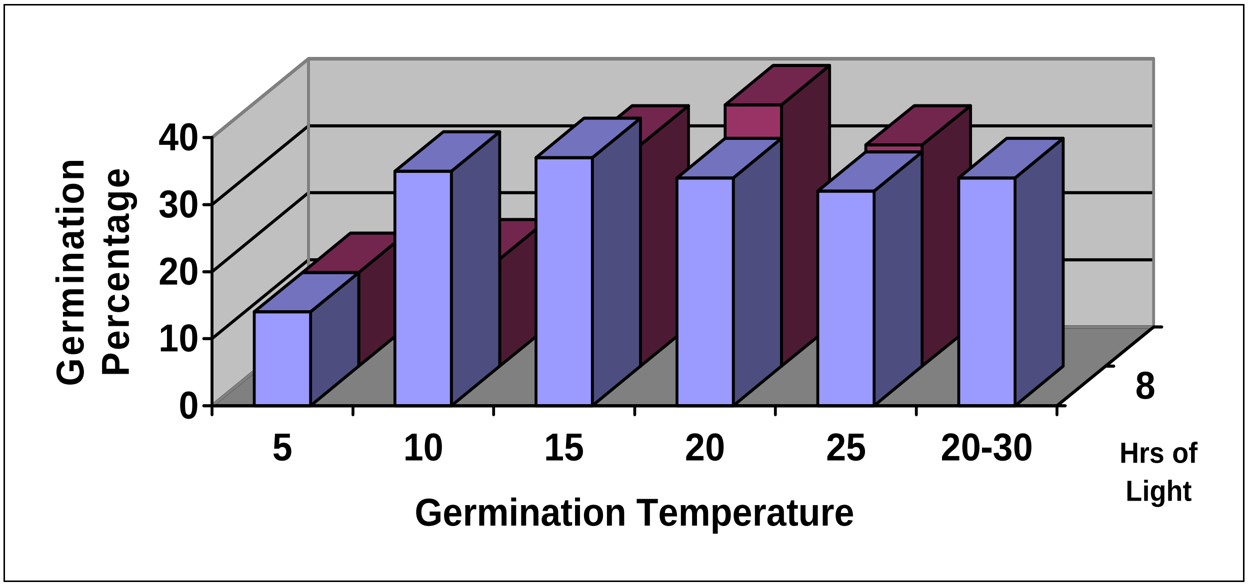


Figure 5. *Eriogonum umbellatum* germination at 11 temperature-light combinations with 28 days of pregermination chilling.

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

Project: Utah State University, Logan, Utah

Principal Investigators and Contact Information:

Corey Ransom
Utah State University
Department of Plants, Soils, and Climate
4820 Old Main Hill
Logan, Utah 84322-4820
435.797.2242, fax: 435.797.3376
corey.ransom@usu.edu

Kim Edvarchuk
Utah State University
Department of Plants, Soils, and Climate
4820 Old Main Hill
Logan, Utah 84322-4820
435.797.2367, fax: 435.797.3376
kandersen@cc.usu.edu

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*), Searls' prairie clover (*Dalea searlsiae*), and tapertip hawksbeard (*Crepis acuminata*).

Materials and Methods
Difficulty in culturing and growing plants in the greenhouse resulted in little valuable data from greenhouse work in 2008. However, the availability of established plantings of both *Astragalus filipes* and *Dalea ornata* allowed field testing of several herbicides on these species. Both sites were established by Doug Johnson of the USDA-FRRL in 2005 by transplanting growing plants from cone-tainers into the field with 0.5 m between plants. Both fields were mixtures of different collections that had been evaluated for various traits. Herbicide plots were two plant rows wide and 13 plants long (1 by 7 m, 26 plants per plot) for *Astragalus filipes* and two plant rows wide and 8 plants long (1 by 4 m, 16 plants per plot) for *Dalea ornata*. 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 on May 13,

2008 at 20 gpa and 30 psi. Plant injury was evaluated visually 10 days after treatment on May 23 and again on July 25 for *Astragalus* and July 11 for *Dalea*. Because of the variability in plant size among individual plants within plots at the time of application, initial plant height and diameter was measured on May 17. The plants were measured again on June 19 and differences in individual plant growth between the two dates were used to determine plant growth in response to herbicide treatment. Changes in height and diameter of all plants within a plot were averaged and used in the analysis of herbicide effects. Ten herbicides were evaluated in the *Astragalus* trial, while there was only room for four herbicide treatments in the *Dalea* trial. Neither trial received irrigation, which may influence the level of herbicide injury exhibited on both species by the herbicides that were tested.

Results

Astragalus filipes

Postemergence applications to *Astragalus filipes* resulted in varying levels of visual injury (Table 1). Prowl H_2O, Outlook, Chateau, and Sencor all had 6% or less injury at either evaluation date. Paramount, Raptor, and 2,4-DB treated plots exhibited little injury at the May evaluation, but 18% or greater injury on July 25. Injury from Goal increased from 13 to 28% from the May to the July rating, while Transline injury was 60% in May and remained greater than 50% in July. Only Transline reduce plant height and plant diameter in comparison the untreated control and in comparison to all other herbicide treatments. There was a significant but weak correlation between the July visual injury ratings and plant height and diameter (Figure 1). It appears that there is great potential to use herbicides including Prowl, Outlook, Chateau, Sencor, and Buctril for weed control in established *Astragalus filipes*. However, further testing is needed to confirm these results and future trials need to evaluate seed production to ensure that treatments causing minimal injury or small reduction in plant size do not reduce seed yield.

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 23	July 25	Height	Width
	lb ai/A	%		cm	
Untreated	--	0	0	18	17
Prowl H_2O	0.71	0	0	17	14
Outlook	0.84	0	0	20	17
Goal	0.25	13	28	15	14
Chateau + NIS	0.064	5	6	19	16
Sencor + NIS	0.5	0	0	17	16
Buctril	0.25	0	5	16	15
2,4-DB	0.25	0	18	17	15
Transline	0.124	60	51	5	6
Paramount + MSO	0.248	5	18	15	15
Raptor + MSO	0.078	5	19	16	15
LSD (0.05)		5.5	10	4	5

*Injury was measured by visual evaluations. Height and width are the difference between plant height and width on May 17, 2008 and the same measurements taken on June 19, 2008.

†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.

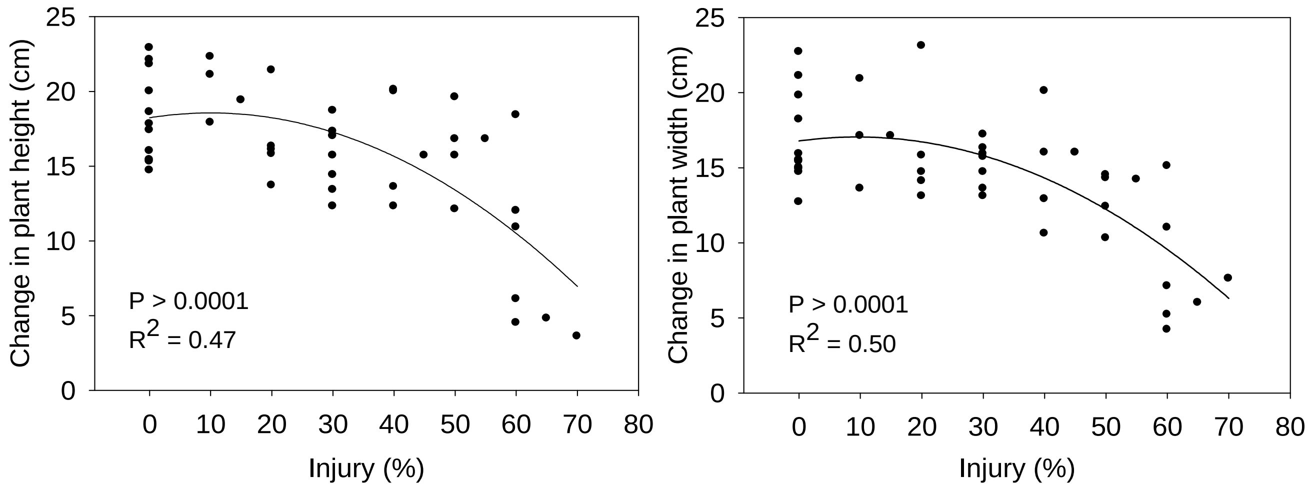


Figure 1. Correlation of plant visual injury ratings and measured plant height and diameter.

Dalea ornata
None of the herbicides applied to established *Dalea ornata* caused visual injury or reduced plant height or diameter (Table 2). This is not surprising since very little growth was present on *Dalea ornata* plants at the time of herbicide application. It is possible that producers could make herbicide applications prior to spring re-growth for control of winter annual weeds. While no injury was observed in this trial, application of these same herbicides at a time when *Dalea* plants have significant leaf growth may result in significant injury.

Table 2. Effect of herbicide treatments on plant injury, average plant height, and average plant width of established *Dalea ornata*.

		Plant response			
		Injury			
Herbicide†	Rate	May 23	July 11	Height	Width
	lb ai/A	——%——		——cm——	
Untreated	--	3	0	37	51
Sencor + NIS	0.5	0	0	37	54
Buctril	0.25	0	0	35	49
Paramount + MSO	0.248	0	0	34	58
Raptor + MSO	0.078	0	0	37	57
LSD (0.05)	--	NS	NS	NS	NS

*Injury was measured by visual evaluations. Height and width are recorded as the difference between average plant height and width on May 17, 2008 and the same measurements taken on June 19, 2008, 2008.
†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 2009

Efforts in 2009 will again focus on evaluating herbicides on additional established planting of *Astragalus filipies* and *Dalea ornata* made available by Doug Johnson. In addition, efforts will be made to evaluate preemergence herbicide effects on emerging seedlings in small-scale field trials if enough seed of all the species is available. Evaluation of herbicide tolerance of seedlings grown on agar media will be investigated as a method to identify potential candidates for field screening.

Presentation:

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

Management Applications:

The preliminary field data suggests several herbicides can be used for selective weed control in established *Astragalus filipes* and *Dalea ornata*. Additional data is needed to confirm these findings and consistent data is still lacking on potential herbicides for weed management during establishment of the native forb species evaluated in this research.

Project Title: Identification of Herbicides for Use in Native Forb Seed Production, 2008

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

Principal Investigators and Contact Information:

Clinton C. Shock
Oregon State University Malheur Experiment Station
595 Onion Ave., Ontario, OR 97914
541.889.2174, fax: 541.889.7831
clinton.shock@oregonstate.edu

Erik Feibert
Oregon State University Malheur Experiment Station
595 Onion Ave., Ontario, OR 97914
541.889.2174, fax: 541.889.7831

Joey Ishida
Oregon State University Malheur Experiment Station
595 Onion Ave., Ontario, OR 97914
541.889.2174, fax: 541.889.7831

Nancy Shaw
U.S. Forest Service, Rocky Mountain Research Station
322 E. Front Street, Suite 401, Boise, ID 83702
208.373.4360, fax: 208.373.4391

Project Description:
Native forb seed is needed to restore rangelands of the Intermountain West. Commercial seed production is necessary to provide the quantity of seed needed for restoration efforts. A major limitation to economically viable commercial production of native forb seed is weed competition. Weeds are adapted to growing in disturbed soil, and native forbs are not competitive with these weeds. There is a considerable body of knowledge about the relative efficacy of different herbicides to control target weeds, but few trials have tested the tolerance of native forbs to commercial herbicides. This report is in two parts. The first part deals with successive years of postemergence herbicide applications and the second deals with postemergence herbicide rates and mixtures.

I. Native Perennial Forb Tolerance to Repeated Annual Application of Post-emergence Herbicide

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

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., 2007) and varied by species. The crop preceding forbs was wheat. Prior to planting, one drip tape was inserted 12 inches deep equidistant between pairs of rows to be planted. The drip tape was supplied with irrigation water using filtration and other common drip irrigation practices (Shock, 2006).

2006 Postemergence Treatments

The 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 (See tables 2-8). Treatments were applied May 24, 2006 at 30 psi, 2.63 mph, in 20 gal/acre using 8002 nozzles with three nozzles spaced 20 inches apart. Plant injury in 2006 was rated visually on May 31, June 15, and June 30.

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

Spring of 2007

By March 30, 2007, it was difficult if not impossible to distinguish any effects of the 2006 postemergence herbicide applications on any of the seven forb species. These observations suggest that some degree of phytotoxic damage may be acceptable in establishing native forb seed fields if effective weed control is achieved.

2007 Postemergence Treatments

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

Drip irrigations were applied every 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, Penstemon deustus,* and *Penstemon speciosus* was harvested by hand as the seed reached maturity. The seed was cleaned and weighed. *Lomatium dissectum, Lomatium triternatum,* and *Lomatium grayi* did not flower in 2007.

2008 Postemergence Treatments

The same treatments as 2006 were applied again to the same plots on March 12, 2008. The same application specifications as in 2006 were used in 2008.

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

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 hotrock 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

General Considerations

The focus of the evaluations was forb tolerance to the herbicides, not weed control. Therefore, weeds were removed as needed in 2006 and 2007. In 2008 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 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 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. All treatments were applied earlier in 2008 (March 12) than in 2007 (April 24). The earlier application in 2008 occurred before all the forb species broke dormancy, except 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 as 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, Penstemon deustus,* and *Penstemon speciosus* in 2008 (Table 1). For *Lomatium triternatum,* seed yield was reduced for the Buctril treatment, despite the early application. The *Lomatium* spp. break dormancy early in the growing season, and *Lomatium triternatum* could have been susceptible at the early application date. Buctril, applied later in 2007 also reduced seed yield of *Lomatium triternatum.*

Lomatium dissectum and *Lomatium grayi* plants need further plant development prior to seed production. Seed productivity may begin in 2009.

Summary

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

Table 1. Yield of five forbs in response to post emergence herbicides applied on March 12, 2008, 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	*Eriogonum umbellatum*	*Penstemon deustus*	*Penstemon acuminatus*	*Penstemon speciosus*	*Lomatium triternatum*
	lb ai/acre		---------------------------------- lb/acre				-------------------------------
Untreated	--		365.1	330.2	93.9	487.5	981.5
Buctril 2.0 EC	0.125	foliar	285.5	309.1	195.6	781.7	187.9
Goal 2XC	0.125	foliar	279.7	427.0	173.3	728.1	820.8
Select 2.0 EC[a]	0.094	foliar	263.0	421.3	107.8	814.7	1062.1
Prowl H_2O 3.8 C	1.000	soil	385.0	345.4	112.6	608.4	922.7
Caparol FL 4.0	0.800	foliar	298.5	267.2	184.6	785.3	1069.8
Outlook 6.0 EC	0.656	soil	354.8	420.1	110.3	569.0	987.0
Lorox 50 DF	0.500	soil	368.4	360.4	140.0	672.2	888.1
LSD (0.05)			NS	NS	NS	NS	388.7

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

II. Native Perennial Forb Tolerance to Rates and Mixtures of Postemergence Herbicides

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

Materials and Methods

In the fall of 2006 *Eriogonum umbellatum, Penstemon acuminatus, Penstemon deustus* and *Penstemon speciosus* were each planted in areas 10 feet wide and 220 feet long (Table 1). The seed 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 12 inches deep equidistant between pairs of rows to be planted. The drip tape was supplied with irrigation water using filtration and other common drip irrigation practices (Shock, 2006). 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, 13 herbicide treatments (Table 2) were applied to plots 4 rows wide and five feet long. The treatments consisted of different rates and combinations of the soil active herbicides Prowl and Outlook. The treatments were arranged within each species in randomized complete block designs with 4 replicates. Treatments were applied at 30 psi, 2.63 mph, in 20 gal/acre using 8002 nozzles with six nozzles spaced 20 inches apart.

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 *Penstemon speciosus.* Plant populations of *P. deustus* prior to herbicide applications were not adequate for data on seed yield to be meaningful. For *P. deustus*, only observations on herbicide damage were made.

General Considerations

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

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

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

Species	Common name	Origin	Year
Eriogonum umbellatum	Sulfur-flower buckwheat	Shoofly Road, Owyhee Co., ID	2004
Penstemon acuminatus	Sharpleaf or sand dune penstemon	Bliss Dam, Elmore Co., ID	2004
Penstemon deustus	Scabland or hotrock 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. Herbicides that damaged forbs as reported here might be helpful if used at a lower rate or in a different environment. The herbicides were relatively safe for 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. 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 *Penstemon speciosus* (Table 2).

Summary

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.

Table 2. Yield of three forbs in response to post emergence herbicides applied on March 12, 2008, Malheur Experiment Station, Oregon State University, Ontario, OR. All herbicides except Select are soil active.

Treatment	Rate	*Penstemon speciosus*	*Penstemon acuminatus*	*Eriogonum umbellatum*
	(lbs ai / ac)	------------------------------------ lb/acre	------------------------------------	------------------------------------
Weed Free, untreated Control		820.9	557.9	276.5
Select 2.0 EC[a]	0.094	876.7	491.0	149.1
Prowl	0.95	644.2	403.7	387.2
Prowl	1.19	1242.0	506.1	533.1
Prowl	1.43	941.0	573.0	250.6
Outlook	0.84	992.5	463.1	319.8
Outlook	0.98	860.4	348.1	143.5
Prowl + Outlook	0.95 + 0.66	653.7	472.3	300.9
Prowl + Outlook	0.95 + 0.84	965.4	483.6	440.0
Prowl + Outlook	0.95 + 0.98	827.3	466.4	330.9
Prowl + Outlook	1.19 + 0.66	917.0	627.8	244.0
Prowl + Outlook	1.19 + 0.84	835.0	434.4	336.7
Prowl + Outlook	1.19 + 0.98	707.4	460.0	285.6
LSD (0.05)		NS	NS	NS

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

Literature Cited:

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

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

Publications:

Shock, C.C., J. Ishida, and E.B.G. Feibert. 2008. Native wildflowers grown for seed production show tolerance to conventional postemergence herbicides. Oregon State University Agricultural Experiment Station, Special Report 1087:197-203. http://www.cropinfo.net/AnnualReports/2007/ForbWeedControl2007.html

Presentations:

Shock, C.C., E.B.G. Feibert, L.D. Saunders, and J. Ishida 2008. Identification of post-emergence herbicides for use in native forb seed production. Great Basin Native Plant Selection & Increase Project Annual Meeting, Salt Lake, UT.

Sampangi, R.K., S.K. Mohan, C.C. Shock, E.B.G. Feibert, and D.A. Glawe. 2008. Powdery mildew of onion caused by *Leveillula taurica* and the possible epidemiological role of alternative hosts in Idaho and Oregon. Am. Phytopathalogical Soc. July 26-30, 2008. Minneapolis, MN.

Shock, C.C., E.B.G. Feibert, L.D. Saunders, E.P. Eldredge, L.B. Jensen, N.L. Shaw, S.K. Mohan, R.K. Sampangi, and H.R. Pappu. 2008. Progress on micro-irrigation in Oregon 2008. Regional working group W1128: Reducing Barriers to Adoption of Microirrigation. Portland, OR. October 22-24. PowerPoint presentation and a written report.

Management Applications:
The report above describes practices that can be immediately implemented by seed growers.

Products:
Seed produced from these planting was used to establish commercial seed production fields.

A field tour for growers was conducted in May 2008.

A tour of the seed production trials was incorporated into the annual Malheur Experiment Station Field Day activities on July 9, 2008.

Project Title: Container production of *Artemisia tridentata*

Location: University of Idaho, Moscow, Idaho

Principal Investigator and Contact Information:

Anthony S. Davis
University of Idaho
PO Box 441133, University of Idaho, Moscow, ID 83844
208.885.7211, 208.885.6226
asdavis@uidaho.edu

Project Description:
Developing a target plant for restoration of degraded sites may aid in cost-effective restoration. This study was conducted to 1) identify the effect of container size on Wyoming big sagebrush seedling morphology and 2) determine the level of cold hardiness attained during Wyoming big sagebrush seedling production. Seedlings were grown for one year (March 2007 to March 2008) in each of three different container sizes (cavity volume of 105, 250, 340 ml) to investigate seedling quality with regard to cold hardiness, and the morphological characteristics of height, root-collar diameter, dry mass, volume, and root:shoot. Cold hardiness was not affected by container size. Plant height, root-collar diameter, shoot volume, and dry mass increased with container size. Seedling root volume in the two largest container sizes (340 and 250) was greater than that of seedlings grown in 105 containers. The results indicate the strong effect that container size has on plant morphology.

Publications:
Herriman, K.R., A.S. Davis, and R.K. Dumroese. Effect of stocktype on sagebrush seedling development following outplanting. National proceedings, forest and conservation nursery associations—2008. Proceedings. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. In press.

Presentations:
Herriman, K.R., A.S. Davis, and R.K. Dumroese. 2008. Effect of stocktype on sagebrush seedling development following outplanting. 8-9 October 2008. 29th Intermountain Container Seedling Growers' Association Meeting. Coeur d'Alene, ID.

Herriman, K.R., A.S. Davis, and R.K. Dumroese. 2008. Effect of stocktype on sagebrush seedling development following outplanting. 23-25 July 2008. Western Forest and Conservation Nursery Association. Missoula, MT. Invited.

Management Applications:
This information provides us with a greater ability to develop target plants for use in restoring degraded sites. These results should be of use to land managers and seedling producers.

Products:

- Description of the relationship between container size and plant size for container grown Wyoming big sagebrush
- Sharing of information to growers at the Intermountain Container Seedling Growers' Association and Western Forest and Conservation Nursery Association Meetings
- Demonstration plantings established in Mt. Home, ID
- Propagation protocol to be shared through the Native Plant Network

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

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

Principal Investigator and Contact Information:

Kent McAdoo
University of Nevada Cooperative Extension
701 Walnut Street
Elko, NV 89801
775.738.1251, fax: 775.753.7843
mcadook@unce.unr.edu

Project Description:

Objectives

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.

Methods

Study Site

The study site, approximately 15 miles southeast of Elko, NV, is located within the 8 – 10 inch 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.

Crested Wheatgrass Control and Revegetation Treatments

The following strategies are being tested in a randomized block, split-split plot design: (1) untreated crested wheatgrass; (2) partially controlled crested wheatgrass; and (3) completely controlled crested wheatgrass.

Within these main plots, 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.

The study site is comprised of 5 blocks.

Revegetation Species and Methods:
Sub-plots designated for seeding will be seeded with commercially-purchased native grass, forb, and shrub species adapted to the ecoregion. Drill-seeded species will be planted at NRCS-recommended rates with a Truax Rough Rider rangeland drill. For small-seed species, seed tubes will be pulled so that seed falls on the soil surface; drill disks will be raised and no furrows made, and a brillion-type cultipacker will be attached to the rear of the drill to press broadcasted seeds into the soil surface.

2008 Results
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 in late October 2008 by personnel from the NRCS Aberdeen Plant Materials Center with a Truax Rough Rider rangeland drill. The seed mixture used is identified in Table 1.

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.

Future Plans:

Sampling

Beginning in spring 2009, we will collect cover and density data for unseeded and seeded species during peak standing crop for three years on plots established in 2007-08. Sagebrush cover will be measured by line intercept, and density will be counted in 10-30 m long x 2 m wide belt transects in each plot. We will ocularly estimate herbaceous cover and density in five 0.5-m^2 quadrats placed randomly on each of 5 transects and perpendicular to each belt transect. Mortality of crested wheatgrass will be determined by comparing density of live plants on treated vs. untreated plots.

We will 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.

Publications:

Intermediate 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.

Management Applications:

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

Products:

Field Tour for NRCS in May 2008 to look at crested wheatgrass reduction methodologies.

Project Title: Effect of herbicide application timing on crested wheatgrass control and subsequent native plant re-establishment success

Project: USDA-ARS, Dubois, ID

Principal Investigators and Contact Information:

Corey Moffet
USDA-ARS, U.S. Sheep Experiment Station
19 Office Loop, Dubois, ID 83423
208.374.5678, 208.374.5582
corey.moffet@ars.usda.gov

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 TNC trend on herbicide efficacy
Two experiments with a fine temporal resolution will be conducted at the U.S. Sheep Experiment Station (USSES) headquarters property near Dubois, Idaho to determine the relationship between total nonstructural carbohydrate (TNC) trend and the efficacy of glyphosate to control crested wheatgrass. The first experiment will characterize the TNC trend in relation to plant phenology. The experiment will be 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 will be collected and placed on ice until they can be dried in the laboratory. The root crowns and stem bases will be analyzed for TNC.

The second experiment is a completely randomized design in a split-plot arrangement with repeated measures. A factorial combination of year (2 levels) and date (8 levels) will be assigned to main plots (1 x 2 m) completely at random. Within each main plot a random half (1 x 1 m) will be assigned to a clipping treatment. The clipped half will be clipped two weeks prior to the date that the main plot is to be sprayed. At the time these plots are selected, corners of the main plot will be 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 a 2 m height using an 8 MP camera (see Fig. 1). 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 glyphosate efficacy.

Figure 1. Example of images collected of the same plots (A) two weeks prior to herbicide application on May 22, 2008, (B) just prior to herbicide application on June 6, 2008, and (C) two weeks after herbicide application on June 20, 2008. In June 2009, the 4th image will be collected.

Large scale seeded plot experiment

The large scale plot experiment will be conducted within a 120 acre area that was seeded to crested wheatgrass near Aberdeen, Idaho over 13 years ago. The site is mapped to 2 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/PSSSP 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 years (2 levels) and crested wheatgrass control treatments (8 levels) will be assigned completely at random to 80 main plots (200 x 140 ft). A random half of each main plot (100 x 140 ft, subplots) will be seeded with a native mix. Between adjacent main plots there will be a minimum 40 ft buffer in all directions. Sampling, within each subplot, will be conducted on a central 80 x 120 ft core sampling area.

The 8 control methods will include combinations of herbicide and disking treatments. The treatments will include a control (no treatment), 4 single pass treatments (spring disking, vegetative stage herbicide application, reproductive stage herbicide application, or late season regrowth herbicide application if regrowth occurs), and 3 dual pass treatments (spring disking followed by herbicide application at one of the 3 herbicide application times). For all herbicide treatments, the recommended rate (44 oz/ac) of glyphosate will be applied with a tractor pulled sprayer. For the disking treatments a tractor pulled disk will be used in the spring before the soils become dry.

The seeded subplots will be seeded with a mix of native grasses, forbs, and shrubs common to the sites historical plant community (Table 1). Seeding will occur in October or early November. A Truax Rough Rider rangeland drill will be used for the seeding.

Establishment success will be evaluated in 2 growing seasons after the treatment and seeding year. Data collection will include 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.

Table 1. Seed mix.

Species	lb-PLS/ac	lb-Bulk Seed/ac
Broadcast		
‘Maple Grove’ Lewis flax	0.40	0.43
Mountain Home Sandberg bluegrass	0.20	0.24
Royal Penstemon	0.40	0.56
Wyoming big sagebrush	0.05	0.29
Rubber rabbitbrush	0.15	1.01
Rice Hulls	–	7.29
Drilled		
Anatone bluebunch wheatgrass	3.20	3.60
‘Magnar’ basin wildrye	0.80	1.04
‘Bannock’ thickspike wheatgrass	0.60	0.74
Thurber’s needlegrass	0.60	0.99
Rice Hulls	–	7.29

Future Plans:
For the large plot study, all experimental plots have been selected, the 8 crested wheatgrass control treatments have been implemented, and seeding has been completed for 2008. In 2009, the second round of control treatments and seeding will be conducted and the first year of establishment success for the 2008 treatment and seeding year will be determined.

For the small plot study, first year spray treatments have been applied and the 2008 imagery has been collected. The root crowns have been collected for 2008 and the phenological stage of the plants on each collection date has been classified. In 2009, the second round of clipping, herbicide application, and photography will be conducted on a new set of plots. The 2008 plots will be photographed and the images analyzed. Plants will be collected for an additional year for TNC and phenologically classified. TNC in crowns collected in 2008 will be analyzed.

Management Applications:
When this study is complete, land managers can use this information to choose crested wheatgrass control practices that have the greatest efficacy and increase the likelihood that subsequent native seeding efforts will be successful.

Project Title: Re-establishing Native Plant Diversity in Crested Wheatgrass Stands in the Great Basin

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

Principal Investigators and Contact Information:

Jane Mangold
USDA-ARS (formerly); Montana State University (currently)
67826-A Hwy 205; Burns, OR 97720 (formerly);
P.O. Box 173120, Bozeman, MT 59717 (currently)
406.994.5513, fax: 406.994.3933
jane.mangold@montana.edu

Cooperators:
USDA-FS-RMRS
322 East Front Street, Suite 401Boise, ID 83702

Malheur National Wildlife Refuge
36391 Sodhouse Lane, Princeton, OR 97720

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

Oregon State University
Dept. of Range Ecology and Management
202 Strand Agriculture Hall, Corvallis, OR 97331-2218

Project Description:
This project investigated the feasibility of increasing native plant diversity in established crested wheatgrass stands in the Great Basin. The study location was 80 km south of Burns, OR, on the Malheur National Wildlife Refuge in a stand of crested wheatgrass approximately 25 years old. Objectives included: 1) determine the effect of crested wheatgrass control methods and revegetation on crested wheatgrass density and cover, 2) determine the effect of crested wheatgrass control methods and revegetation on establishment of native species, and 3) determine the effect of crested wheatgrass control methods and revegetation on cheatgrass density and cover.

Methods

Procedures included varying the method and intensity of crested wheatgrass control, followed by seeding a mix of native shrubs, grasses, and forbs. Crested wheatgrass control treatments were tested in a randomized block, split-plot design with control method and intensity as whole plots and seeded vs. unseeded as split-plots. Control treatments included mechanical (disking), herbicide (glyphosate application), or undisturbed (no crested wheatgrass control). Control treatment intensity was varied by the number of passes with the disk (partial = one pass, full = two passes) and the rate of glyphosate application (partial = 10 oz ac^{-1}, full = 44 oz ac^{-1}). Half the plot was seeded and half the plot was left unseeded to simulate seeding failure following control treatment. The five treatments [full control mechanical (FCM), partial control mechanical (PCM), full control herbicide (FCH), partial control herbicide (PCH), undisturbed (UD)] were replicated across five blocks each year on 0.4 ha (1 acre) plots for a total of approximately 10 ha (25 acres) treated annually (5 ha (12.5 acres) seeded, 5 ha unseeded). Control and seeding treatments were applied 2005 (Trial 1) and 2006 (Trial 2). Plots were monitored 2006, 2007, and 2008. Cover and density of unseeded and seeded species was collected in June for three years on Trial 1 plots and for two years on Trial 2 plots. A detailed description of sampling procedures and data analysis can be found in previous years' reports.

Results

– Crested Wheatgrass

Treatment and year interacted to affect crested wheatgrass density (P < 0.0001; Figure 1) in Trial 1. In 2006 all treatments resulted in similar crested wheatgrass density. Except in the UD treatment, which remained constant at 6.7 ± 0.3 plants·m^{-2}, crested wheatgrass density increased from 2006 to 2007. By 2007, the FCM treatment increased crested wheatgrass density to 14.3 plants·m^{-2}, which was higher than any other treatment. In addition the PCM (8.5 plants·m^{-2}) treatment was higher in density than the FCH (7.2 plants·m^{-2}) and UD treatments. The density of crested wheatgrass in 2008 was similar to that of 2007 for each treatment. Three years post-treatment, the mechanical control treatments resulted in increased crested wheatgrass density compared to undisturbed plots.

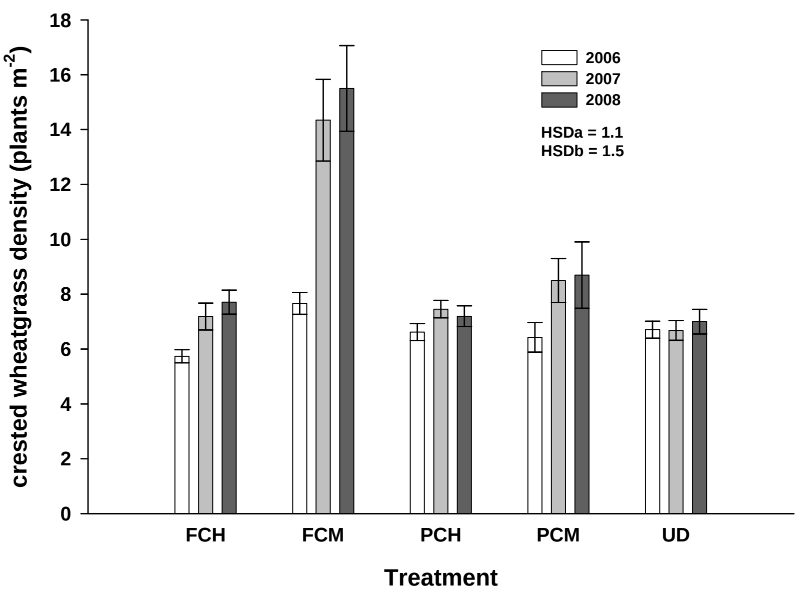


Figure 1. Crested wheatgrass density as affected by treatment and year in Trial 1. HSDa separates means within a treatment across years. HSDb separates means across treatments within a year. Error bars equal ± 1.0 SE. FCH = full control herbicide. FCM = full control mechanical. PCH = partial control herbicide. PCM = partial control mechanical. UD = undisturbed.

In Trial 2 the main effect of treatment influenced crested wheatgrass density (P = 0.0073). All treatments increased crested wheatgrass density over that of the UD treatment (7.0 ± 0.4 plants·m^{-2}).

Similar to Trial 1, the highest density was found in the FCM treatment (11.7 ± 0.7 plants·m^{-2}) followed by FCH (10.5 ±1.2 plants·m^{-2}), PCM (9.2 ± 0.3 plants·m^{-2}), and PCH (8.3 ± 0.4 plants·m^{-2}).
In Trial 1 treatment and year interacted to affect crested wheatgrass cover (*P* = 0.0037; Figure 2). Except for the FCM treatment, cover decreased from 2006 to 2008. In 2006 the FCM treatment demonstrated the lowest crested wheatgrass cover compared to all other treatments at 9.9 %, and it increased in 2007 and 2008 to 12.6% and 14.8%, respectively. By 2008 crested wheatgrass cover was lowest in the PCM treatment (11.1%) and highest in the FCM (14.8%) and UD (14.1%) treatments.

The main effect of year influenced crested wheatgrass cover in Trial 2 (*P* = 0.0004). Cover was 11.3 ±0.6% in 2007 and increased to 15.1 ± 0.8% in 2008. Crested wheatgrass cover was also influenced by an interaction between treatment and seeding level (*P* = 0.0465; Figure 3). In the PCH treatment, the seeded plots (14.8%) resulted in lower crested wheatgrass cover than the unseeded plots (18.4%). In contrast the UD treatment resulted in lower crested wheatgrass cover in the unseeded plots (14.3%) as compared to the seeded plots (17.8%). Seeding level did not matter in the FCH, FCM and PCM treatments.

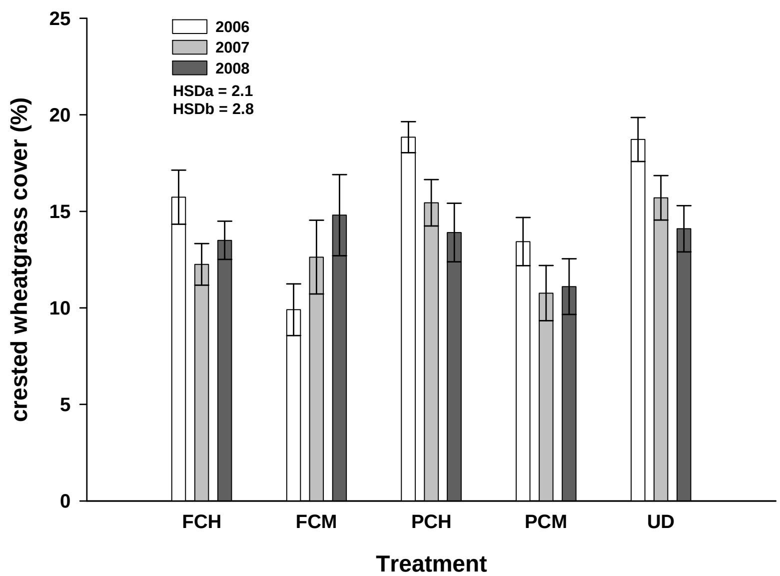


Figure 2. Crested wheatgrass cover as affected by treatment and year in Trial 1. HSDa separates means within a treatment across years. HSDb separates means across treatments within a year. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment codes.

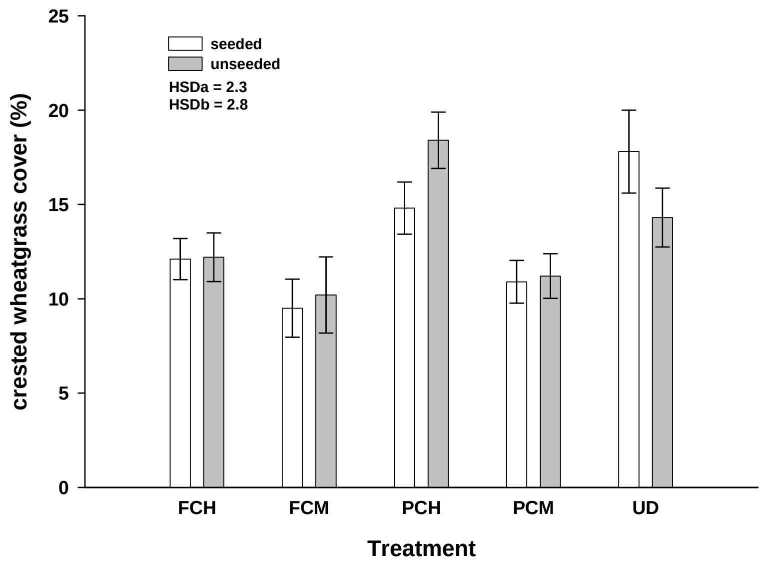


Figure 3. Crested wheatgrass cover as affected by treatment and seedling level in Trial 2. HSDa separates means within a treatment across seedling level. HSDb separates means across treatments within a seeding level. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment codes.

Seeded Species Establishment

In Trial 1 year interacted with treatment to affect seeded species density ($P < 0.0001$; Figure 4). The highest seeding density of 43.9 plants·m^{-2} occurred in the FCM treatment in 2006. Except for the UD treatment, which saw no change in seedling density (18.2 plants·m^{-2}), seedling mortality ranged from 25% to 67% between 2006 and 2007. By 2008 all treatments experienced an 88% to 98% decrease in seeded species density, and all treatments resulted in similar seeded species density (mean = 1.8 plants·m^{-2}).

The main effect of year influenced seeded species density in Trial 2 ($P < 0.0001$). Density decreased from 2007 to 2008 from 26.1 ± 1.5 plants·m^{-2} to 1.0 ± 0.2 plant·m^{-2}, respectively.

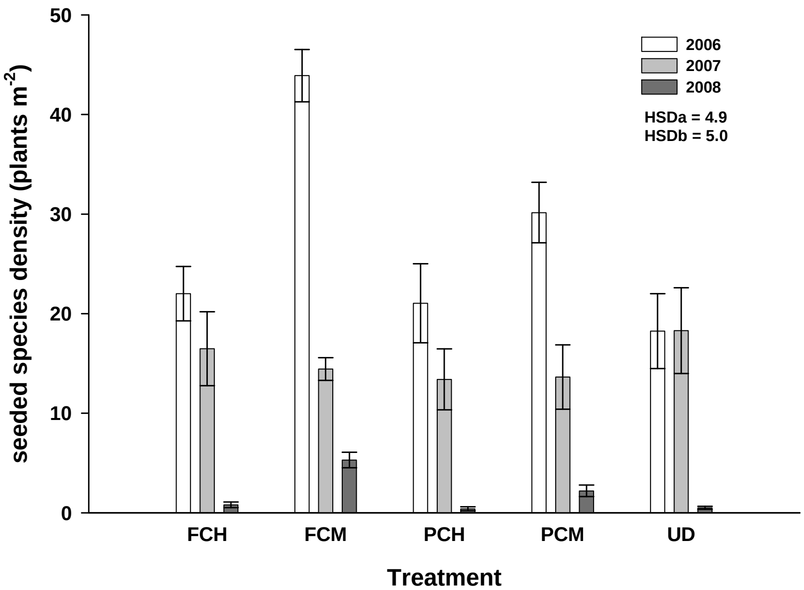


Figure 4. Seeded species density as affected by treatment and year in Trial 1. HSDa separates means within a treatment across years. HSDb separates means across treatments within a year. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment codes.

Cheatgrass

In Trial 1 no main effects or interactions significantly affected cheatgrass density. Cheatgrass cover was affected by the main effect of year (P = 0.0284). Cheatgrass cover was highest in 2006 at 3.5 ± 0.4% and decreased over three years to 2.3 ± 0.2% in 2008.

In Trial 2 cheatgrass density was influenced by the main effect of year (P = 0.0026), the interaction of treatment and year (P = 0.0004), and the interaction of treatment and seeding level (P = 0.0028). Across treatments and seeding levels, cheatgrass density increased from 29.4 ± 3.1 plants•m^{-2} in 2007 to 73.6 ± 8.6 plants•m^{-2} in 2008. Except for the PCH and UD treatments, cheatgrass density increased from 2007 to 2008 (Figure 5) in Trial 2. The highest cheatgrass density was found in the FCH treatment in 2008 at 133.1 plants•m^{-2}. Cheatgrass density was lower in the unseeded FCH treatment than in the seeded (96.8 vs. 62.8 plants m^{-2}, respectively), but the opposite was true in the UD treatment (19.2 vs. 63.6 plants m^{-2}, respectively) (Figure 6). Otherwise, no trends were observed in cheatgrass density as affected by seeding level.

In Trial 2 cheatgrass cover was affected by year (P = 0.0429) and the interaction of treatment and seed (P = 0.0446). Cheatgrass cover was 2.3 ± 0.1% in 2007 and increased to 3.1 ± 0.4% in 2008. The response of cheatgrass cover to the treatment by seeding level interaction was similar to cheatgrass density response (Figure 7). The highest cover was found in the seeded FCH treatment (5.2%) and lowest in the seeded PCH and UD (1.0 and 1.4%, respectively) treatments and unseeded PCH treatment (1.3%).

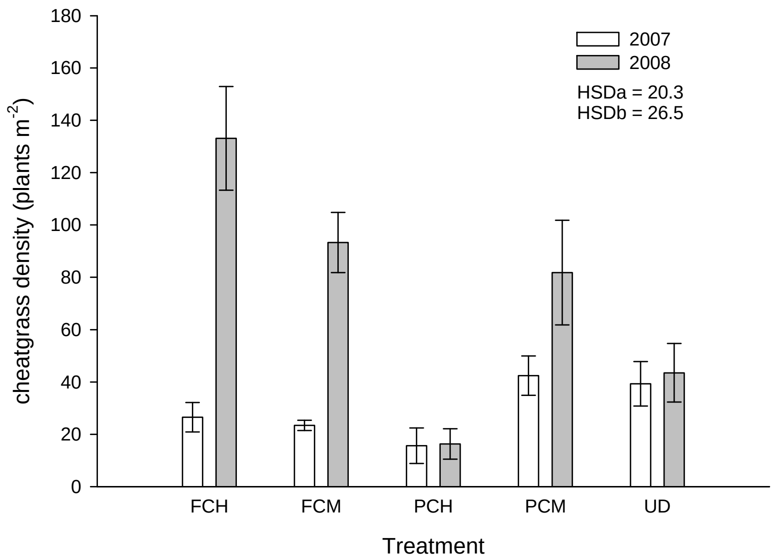


Figure 5. Cheatgrass density as affected by treatment and year in Trial 2. HSDa separates means within a treatment across years. HSDb separates means across treatments within a year. Error bars equal ± 1.0 SE. See Figure 1 for explanation of treatment codes.

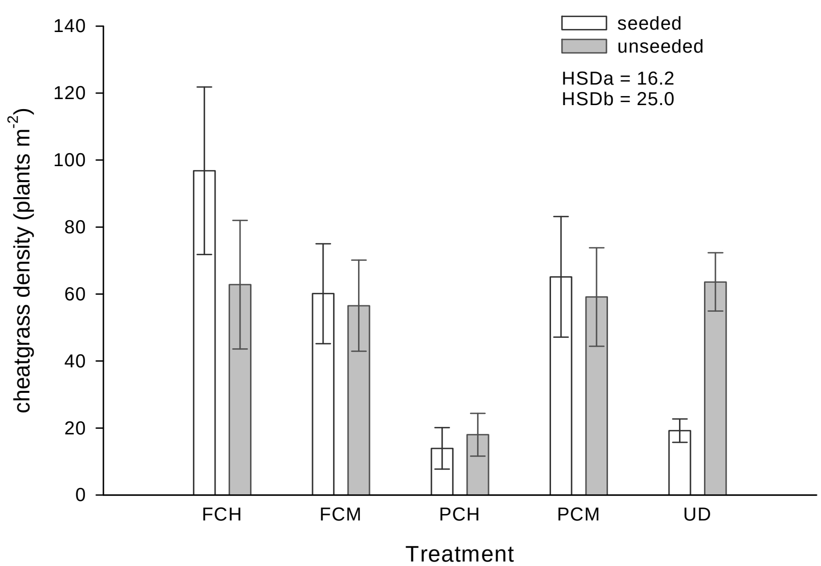


Figure 6. Cheatgrass density as affected by treatment and seeding level in Trial 2. HSDa separates means within a treatment across seeding levels. HSDb separates means across treatments within a seeding level. See Figure 1 for explanation of treatment codes.

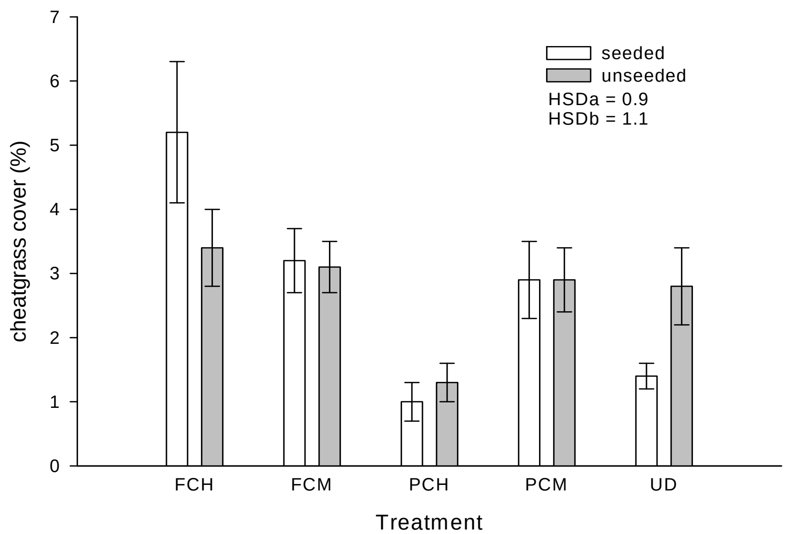


Figure 7. Cheatgrass cover as affected by treatment and seeding level in Trial 2. HSDa separates means within a treatment across seeding levels. HSDb separates means across treatments within a seeding level. See Figure 1 for explanation of treatment codes.

Publications:

Fansler, V.A. and J.M. Mangold. Establishing native plants in crested wheatgrass stands. Journal of Rangeland Ecology and Management. In review.

Presentations:

Results from this project were included in nine presentations that reached over 500 audience members in 2008.

Management Applications:

Restoration of crested wheatgrass stands into more diverse plant communities that meet multiple land-use objectives has been proposed and in some cases mandated. In spite of high initial densities of seeded species, seedling mortality was high and most of the seedlings that emerged the first year did not truly establish and persist until the end of the study. Our study suggested that strategies to increase native plant diversity in crested wheatgrass stands need to address not only crested wheatgrass control and introduction of native propagules, but also follow up management to favor the persistence of seeded species, especially between the first and third year after seeding. Our results would probably be less than satisfactory for a land manager whose objective is to restore plant diversity to a site, and we believe subsequent management that favors the persistence of native species and retards crested wheatgrass, such as properly timed grazing or consistent wick application of herbicide, is critical. Otherwise, attempts to control crested wheatgrass and establish native species will lead to failure and lost investments. Treatments that address species performance subsequent to revegetation with native species should be considered in future research projects.

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

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

Principal Investigators and Contact Information:

Nancy Shaw
USDA FS Rocky Mountain Research Station
Grassland, Shrubland and Desert Ecosystem Research Program
322 E. Front Street, Suite 401
Boise, ID 83702
208.373.4360, fax : 208.373.4391
nshaw@fs.fed.us

Robert Cox
Depatment of Natural Resources Management
Texas Tech University
Box 42125
Lubbock, TX 79409
806.742.1983, fax: 806.742.2280
Robert.Cox@ttu.edu
(formerly USDA FS RMRS, Boise)

Amy Ganguli
USDA FS Rocky Mountain Research Station
Grassland, Shrubland and Desert Ecosystem Research Program
322 E. Front Street, Suite 401
Boise, ID 83702
208.373.4358, fax: 208.373.4391
aganguli@fs.fed.us

I. Plant Materials

Project Description:

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

Project Status:

Seed Collection and Distribution
Fifty-two collections were made in 2008. Ten collections were provided to the National Seed Laboratory for development of seed testing protocols and 72 were provided to the USDA ARS Western Regional Plant Introduction Station for ex situ germplasm conservation.

Research Species and Buy-back Program

Bluebunch wheatgrass (*Pseudoroegneria spicata*): Collaborative genecological studies of are being conducted with USDA FS PNW Corvallis, OR and USDA ARS Pullman, WA. Three common gardens of 140 sources were established in 2006 at Pullman, WA, Central Ferry, WA and at the USDA FS Lucky Peak Nursery near Boise. Two years of morphological and phenological data have been collected and are being analyzed. Water use efficiency of selected populations will be compared in 2009.

Blue penstemon (*Penstemon cyaneus*): Snake River Plain seed was provided to a grower for seed increase.

Fernleaf biscuitroot (*Lomatium dissectum*): Morphological and phenological data is being collected from about 40 accessions in common gardens at Lucky Peak Nursery. Additional data is collected from common gardens at Wells, NV and Corvallis, OR. Molecular genetics work with these accessions has been conducted by the USDA ARS Western Regional Plant Introduction Station.

Hotrock or scabland penstemon *(Penstemon deustus)*: Blue Mountains/Northern Basin and Range seed provided to a seed grower for seed increase.

Nineleaf biscuitroot (*Lomatium triternatum*): Pooled Northern Basin and Range seed was provided to a seed grower for seed increase.

Sharpleaf or sand penstemon (*Penstemon acuminatus*): Snake River Plain/Northern Basin and Range seed was provided to a grower for seed increase.

Sulfur-flower buckwheat (*Eriogonum umbellatum*): Two common gardens are being maintained near Boise, ID. Data collection will continue through 2009. Northern Basin and Range seed was distributed to a grower for seed increase.

Thurber needlegrass (*Achnatherum thurberianum*): Northern Basin and Range seed was provided to a grower for seed increase.

Western yarrow (*Achillea millefolium*): G0 Eagle material provided to a grower for production of stock seed.

Wyeth buckwheat *(Eriogonum heracleoides*): Pooled Northern Basin and Range/Snake River Plains) seed was provided to a seed grower for seed increase.

Other Seed Distribution

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

Fernleaf biscuitroot *(Lomatium dissectum)* and Thurber needlegrass (*Achnatherum thurberianum*): seed was provided to Clint Shock, Oregon State University for studies of cultural practices.

Wyeth buckwheat, fernleaf lomatium, and sharpleaf penstemon from the Snake River Plain were also distributed for increase of source-identified seed.

Native seed for establishment of a native plant demonstration area in Owyhee County was provided to Susan Filkins and Roger Rosentreter, USDI Bureau of Land Management, Idaho State Office.

The Boise seed database was provided to Jim Cane for location of potential study sites for examining bee response to wildfires.

Big flower agoseris *(Agoseris grandiflora)*, tapertip hawksbeard (*Crepis acuminata)*, and dusty maiden (*Chaenactis douglasii*) are being screened for growth characteristics, seed production and cultural requirements at the Lucky Peak Nursery. Data on big flower agoseris and dusty maiden are provided to Scott Jensen, RMRS, Provo, UT, and G1 seed of big flower agoseris was provided to him for seed production studies.

II. Re-establishing Diverse Native Wyoming Big Sagebrush Communities: A Comparison of seeding equipment and techniques.

Additional Collaborators:

Loren St. John, USDA NRCS Aberdeen Plant Materials Center
Dan Ogle, USDA NRCS Idaho State Office, Boise, ID
Mike Pellant, USDI BLM, Reno, NV

Project Description:

Objectives and Methods

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

At each location, 35 plots were established in 5 blocks (7 plots per block). Two seeding rates of native species plus a control of no seed were seeded into the plots on Nov. 7-10, 2006. An untreated “double control” (no seed and no drill) was included to provide adequate comparison. Species and rates seeded are listed in Table 1. BLM Elko Field Office personnel were instrumental in all stages of this project, including planning, site selection, treatment application, and logistics. Tom Warren, Stan Kemmerer, Mark Coca, Brock Uhlig, Mike Mowray and Kyle Blackburn were especially helpful. 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. On December 19, 2006, autonomous weather stations were placed at each location to record rain, temperature, and soil moisture.

2008 Activities and Results

Data collection for this project occurred from June 9-14, 2008. As in 2007, data were collected based on the template provided by Dr. David Pyke, USGS, for entry into the "Rangeland Database and Field Data Entry System", a cooperative effort between ARS, NRCS, BLM, and USGS. This year, five 30m transects were established perpendicular to the drill rows, in each plot. On each transect, the density of all seeded species, plus cheatgrass and any native perennial species, were observed and recorded in four, 0.5 m^2 quadrats; species richness was also recorded by noting all unique species in each quadrat. Line-point intercept data was collected along each transect, by placing a point every 1m from a random starting point between 5.0 and 5.9m along the transect (for a total of 20 points per transect, 100 total points per plot). Finally, basal gap intercept was collected along the same transects, by recording the length of all gaps longer than 20cm between perennial species along the transect, beginning at the 5m mark and continuing until the 25m mark. Data collection involved up to10 field workers and required 1 week.

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

Table 1. Species seeded and rates, in PLS/m2.

Density data were analyzed with Proc Glimmix in SAS, and mean separations were performed with the Tukey adjustment (P=0.01). Analysis of other variables will proceed for the remainder of the year. 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 (Figs. 1a and 1b). 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 (Figs. 2a and 2b). 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 that did Rangeland drill seeded areas in both 2007 and 2008. Density also dropped greatly from 2007 to 2008 (Figs. 3a and 3b). 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. Density dropped greatly between years (Figs. 4a and 4b). Density of cheatgrass seedlings was much greater at the Gopher site than at the Humboldt site and greater in Minimum-till seeded areas than in Rangeland seeded areas (2008 data not analyzed yet) (Figs. 5a and 5b).

Future Plans:

The fieldwork portion of this study is completed, although the plots have been fenced and will be r evisited in several years for reassessment of longer-term success. The data analysis will continue

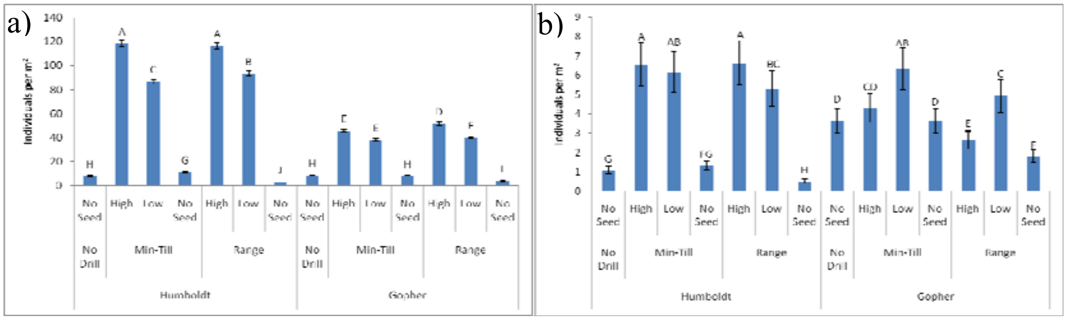


Fig 1. Density of all seeded species in 2007 (a) and 2009 (b).

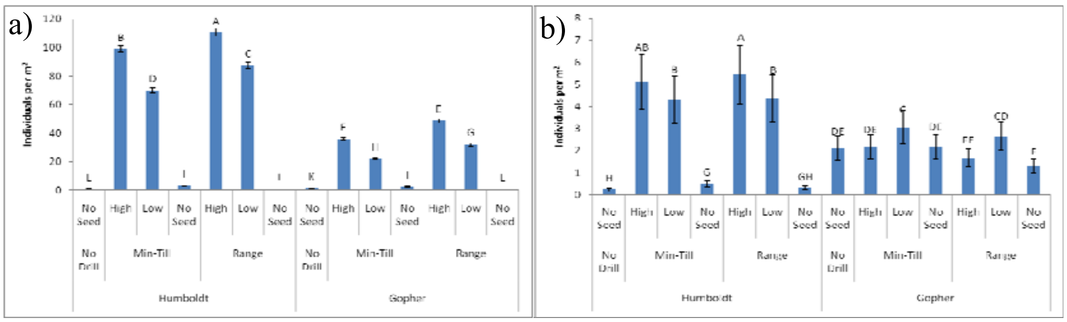


Fig 2. Density of drill-seeded species in 2007 (a) and 2008 (b).

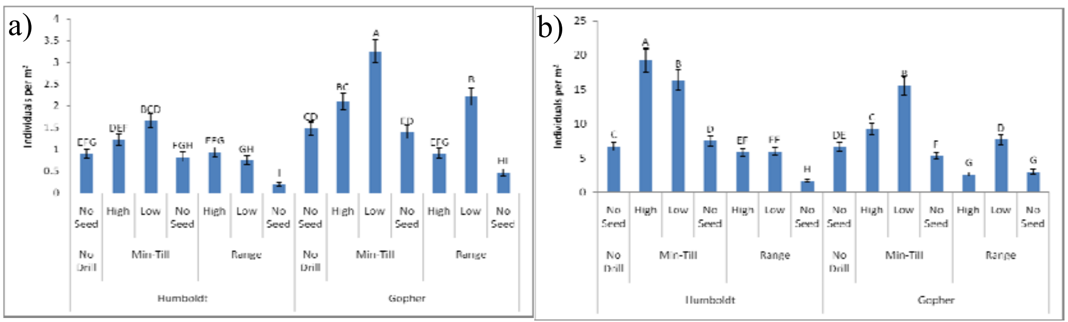


Fig 3. Density of broadcast-seeded species in 2007 (a) and 2008 (b).

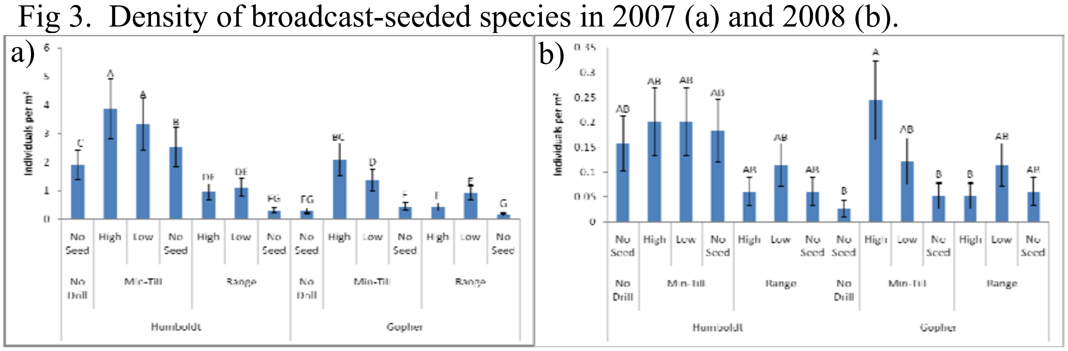


Fig 4. Density of Wyoming big sagebrush in 2007 (a) and 2008 (b).

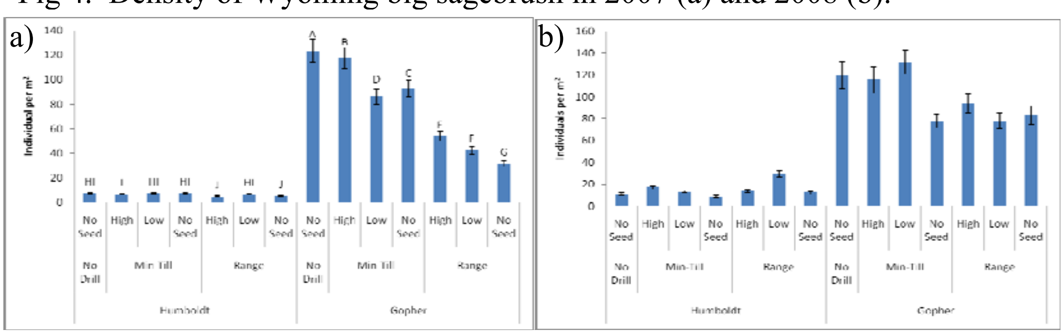


Fig 5. Density of cheatgrass in 2007 (a) and 2008 (b).

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

Products:
Products expected from this project include equipment development and modification, field tours for managers and practitioners, fact sheets and brochures, and likely publication in an agency or journal venue.

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

Additional Cooperators:

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.

Project Description:
Objectives and Methods
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.

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.

2008 Activities
Data collection for plots established in 2007 occurred from May 19-30, 2008 for plots located at the Glass Butte study site, near Burns, Oregon, and from June 2-5, 2008 for plots located at the Mountain Home study site. 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. Within each plot, five 30m transects were established, perpendicular to the drill rows, in each plot. On each transect, the density of all seeded species, plus cheatgrass and any native perennial species, were observed and recorded in four $0.5m^2$ quadrats; species richness was also recorded by noting all unique species in each quadrat. Line-point intercept data was collected along each transect, by placing a point every 1m from a random starting point between 5.0 and 5.9m along the transect (for a total of 20 points per transect, 100 total points per plot). Finally, basal gap intercept data was collected along the same transects by recording the length of all gaps longer than 20cm between perennial plant species, beginning at the 5m mark and continuing until the 25m mark. Data collection involved up to10 field workers, and required 3 weeks to complete both sites. In November 2008, an additional site was seeded on a burned site west of Snowville in northern Utah.

Future Plans:
Data will be collected from Oregon, Idaho, and Utah field plots in late May and early June 2009, and from Utah plots in 2010. A final set of plots will be established in fall 2009, with data collection for those plots occurring in late spring 2010 and 2011.

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 equipment development and modification, field tours for managers and practitioners, fact sheets and brochures, a website to facilitate public access of the project and its information, and likely publication in an agency or journal venue.

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

Collaborator:

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

Project Description:
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. Much of the filming has been completed and the script is being developed.

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

Additional Collaborator:

Robert Karrfalt, USFS National Seed Laboratory, Dry Branch, GA

Project Description:
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 (approx. 1.5grams each) from 5 different wild locations in the Great Basin. Seeds from each source were be stored at 2 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 3 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>2008 Activities</u>
In 2008, seedlots at each storage condition were tested for germination viability in Feb, May, and November (9, 12, and 18 months, respectively). Along with germination tests of each seedlot, temperature, moisture content, and packaging type combination, moisture content has also been tested and recorded.

Future Plans:
Germination and moisture tests of each seed packet will continue every 9 months for the remainder of the study (approximately 4 years, or until viability reaches zero).

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.

VI. Hydrothermal Germination Time for Wyoming Big Sagebrush

Additional Collaborator:

Stuart Hardegree, USDA ARS Northwest Watershed Research Center, Boise, ID

Project Description:

Objectives and Methods

This study attempts to determine germination and time to germination for Wyoming big sagebrush at a range of temperature and water potential combinations. Such information will allow restoration practitioners and land managers to more effectively predict the outcome of restoration seedings.

This study was established at the USDA-ARS Northwest Watershed Research Center, in the array of temperature-controlled germination chambers built by Dr. Stuart Hardegree. Five seedlots of Wyoming big sagebrush, collected from wildland populations, were tested over a range of 11 temperatures (3, 6, 9, 12, 15, 18, 21, 24, 27, 30, and 33^{o}C) and seven water potential (-0.33, -0.1, -0.4, -0.7, -1.0, -1.3, -1.6) combinations, and the total germination at each temperature/water potential combination was recorded daily until germination was essentially complete to provide comparisons of germination and germination rate. Individual germination tests occurred in lots of 30 seeds, and were conducted in the adjustable water potential vial apparatus already used for several other studies by Dr. Hardegree.

2008 Activities and Results

Seeds were counted in summer 2008 and seeds were placed in vials and germination chambers in late summer and fall 2008.

Future Plans:

Data analysis for this study is currently underway; full results and conclusions will be published in appropriate agency or scientific journal venues.

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 germinates under differing temperature and moisture conditions. This information may be used to better predict response of seed to seedbed environments.

Products:

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

Publications:

Karrfalt, R.; Shaw, N.L. Ten steps to a successful native plant materials program (submitted to Native Plant Journal).

Meyer, S.E.; Booth, D.T.; Shaw, N.L. 2008. *Purshia* DC. Ex Poir. bitterbrush, cliffrose, p. 916-921. In: F.T. Bonner and R.P. Karrfalt, eds. Woody Plant Seed Manual. Agricultural Handbook 727. Washington, DC: U.S. Department of Agriculture, Forest Service. http://www.nsl.fs.fed.us/nsl_wpsm.html

Rudolf, P.O.; Slabaugh, P.E.; Shaw, N.L. 2008. *Syringa* L. lilac, p. 1083-1086. In: F.T. Bonner and R.P. Karrfalt, eds. Woody Plant Seed Manual. Agricultural Handbook 727. Washington, DC: U.S. Department of Agriculture, Forest Service. http://www.nsl.fs.fed.us/nsl_wpsm.html

Scholten, M., Donahue, J., Shaw, N.L., Serpe, M.D. in press. Environmental regulation of dormancy loss in *Lomatium dissectum* (Apiaceae) seeds. Annals of Botany.

Shaw, N.L.; Haferkamp, M.R.; Hurd, E.G. 2008. *Grayia spinosa* (Hook.) Moq. spiny hopsage, p. 567-572. In: F.T. Bonner and R.P. Karrfalt, eds. Woody Plant Seed Manual. Agricultural Handbook 727. Washington, DC: U.S. Department of Agriculture, Forest Service. http://www.nsl.fs.fed.us/nsl_wpsm.html

Shaw, N. L.; Hild, A. L.; Kinter, L. *Chondrilla juncea* L.: 2008. Post-fire invasiveness in *Artemisia tridentata* communities of western North America, p. 808. In: Organizing Committee of 2008 IGC/IRC Conference, eds. Multifunctional grasslands in a changing world. Guangdong People's Publishing House, Beijing, China.

Shaw, N.L.; Hurd, E.G. 2008. *Chamaebatiaria millefolium* (Torr.) Maxim. fernbush, p. 387-390. In: F.T. Bonner and R.P. Karrfalt, eds. Woody Plant Seed Manual. Agricultural Handbook 727. Washington, DC: U.S. Department of Agriculture, Forest Service. http://www.nsl.fs.fed.us/nsl_wpsm.html

Shaw, N.L.; Hurd, E.G.; Stickney, P.F. 2008. *Holodiscus* (K. Koch) Maxim. ocean-spray, p. 592-594. In: F.T. Bonner and R.P. Karrfalt, eds. Woody Plant Seed Manual. Agricultural Handbook 727. Washington, DC: U.S. Department of Agriculture, Forest Service. http://www.nsl.fs.fed.us/nsl_wpsm.html

Shaw, N.L.; Hurd, E.G.; Stickney, P.F. 2008. *Philadelphus* L. mock orange, p. 786-789. In: F.T. Bonner and R.P. Karrfalt, eds. Woody Plant Seed Manual. Agricultural Handbook 727. Washington, DC: U.S. Department of Agriculture, Forest Service. http://www.nsl.fs.fed.us/nsl_wpsm.html

Shaw, N.L.; Pellant, M.; Olwell, M.; Jensen, S. 2008. Native plant development and restoration program for the Great Basin, USA, p. 454. In: Organizing Committee of 2008 IGC/IRC Conference, eds. Multifunctional grasslands in a changing world. Guangdong People's Publishing House, Beijing, China.

Shaw, N.L.; Pendleton, R.L.; Hurd, E.G. 2008. *Zuckia brandegei* (Gray) Welsh & Stutz ex Welsh siltbush, p. 1185-1189. In: F.T. Bonner and R.P. Karrfalt, eds. Woody Plant Seed Manual. Agricultural Handbook 727. Washington, DC: U.S. Department of Agriculture, Forest Service. http://www.nsl.fs.fed.us/nsl_wpsm.html

Slabaugh, P.E.; Shaw, N.L. 2008. *Cotoneaster* Medik. cotoneaster, p. 442-446. In: F.T. Bonner and R.P. Karrfalt, eds. Woody Plant Seed Manual. Agricultural Handbook 727. Washington, DC: U.S. Department of Agriculture, Forest Service. http://www.nsl.fs.fed.us/nsl_wpsm.html

Presentations and Abstracts:

Cox, R.D., Shaw, N.L., Pellant, M. Reestablishing diverse native Wyoming Big Sagebrush communities: a comparison of seeding equipment. Society for Range Management/American Forage and Grassland Council, 2008 Joint Annual Meeting, 2008 January 26-31. Louisville, KY. Abstract.

Cox, R.D., N.L. Shaw, M. Pellant, D. Pyke, L. St. John, D. Ogle, S. Perkins, J. Truax. Seed and seeding technologies for reestablishing Wyoming big sagebrush in diverse seed mixes. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2008 February 13-14, Salt Lake City, Utah.

Johnson, R.C., N. Shaw, M. Cashman, B. Hellier, B. St. Clair. Adapted germplasm for the Great Basin: taper-tip onion, Indian ricegrass, bluebunch wheatgrass and friends. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2008 February 13-14, Salt Lake City, UT.

Parkinson, H.A., N.L. Shaw, C.A. Zabinski. Seeding Great Basin forbs: assessing the effects of grass competition Society for Range Management/American Forage and Grassland Council, 2008 Joint Annual Meeting, 2008 January 26-31, Louisville, KY. Abstract.

Shaw, N. Development of native plants for the Great Basin. 2008 March, 17-18, USDI BLM Wenatchee District Office, Wenatchee, WA. Also attended field tour to visit a local seed grower and nurseryman.

Shaw, N. GBNPSIP Update. Idaho BLM Annual Wildlife and Botany Meeting, Feb. 21, 2008, Boise, ID.

Shaw, N. Native plants for the Great Basin. Animal Science and Technical College, 2008 July, China Agricultural University, Beijing, China.

Shaw, N., R. Cox, N. Williams, K. Sherich, J. Gurr, M. Fisk, H. Wiedemann, J. Truax, H. P., C. Zabinski, M. Scholten, M. Serpe, J. Muscha, M. Haferkamp, L. Vemeire. Native forbs – selection, species interactions and seedbed ecology. Great Basin Native Plant Selection and Increase Project Annual Meeting, 2008 February 13-14, Salt Lake City, Utah.

Shaw, N.L. A collaborative science-based program to provide native plant materials and restoration. Its about the land – Success in BLM Partnerships. Society for Range Management/American Forage and Grassland Council, 2008 Joint Annual Meeting, 2008 January 26-31, Louisville, KY. Abstract.

Shaw, N.L., A.L. Hild, L. Kinter. *Chondrilla juncea* L. Post-fire invasiveness in *Artemisia tridentata* communities of western North America. 29 June 2008 – 6 July 2008, XXI International Grassland Congress/ VIII International Rangeland Congress, Hohhot, Inner Mongolia, China. Abstract.

Shaw, N.L., M. Pellant, P. Olwell, S. Jensen, E.D. McArthur**.** Native plant development and restoration program for the Great Basin, USA. 29 June 2008 – 6 July 2008, XXI International Grassland Congress/ VIII International Rangeland Congress, Hohhot, Inner Mongolia, China. Abstract.

Shaw, N.L., R. Cox, M. Pellant. Native plants and seeding methods for the Great Basin. Restoration and rehabilitation of grazing lands. Society for Range Management/American Forage and Grassland Council, 2008 Joint Annual Meeting, 2008 January 26-31, Louisville, KY. Abstract.

Websites:

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

Equipment and strategies to enhance the post-wildfire establishment and persistence of Great Basin native plants
http://www.fs.fed.us/rm/boise/research/shrub/fire.shtml
Maintained by Amy Ganguli and Kelsey Sherich

Revegetation Technology and Equipment Council
http://rtec.rangelands.org/index.htm
Maintained by Amy Ganguli and Kelsey Sherich

Reports, Taskorders Agreements, Contracts:

Great Basin Native Plant Selection and Increase Project FY07 Progress Report. 2008. USDA Forest Service, Rocky Mountain Research Station, Boise, ID and Cooperators. 177 p.

Nevada Native Plant Development Project, Agreement No. DAI 010013. FY07 Progress Report. 2008. USDA Forest Service, Rocky Mountain Research Station, Boise, ID and Cooperators. 14 p.

Great Basin Native Plant Selection and Increase Project Progress Report 2001-2007 and Species Status Summary. 2008. USDA Forest Service, Rocky Mountain Research Station, Boise, ID and Cooperators. 56 p. (Prepared for the USDI BLM Native Plant Materials Program Report to Congress).

Great Basin Native Plant Selection and Increase Project Taskorder FY08. 2008. USDA Forest Service, Rocky Mountain Research Station, Boise, ID. 12 p. (Prepared for the USDI BLM Great Basin Restoration Initiative Coordinator).

Seventeen agreements or amendments, two interagency agreements and one contract were implemented in 2008.

Grant Proposals Leveraged by GBNPSIP Projects:

Shaw, N.; Erickson, Vicky; Pellant, Mike. 2008. Calibration of drills for rehabilitation and restoration seedings on western wildlands. USDA Forest Service, Missoula Technology and Development Center (MTDC). 2400 9E92E89 Drill calibration video training. Leader: Lisa Outka-Perkins, MTDC, Missoula, MT. Status: Completion expected by September 2009.

Shaw, N. 2008. GPS applications for monitoring drill seedings. USDA Forest Service, Missoula Technology and Development Center. 2008. 2200 9E92D87 GPS Rangeland drill monitor. Leader: Gary Kees, MTDC, Missoula, MT. National goal 7: Provide Science-based Applications and Tools for Sustainable Natural Resources Management.

Meetings, Field Tours, Workshops:

Annual Great Basin Native Plant Selection and Increase Project meeting, February 13-14, 2008, Salt Lake City, UT. Organized by Utah Division of Wildlife Resources and USDA Forest Service, Rocky Mountain Research Station, Boise, ID.

Seed Collection Workshop. Duck Valley Tribes (Shoshone – Paiute), July 16, 2008. Organized by USDI Bureau of Land Management, Idaho State Office, Idaho Department of Fish and Game and the USDA Forest Service, Rocky Mountain Research Station, Boise, ID (Matt Fisk).

Media Releases, Popular Articles:

Pat McCoy. 22 March 2008. Restoration projects call for native plants. Capitol Press, Salem, Oregon.

Rush Skeletonweed in the Great Basin. http://www.fs.fed.us/rm/boise/research/shrub/projects/documents/shaw_rust_tech_transfer110107.pdf

Wells, Gail. 2008. Big Changes in the Great Basin. Fire Digest. National Interagency Fire Center, Joint Fire Sciences Program. 11 p.

McKnight, Laurie. April 2008. Challenging cheatgrass. RMRScience. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO. 5 p.

Natural doesn’t come easy. 23 May 2008. Capitol Press, Salem, Oregon.

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

Project Location: Department of Biology, Boise State University

Principal Investigator and Contact Information:

Marcelo Serpe, Ph.D., Associate Professor
Department of Biology
Boise State University
Boise, ID 83725-1515
208.426.3687, fax: 208.426.4267
mserpe@boisestate.edu

Project Description:

Objective 1

To analyze the effect of longer periods of cold stratification on seed germination and characterization of the stratification requirements of different seed populations.

We have analyzed the stratification requirements of eight populations of *Lomatium dissectum*. For this purpose, we collected seeds from four populations of *L. dissectum var. dissectum* and four populations of *L. dissectum var. multifidum*. Our results indicate that all populations require long periods of cold stratification to germinate. However, there were differences in the cold stratification requirements of the various populations. Seeds of *L. disssectum var. multifidum* from the intermediate elevations (1287, 1347, and 1700m) began to germinate after 8 weeks (Fig. 1a). In contrast, seeds from Moore's Mountain (2200m) and seeds of *L. dissectum var. dissectum* began to germinate after 10 weeks. The mean germination time (MGT) for seeds of *L. dissectum var. multifidum* collected at intermediate elevations were between 10.5 and 11 weeks, which were significantly shorter than those of *L. dissectum var. dissectum* seeds (14.4 to 16 weeks) (Fig. 1b). The seeds collected at the highest elevation (2200m) had an intermediate MGT of about 13 weeks (Fig. 1b). The longer germination time of *L. dissectum var. dissectum* seeds did not appear to be attributed to a negative effect of cold temperatures on germination. Seeds of *L. dissectum var. dissectum* collected at Adair 1 and Adair 2 were placed at 4°C for 12 weeks and then some seeds were kept at this temperature while others were exposed to a daily (12/12 h) alternating temperature regimen of 5/15°C. The seeds exposed to the alternating temperatures showed much lower germination than those maintained at a constant temperatures of 4°C (Fig. 1c).

In general, the above results indicate that seeds collected from moist habitats have longer cold stratification requirements that those from semiarid environments. 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 extend the growth period allowing the seedlings to photosynthesize and accumulate reserves until the dry summer. On the other hand, variety dissectum seeds were from sites where temperature and precipitation allow plant growth through most of the spring and summer. Under these conditions, early germination is not so critical for seedling survival.

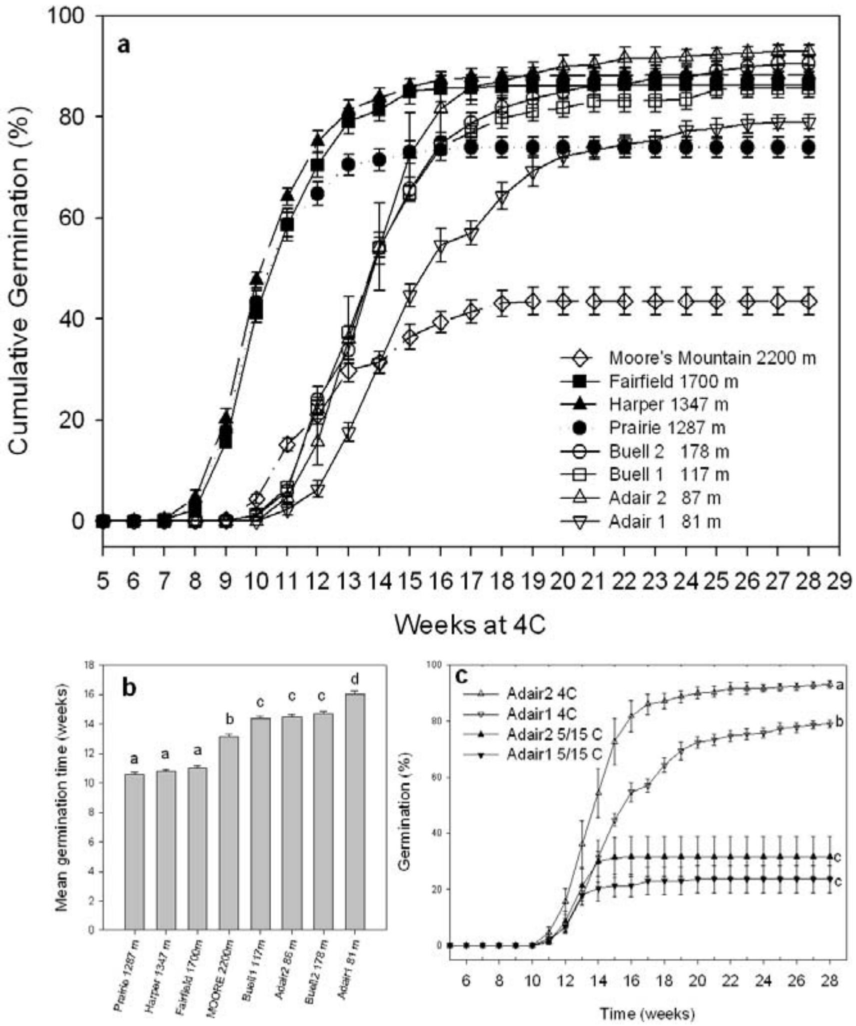


Figure 1. Germination of *Lomatium dissectum* seeds collected at different sites.
a, Germination time courses.
b, Mean germination time.
c, Comparison of the effect of changing the incubation temperature; after 12 weeks at 4°C some seeds were maintained at this temperature while others were exposed to a 12/12 h alternating temperature regimen of 5/15°C. *Lomatium dissectum* var. *dissectum* seeds were collected at Adair 1, Adair 2, Buell 1, and Buell 2. *Lomatium dissectum* var. *multifidum* were collected at Prairie, Harper, Fairfield, Moore's Mountain. Mean (± SE) of five to ten replications with 60 seeds per replication. In b and c, means not labeled with the same letter are significantly different ($p < 0.05$)

<u>Objective 2</u>
To analyze of the effects of fluctuations in temperature on seed germination.

We have stratified seeds at 4°C for 8 weeks and subsequently transferred them to growth chambers that provided the following diurnal temperature fluctuations: 17.5/12.5, 20/10 or 15/5°C. These treatments resulted in much lower germination than that of seeds kept constantly at 4°C (cf. fig. 1c).

The fluctuations that we tested were at temperatures that appear to inhibit germination. Based on additional experiments, we determined that the optimum temperatures for germination of *L. dissectum* range between 3 and 5°C (Fig. 2). Perhaps, smaller oscillations in temperature within the range permissive for embryo growth and germination may reduce the cold stratification period.

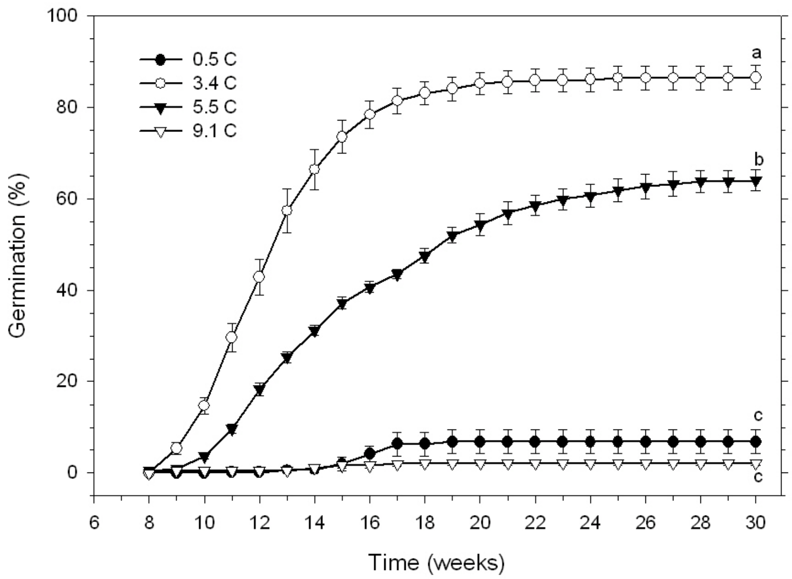


Figure 2. Effect of different stratification temperatures on germination of *Lomatium dissectum* seeds. The seeds were left to germinate at the same temperatures used for cold stratification. Mean (±SE) of ten replications with 60 seeds per replication. Means not labeled with the same letter are significantly different ($p < 0.05$).

Objective 3

To determine the effects of plant growth regulators on seed germination.

Attempts were made to reduce the period of cold stratification using plant growth regulators. Gibberellic acid (GA3) in particular can replace the cold stratification requirement of some seeds. This, however, was not the case for *L. dissectum*. We tested four concentration of GA3 (0, 0.03, 0.3 and 3mM) at two temperatures (4 and 12°C). Embryo growth was significantly higher at 4 than at 12° C and GA3 did not substitute the requirement for low temperatures. At 12°C, embryo elongation was minimal and no significant differences were observed between seeds incubated in water and those incubated in GA3 solutions (Fig. 3). Gibberellic acid did not promote embryo growth at 4°C; the elongation of the embryo was similar in water and in 0.03 and 0.3mM GA3, while 3mM GA3 significantly inhibited embryo growth (Fig. 3). Furthermore, at 4°C most of the seeds germinated after 10 to 12 weeks except for those incubated in 3mM GA3 (data not shown). In contrast, no germination was observed in seeds incubated at 12°C. The observation that GA3 does not replace the cold stratification requirements indicates that *L. dissectum* seeds have complex morphophysiological dormancy.

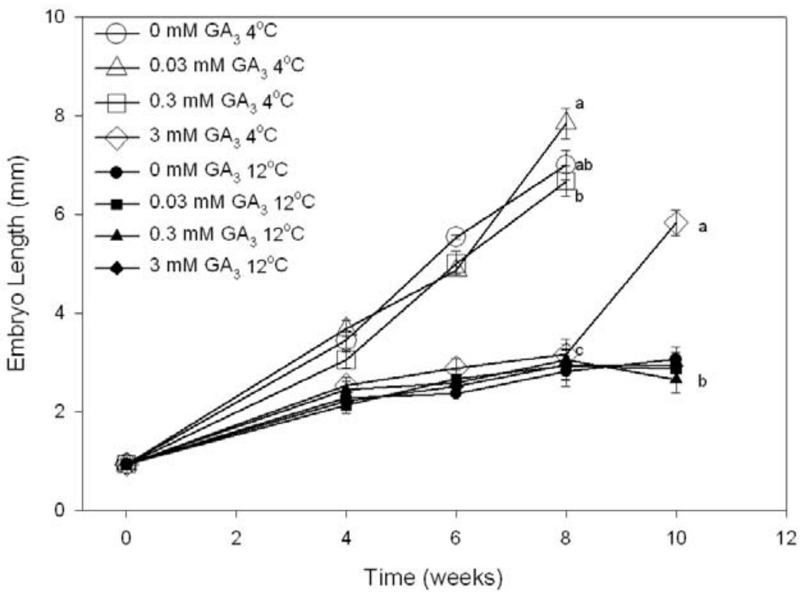


Figure 3. Embryo elongation in *Lomatium dissectum* seeds incubated at 4 or 12°C in various concentrations of GA3. Means (±SE) of four replications with ten embryos per replication. For a particular week, means not labeled with the same letter are significantly different ($p < 0.05$).

We also investigated the effect of GA3 in combination with kinetin on embryo growth at 4°C. None of the treatments tested significantly improved embryo growth with respect to seeds incubated with water (Table 1).

Kinetin (µM)	GA3 (µM)	Embryo length (mm)
0	0	5.9± 1.3
50	0	4.7 ± 1.6
100	0	5.1 ± 2.1
0	250	5.2 ± 1.8
50	250	5.9 ± 2.0
100	250	6.5 ± 2.4
0	500	6.1 ± 1.8
50	500	6.0 ± 2.3
100	500	5.9 ± 1.9
0	1000	5.0 ± 1.8
50	1000	6.4 ± 2..6
100	1000	5.1 ± 1.8

Table 1. Effect of GA3 and kinetin on embryo growth of *L. dissectum* at 4°C. Embryo length was measured after 10 week of incubation. Means (± SD) of three replications with 10 embryos per replication.

Presentation:

Donahue J, Scholten M, Shaw NL, Smith JF, Serpe M (2008) Differences in cold stratification requirements among populations of *Lomatium dissectum* seeds. Presented at the annual meeting of the Botanical Society of America.

Publication:

Scholten M, Donahue J, Shaw NL, Serpe MD. 2009. Environmental regulation of dormancy loss in seeds of *Lomatium dissectum* (Apiaceae). Annals of Botany 103:1091-1101.

Project Title: Revegetation Equipment Catalog

Project Location: Texas Tech University, Lubbock, TX

Principal Investigators and Contact Information:

Robert Cox
Department of Natural Resources Management
Texas Tech University
Box 42125
Lubbock, TX 79409
806.742.1983, fax: 806.742.2280
Robert.Cox@ttu.edu

Project Description:

Objectives and Methods
The purpose of this project is to provide a web-based catalog of descriptions and sources of equipment items used in rangeland restoration. This will be a centralized source of information on equipment used for all aspects of rangeland restoration. The website, currently hosted at Texas A&M University (TAMU), will be migrated to Texas Tech University (TTU) and maintained, updated and expanded. This will improve the access of revegetation specialists to information on commercially available equipment for accomplishing a wide variety of revegetation goals.

2008 Activities
The Catalog was updated and maintained by Mr. Harold Weidemann (TAMU) until his passing in October, 2008. Robert Cox (TTU) has agreed to manage the catalog in the future.

Future Plans:
The Catalog will me migrated to a TTU address. Robert Cox will also update and maintain the catalog.

Management Applications:
Various agency personnel, private land managers and revegetation/restoration practitioners will have easy access to information about commercially available revegetation equipment.

Products:
Products expected from this project include the online Revegetation Catalog itself, as well as various brochures and presentations, including trade shows.

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:

Lisa Outka-Perkins
USDA Forest Service
Missoula Technology and Development Center
Missoula, MT 59804
406.329.3849, fax: 406.329.4811
loutka-perkins@fs.fed.us

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.

Filming for the video was conducted at the USDI Bureau of Land Management Vale Equipment Shop and at the Oregon State University Malheur Experiment Station. Completion of the project is expected by September 2009. A shorter version of the video may be linked to the Revegetation Equipment Catalog.