NOTICE OF RELEASE OF

FANNY GERMPLASM, CARMEL GERMPLASM, AND BONNEVILLE GERMPLASM SEARLS' PRAIRIE CLOVER

SELECTED CLASS OF NATURAL GERMPLASM

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Flower spike of Searls' prairie clover being pollinated by a honey bee. Photo by Derek Tilley

ABSTRACT

Three natural-track selected germplasms of Searls' prairie clover (*Dalea searlsiae* (A. Gray) Barneby [Fabaceae]) have been released by the USDA's Agricultural Research Service (ARS) for use in revegetation and restoration of semiarid rangelands in the western US. Searls' prairie clover is a perennial leguminous forb that is native to Utah, Nevada, Arizona, and California. Data from common-garden and DNA-marker studies were used to develop and document these releases. The ARS Forage and Range Research Laboratory was asked by the USDI Bureau of Land Management (BLM) and Colorado Plateau land managers to identify genetically similar collections within geographical regions and to subsequently release germplasms of Searls' prairie clover for the Great Basin (Fanny germplasm) and Colorado Plateau (Carmel germplasm). In addition, several collections originating from near the Great Salt Lake in northwestern Utah were genetically distinct from Fanny and Carmel germplasms. Thus, Bonneville germplasm was identified to represent this distinct genetic group. This species is new to the commercial seed trade, and these are the first releases of this species for rangeland improvement.

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KEY WORDS
Dalea searlsiae, Fabaceae, rangeland, revegetation, restoration, Great Basin, Colorado Plateau, legume, native pollinators

NOMENCLATURE
Plants: USDA NRCS (2015a)
Animals: ITIS (2015)

CONVERSIONS
m × 3.3 = ft
cm × 0.4 = in
mm × 0.04 = in
g × 0.0353 = oz
(°C × 1.8) + 32 = °F

Species: *Dalea searlsiae* (A. Gray) Barneby
Common name: Searls' prairie clover
Plant symbol: DASE3
Accession number: Fanny Germplasm (Ds-26 or Patterson Pass or PP Population), Carmel Germplasm (Ds-14 or Mount Carmel or MC Population), and Bonneville Germplasm (Ds-23 or Elephant Knoll or EK Population).

Fanny germplasm, Bonneville germplasm, and Carmel germplasm were approved for release by the USDA Agricultural Research Service on 1 June 2015. All 3 releases are natural-track selected class pre-variety germplasms.

JUSTIFICATION

Rangeland ecosystems in the western US are increasingly vulnerable to wildland fires, weed invasion, human-caused disturbances, and soil erosion (Pierson and others 2011). Although some of these problems on rangelands can be solved by improved management, many rangeland ecosystems suffer from long-term reductions in biodiversity, altered nutrient and water cycling, diminished forage production for livestock and wildlife, increased frequency of wildfires, and increased soil erosion and stream sedimentation (Sheley and others 2008). Without human intervention, a large portion of these degraded rangelands may not recover. As a result, revegetation/restoration is required to improve degraded conditions, aid recovery, and reduce risks of further erosion and degradation. Many land managers prefer a diverse mix of plant species for revegetating rangelands because functionally diverse plant species may minimize the risk of weed invasion and increase ecosystem function (Pokorny and others 2005; Sheley and Carpinelli 2005; Walker and Shaw 2005).

Legumes are of particular value for revegetation/restoration because they fix nitrogen; enhance forage quality; and provide food sources for grazing animals, pollinators, and wildlife, including sage grouse (*Centrocercus* Swainson [Phasianidae]) (Cherney and Allen 1995; Madison and Robel 2001; Aydin and Uzun 2005; Walker and Shaw 2005). They can enhance nitrogen and carbon pools and carbon and nutrient fluxes (Liao and others 2008), and they may be able to occupy available niches that would otherwise be colonized by invasive weeds (Pfisterer and others 2004; Walker and Shaw 2005; Brown and others 2008). Legumes are also beneficial for maintaining and restoring natural successional trajectories while providing important ecosystem services (Richards and others 1998; Hobbs and Harris 2001). Some legumes contain compounds such as condensed tannins, which can have beneficial effects on ruminant productivity through improved protein supply, greater nitrogen-use efficiency, reduced bloat risk, and decreased parasite activity (Haring and others 2008).

Seed of North American legumes often is not commercially available for revegetation/restoration projects and (or) is extremely expensive. As a result, the need is critical to identify and develop North American legumes that can be used for rangeland revegetation/restoration and have potential for commercial seed production. Improvements in seed production can lower seed cost and make them more affordable for revegetation/restoration projects on semiarid rangelands of the western US.

Dalea L. (prairie clover [Fabaceae]) is a genus with 161 species distributed throughout North and South America, from southwestern Canada through Central America and the Caribbean southward to Argentina (Barneby 1977). The center of diversity for this species occurs in Mexico with 115 species, while 62 species are widely distributed in the US and Canada (USDA NRCS 2015a). *Dalea searlsiae* (A. Gray) Barneby (Searls' prairie clover) is a perennial herbaceous legume within this genus that naturally occurs in southern Nevada, northwestern and southern Utah, southeastern California, and northern Arizona. It is distributed in the Central Basin and Range, Colorado Plateau, Arizona Plateau, and Mojave Basin and Range Level III Ecoregions (Omernik 1987; US EPA 2013). The species was named after Fanny Searls who first collected the species near the Pahranagat Mines in southeastern Nevada in 1871 (Tiehm 1985).

Little research has been conducted with Searls' prairie clover. Bhattarai and others (2011) characterized the phenotypic and genotypic variation in 20 collections of this species throughout its Great Basin and Colorado Plateau distribution. They evaluated these collections for a wide range of phenotypic characteristics in common-garden plots in northern Utah and characterized their genetic differences using DNA-marker fingerprinting. Cane and others (2012) studied the breeding biology and pollinators of this species and found that it is primarily an insect-pollinated forb. Searls' prairie clover does not contain significant levels of swainsonine, selenium, or

Seed increase field of Searls' prairie clover near Logan, Utah. Photo by Kevin Connors

nitrotoxins that are known to be toxic to livestock (Douglas A Johnson, unpublished data).

Plant collections can be grouped into geographically based metapopulations to balance concerns of genetic identity, ecological adaptation, and economic seed production. Boundaries of natural metapopulations have been identified for several rangeland plant species from the western US (Larson and others 2004; Bushman and others 2007; Jones and others 2008; Phillips and others 2008). Common-garden studies can be used to evaluate collections for their adaptive and economic traits as well as to compare collections for their genetic and phenotypic trait variation and potential for local adaptation (McKay and others 2005). DNA markers can also be used to estimate variation within collections, infer gene flow barriers by identifying genetically differentiated groups, test for isolation by distance, and estimate correlations with phenotypic variation.

These common-garden and DNA fingerprinting procedures were used previously to formulate germplasm releases for 2 North American legume species, namely *Astragalus filipes* Torr. ex A. Gray (Fabaceae; basalt milkvetch) (Bhattarai and others 2008; Johnson and others 2008; Bushman and others 2010) and *Dalea ornata* (Douglas ex Hook.) Eaton & J. Wright (western prairie clover) (Bhattarai and others 2010). We employed this approach to formulate pre-variety germplasm releases of Searls' prairie clover.

COLLECTION SITE INFORMATION

Twenty collections of Searls' prairie clover were made in the summer of 2005 (Table 1). The parental population of Fanny germplasm originates from Patterson Pass in east-central Nevada (collection Ds-26); the parental population of Carmel germplasm originates in south-central Utah (collection Ds-14); and the parental population of Bonneville germplasm originates in northwestern Utah near the Nevada border (collection Ds-23).

Average annual precipitation at the Fanny germplasm site is approximately 321 mm and elevation is about 2050 m, with the site identified as being in plant hardiness zone 5b and in heat zone 5 (Tables 1 and 2). This site is classified by the USDA Natural Resources Conservation Service (NRCS) as Major Land Resource Area 28a (Great Salt Lake Area), by the USDA Forest Service (USFS) as Province M341 (Nevada-Utah Mountains Semi-Desert Coniferous Forest-Alpine Meadow Province), and by the Environmental Protection Agency (EPA) as Level III Ecoregion 13 (Central Basin and Range). Average annual precipitation at the Carmel germplasm site is approximately 347 mm and elevation is about 1695 m, with the site identified as being in plant hardiness zone 7a and in heat zone 7. The Carmel germplasm site is classified by the NRCS as Major Land Resource Area 35 (Colorado Plateau), by the USFS as Province 313 (Colorado Plateau Semi-Desert Province), and by the EPA as Level III Ecoregion 20 (Colorado Plateaus).

The Bonneville germplasm site is a considerably drier, lower elevation site than the Fanny and Carmel germplasm sites, with an average annual precipitation of approximately 178 mm and elevation of about 1400 m. The site is identified as being in plant hardiness zone 6b and heat zone 7. The Bonneville germplasm site is classified by the NRCS as Major Land Resource Area 28a (Great Salt Lake Area), by the USFS as Province 341 (Intermountain Semi-Desert and Desert Province), and by the EPA as Level III Ecoregion 13 (Central Basin and Range).

Soil at the Fanny germplasm site (Ds-26) is classified as a coarse-loamy, mixed, superactive, mesic, Torrifluoventic Haploxerolls (soil map unit 4002, Jarab-Ravendog Association, 2 to 8% east slope) (USDA NRCS 2015b). Soil at the Bonneville germplasm site (Ds-23) is classified as a mixed, mesic, Typic Torripsamments (soil map unit: 74, Jenrab-Badlands Complex, 2 to 15% east slope). The soil at the Carmel germplasm site (Ds-14) has not been classified.

DESCRIPTION

Dalea L. is separated from other genera in the Amorpheae tribe of Fabaceae by its base chromosome number of $x = 7$ (rarely 8) and 2 collateral ovules (Barneby 1977). Searls' prairie clover is a tap-rooted, perennial, and herbaceous plant that reaches a height of 25 to 61 cm. A cluster of stems arises from a woody crown and the stems die during winter. Compound leaves are alternate and odd-pinnate and comprise 5 or 7 oval-shaped leaflets. Flower stalks bear dense clusters of beautiful small pink- to purple-colored flowers with 5 petals that occur in dense, cylindrical-shaped spikes. Flowers bloom upward from the base of the spike to the tip during a 3-wk period (approximately)

TABLE 1

Site information for 20 collections of Searls' prairie clover.

Collection	County, State	Latitude (N)	Longitude (W)	Elevation (m)	Mean annual temperature[z] (°C)	Mean annual precipitation[z] (mm)
Ds-01	Garfield, UT	37.766667	111.416667	1604	11.3	197
Ds-03	Lincoln, NV	37.883333	114.316667	1614	10.2	255
Ds-05	Nye, NV	38.7	115.416667	1695	9.0	214
Ds-07	Nye, NV	38.05	115.866667	1890	9.0	238
Ds-08	Lincoln, NV	37.716667	114.083333	1796	8.9	291
Ds-09	Nye, NV	38.466667	117.133333	2000	8.2	185
Ds-10	Nye, NV	38.683333	117.883333	1646	9.9	152
Ds-11	Mineral, NV	38.6	117.85	1888	8.6	171
Ds-12	Box Elder, UT	41.416667	113.8	1413	8.8	209
Ds-13	Iron, UT	37.6	113.366667	1943	8.3	372
Ds-14[y]	**Kane, UT**	**37.216667**	**112.683333**	**1695**	**10.7**	**347**
Ds-15	Washington, UT	37.6	113.516667	1732	9.5	336
Ds-16	Box Elder, UT	41.466667	113.1	1597	8.3	267
Ds-17	Kane, UT	37.283333	112.6	1749	10.1	343
Ds-18	Lincoln, NV	38.166667	114.583333	1834	9.4	305
Ds-20	Nye, NV	38.4	115.1	1597	9.9	238
Ds-21	Tooele, UT	40.933333	113.683333	1326	10.0	172
Ds-23[x]	**Tooele, UT**	**40.316667**	**113.95**	**1419**	**9.7**	**178**
Ds-25	White Pine, NV	39.1	115.033333	1950	7.2	249
Ds-26[w]	**Lincoln, NV**	**38.583333**	**114.7**	**2036**	**7.6**	**321**

Notes: Information adapted from Bhattarai and others 2011. Each collection comprised seed harvested from a minimum of 100 plants.

[z]Climate data (means from 1961 to 1990) were obtained from the Moscow Forestry Sciences Laboratory, Moscow, Idaho (2009).

[y]Wildland-collected seeds of Ds-14 were used to constitute the G_0 generation for Carmel germplasm.

[x]Wildland-collected seeds of Ds-23 were used to constitute the G_0 generation for Bonneville germplasm.

[w]Wildland-collected seeds of Do-26 were used to constitute the G_0 generation for Fanny germplasm.

TABLE 2

Major Land Resource Area (MLRA), plant hardiness zone, heat zone, USDA Forest Service province, and Level III ecoregion for the 3 Searls' prairie clover germplasms.

Germplasm	Winter hardiness zone	Heat zone	MLRA	Forest Service province	Level III ecoregion
Fanny	5b	5	28a, Great Salt Lake Area	M341, Nevada-Utah Mountains Semi-Desert Coniferous Forest-Alpine Meadow Province	13, Central Basin and Range
Carmel	7a	7	35, Colorado Plateau	313, Colorado Plateau Semi-Desert Province	20, Colorado Plateau
Bonneville	6b	7	28a, Great Salt Lake Area	341, Intermountain Semi-Desert and Desert Province	13, Central Basin and Range

Sources: MLRA (USDA NRCS 2006), plant hardiness (USDA ARS 2012), heat zone (AHS 1997), province (Bailey 1995), ecoregion (US EPA 2013).

Close-up of flower spike of Searls' prairie clover showing progressive flowering pattern beginning at the base of the spike and ending at the tip. Photo by Kevin Connors

in late June and early July. Thus, plants have a somewhat indeterminate flowering habit, where the lower seeds mature and begin to drop when flowers near the tip of the spike are blooming. The plant is primarily insect-pollinated (Cane and others 2012). According to Barneby (1977), although 2 ovules are present in each flower, only 1 seed matures. Consequently, the fruit is a small hairy pod with 1 seed. The relatively upright growth habit of Searls' prairie clover makes it a potential candidate for commercial seed production.

METHOD OF DEVELOPMENT

Details concerning the research materials and methods for development of these germplasms are contained in Bhattarai and others (2011). Therefore, only the general procedures are presented here. The 20 seed collections of Searls' prairie clover obtained in Nevada and Utah (Table 1) had latitudes ranging from 37.22 to 41.247, longitudes ranging from 111.42 to 117.88, and elevations ranging from 1326 to 2036 m above sea level.

Seedlings from each of the collections were grown in a greenhouse, and DNA was extracted from the shoot apical regions of 8 individual plants for each collection prior to field outplanting. Amplified fragment length polymorphism (AFLP) DNA markers were used to estimate the population structure and genetic diversity among the Searls' prairie clover collections. Population structure analyses (Falush and others 2007) were also conducted using these data.

During spring 2006, 2 common-garden sites were established in northern Utah (Hyde Park and Millville) from greenhouse-grown transplants of each collection (Bhattarai and others 2011). The experimental design at each of the field sites was a randomized complete block with 8 replications, and collections were assigned randomly within each replication. Each replication included 5 individual plants of each collection, for a total of 40 plants of each collection at each location. Plants were allowed to establish during 2006, and field data were obtained during 2007 and 2008. Plant characteristics evaluated at the common-garden sites included dry-matter yield, number of stems and inflorescences, plant height, foliage diameter, acid- and neutral-detergent fiber, crude protein, and flowering date. These field data were subjected to analysis of variance using the MIXED procedure of SAS, and principal component analyses were conducted using the FACTOR procedure of SAS (2014; SAS Institute, Cary, North Carolina).

DNA-MARKER DATA SUPPORTING RELEASE

Analysis of molecular variance (AMOVA) (Peakall and Smouse 2012) apportioned 24% ($P < 0.0001$) of the genetic variation among collections and 76% ($P < 0.0001$) of the variation within collections. Based on Bayesian clustering analysis (Falush and others 2007), the AFLP fingerprinting technique identified 2 distinct metapopulations. The first metapopulation included 4 collections from northwestern Utah (Ds-12, Ds-16, Ds-21, and Ds-23), and the second included the remaining 16 collections from southern Utah and Nevada. The percentage of variation apportioned between the 2 metapopulations was 14% ($P < 0.001$), among collections within metapopulations was 17% ($P < 0.001$), and within collections was 69% ($P < 0.001$). The genetic-distance matrix (calculated using AMOVA) (Peakall and Smouse 2012) was highly and positively correlated with a Euclidean geographic distance matrix ($r = 0.77$, $P < 0.001$), even after controlling for the effects of elevation, precipitation, and temperature.

Although the populations were genetically similar, discussions with land managers from the USDI Bureau of Land Management (BLM) and USFS suggested that collections Ds-01, Ds-14, and Ds-17 from the Colorado Plateau Ecoregion (Omernik 1987; US EPA 2013) should be subdivided into a separate group within the second metapopulation because land managers were interested in having separate pre-variety germplasms available for the Great Basin and Colorado Plateau. Thus, the second metapopulation was subdivided based on geographical origin into one germplasm group for the Great Basin and a second group for the Colorado Plateau (Figure 1). As a result, 3 germplasms of Searls' prairie clover are being released: the first for northwestern Utah (Bonneville germplasm), a second for Nevada and southwestern Utah (Fanny germplasm), and a third for the Colorado Plateau (Carmel germplasm).

The 4 collections from northwestern Utah (Ds-12, Ds-16, Ds-21, and Ds-23) exhibited the lowest percentage of polymorphism and had the highest within-collection similarity (or lowest genetic diversity). These 4 collections originated from sites located within the area of ancient Lake Bonneville, and their separation and relative lack of diversity may be attributable to migration when Lake Bonneville receded to the much smaller area covered by the present-day Great Salt Lake (Oviatt 1997).

COMMON-GARDEN DATA SUPPORTING RELEASE

Nine field-performance traits were measured for the 20 collections during 2007 and 2008 at Hyde Park, and 4 traits were measured at Millville (Table 2). Significant variation was detected among the collections for all traits measured (Table 3). Dry matter yields across years for Fanny (161 g/plot) and Carmel (178 g/plot) germplasms were significantly greater ($P < 0.05$) than for Bonneville germplasm (79 g/plot). Fanny germplasm had significantly ($P < 0.05$) more inflorescences per plant (35) than did Bonneville germplasm (16) but was similar to Carmel germplasm (26). Plant height was significantly greater ($P < 0.05$) in Carmel germplasm (39 cm) as compared to Bonneville germplasm (30 cm) but was similar to Fanny germplasm (35 cm). Canopy diameter for Fanny (57 cm) and Carmel (58 cm) germplasms was significantly greater ($P < 0.05$) than for Bonneville germplasm (36 cm). Fanny germplasm flowered 7 d earlier (Day of Year [DOY] 160) than did Bonneville germplasm (DOY 167) and Carmel germplasm (DOY 167). Flowering dates ranged from 8 to 20 June (DOY 160 to 173) in all 3 germplasms. Bonneville germplasm exhibited a higher crude protein concentration (207 g/kg) compared to Fanny (179 g/kg) and Carmel (170 g/kg) germplasms ($P < 0.05$). No observable differences in number of reproductive stems and acid- and neutral-detergent fiber concentrations were detected among Fanny, Carmel, and Bonneville germplasms. Both Fanny and Carmel germplasms were selected for their ability to produce greater amounts of wildland-collected seed.

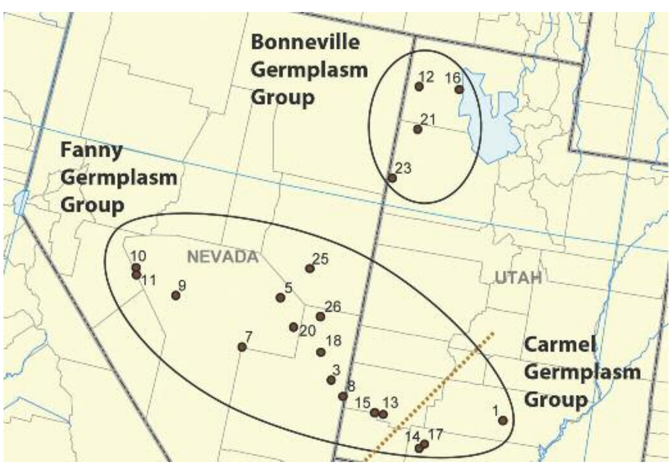

Figure 1. Collection sites of 20 populations of *Dalea searlsiae* with Bonneville germplasm group representing one metapopulation, Fanny germplasm group representing a second metapopulation, and Carmel germplasm group representing collections from the Colorado Plateau Ecoregion within the second metapopulation.

Wildland-collected seeds of Ds-26 were used to constitute the G_0 generation for Fanny germplasm. Wildland-collected seeds of Ds-23 were used to constitute the G_0 generation for Bonneville germplasm. Wildland-collected seeds of Ds-14 were used to constitute the G_0 generation for Carmel germplasm.

SEED GERMINATION AND PRODUCTION

Seeds per kg ranged from 269,000 to 384,000 (122,040 to 174,213 seeds/lb) for wildland-collected seeds of the Searls' prairie clover collections. In an agronomic production environment, the test weight for seed was 301,000 seeds per kg (136,557 seeds/lb) for Fanny germplasm, 250,220 seeds per kg (113,500 seeds/lb) for Carmel germplasm, and 347,000 seeds per kg (157,427 seeds/lb) for Bonneville germplasm.

A large proportion of seed produced by Searls' prairie clover is hard seed (has physical dormancy), which may limit germination. For example, untreated seed of Bonneville germplasm was 84% viable hard seed with only 5% germination (Bushman and others 2015). Mechanical scarification decreased the percentage of hard seed to 20% and increased germination to 74%. Soaking seeds for 5 min in concentrated sulfuric acid decreased the viable hard seeds to 4% and increased germination to 83%. Results from 2 separate greenhouse studies with a variety of sand and clay soil mixtures demonstrated that non-scarified seed of Fanny germplasm had significantly greater ($P < 0.05$) seedling emergence at 49% compared to 32% for Bonneville germplasm, regardless of planting depth (6 or 19 mm). The rate of seedling emergence was significantly greater ($P < 0.05$) for Bonneville than for Fanny germplasm when planted at 19 mm. In both Fanny and Bonneville germplasms, acid and mechanical seed scarification significantly increased ($P < 0.05$) total seedling emergence and the rate of emergence compared to non-scarified seeds.

In field studies reported by Bushman and others (2015), seedling emergence was significantly greater ($P \leq 0.05$) for Fanny (22.5%) as compared to Bonneville germplasm (10.5%) in an early spring seeding with scarified seed at Panguitch, Utah. At Pleasant View, Colorado, seedling emergence was

TABLE 3

Means and differences for dry-matter yield, number of stems and inflorescences, plant height, canopy diameter, acid-detergent fiber, neutral-detergent fiber, crude protein, inflorescence weight, and flowering date of 20 Searls' prairie clover collections at Hyde Park and Millville.

	Hyde Park								Millville			Combined
										Inflorescences		
Collection	Dry-matter yield (g/plot)	Stems (number)	Inflorescences (number)	Plant height (cm)	Canopy diameter (cm)	Acid-detergent fiber (g/kg)	Neutral-detergent fiber (g/kg)	Crude protein (g/kg)	Dry-matter yield (g/plot)	(number)	(g/plot)	Flowering date[z]
Fanny germplasm group												
Ds-26	**160.5**	**11.0**	**35.2**	**35.3**	**56.7**	**365**	**495**	**179**	**120.5**	**46.7**	**61.3**	**160.4**
Ds-03	134.3	10.1	32.9	35.6	50.8	387	485	179	140.0	44.0	57.6	164.0
Ds-05	84.3	8.0	15.3	35.0	40.0	354	482	168	70.4	26.1	20.7	168.0
Ds-07	40.4	6.4	18.2	21.2	35.6	361	464	188	38.0	23.9	22.1	161.6
Ds-08	126.9	10.9	35.5	31.4	59.1	364	478	171	108.8	45.2	49.1	163.1
Ds-09	74.3	9.1	20.4	26.7	49.9	333	402	193	63.1	33.8	32.6	164.4
Ds-10	108.6	11.5	24.6	26.1	51.3	366	456	173	78.0	43.1	33.5	162.2
Ds-11	81.2	9.4	24.1	29.8	45.9	353	476	202	65.2	35.2	27.9	165.7
Ds-13	195.7	10.8	45.0	29.3	54.7	369	481	178	101.0	52.3	65.4	162.8
Ds-15	187.8	11.3	45.9	33.6	54.8	360	453	173	117.2	60.5	82.5	161.9
Ds-18	151.8	11.0	35.2	35.5	54.5	366	463	184	95.9	44.6	51.3	161.2
Ds-20	116.7	11.7	32.6	35.3	44.8	370	493	171	73.8	33.6	29.5	162.5
Ds-25	151.5	11.5	32.5	33.2	52.7	346	485	181	98.5	44.7	46.3	160.1
Group mean	124.2	10.2	30.6	31.4	50.1	361	470	180	90.0	41.1	44.6	162.9
LSD (0.05)	32.3	2.6	9.3	4.2	6.6	24	44	17	21.5	11.3	15.0	2.2

continued

TABLE 3 *continued*

Means and differences for dry-matter yield, number of stems and inflorescences, plant height, canopy diameter, acid-detergent fiber, neutral-detergent fiber, crude protein, inflorescence weight, and flowering date of 20 Searls' prairie clover collections at Hyde Park and Millville.

	Hyde Park								Millville			Combined
										Inflorescences		
Collection	Dry-matter yield (g/plot)	Stems (number)	Inflorescences (number)	Plant height (cm)	Canopy diameter (cm)	Acid-detergent fiber (g/kg)	Neutral-detergent fiber (g/kg)	Crude protein (g/kg)	Dry-matter yield (g/plot)	(number)	(g/plot)	Flowering date[z]
Bonneville germplasm group												
Ds-23	**79.1**	**8.6**	**16.3**	**29.9**	**36.3**	**326**	**439**	**207**	**69.9**	**27.8**	**30.2**	**166.6**
Ds-12	109.0	10.8	25.4	32.4	46.0	362	476	174	71.4	32.2	29.6	162.4
Ds-16	35.1	5.9	8.8	21.3	34.2	312	456	195	48.5	26.8	21.7	165.1
Ds-21	58.4	8.3	9.8	27.2	38.4	279	411	207	87.9	22.3	22.7	169.4
Group mean	70.4	8.4	15.1	27.7	38.7	320	446	196	69.4	27.3	26.1	165.9
LSD (0.05)	24.9	2.3	4.5	4.5	8.1	49	55	32	18.9	9.7	10.5	3.0
Carmel germplasm group												
Ds-14	**178.3**	**11.6**	**25.8**	**39.0**	**58.2**	**362**	**465**	**170**	**158.2**	**42.0**	**72.7**	**166.5**
Ds-01	—	—	—	—	—	—	—	—	79.8	29.9	20.7	172.9
Ds-17	118.8	10.1	21.1	33.0	48.0	339	451	177	120.8	34.1	58.4	167.0
Group mean	148.6	10.9	23.5	36.0	53.1	351	458	174	119.6	35.3	50.6	168.8
LSD (0.05)	53.5	2.5	9.6	4.4	7.3	38	46	18	36.6	13.5	22.3	2.1
Overall (across all collections)												
Mean	115.4	9.9	26.6	31.2	48.1	351	464	183	90.3	37.4	41.8	164.2
LSD (0.05)	32.7	2.5	8.4	4.2	6.8	32	47	19	23.7	11.5	15.0	2.6

Notes: Adapted from Bhattarai and others 2010.

[z] Flowering date is indicated as Day of Year (DOY) starting from 1 January.

significantly greater ($P \leq 0.05$) for Fanny (30.6%) than for Bonneville germplasm (7.1%). As a result, seed scarification treatments are required to improve uniformity of germination for Searls' prairie clover prior to planting. Detailed procedures for acid scarification of seed are reported by Johnson and others (2011). Seed scarification can also be accomplished by using sandpaper blocks in a cement mixer.

The indeterminate flowering habit and resulting extended seed maturation period in Searls' prairie clover present a challenge to growers for seed production because flowers bloom upward along the spike for 2 to 3 wk during July. This results in flowers at the top of the spike being delayed in blooming relative to flowers at the bottom. Consequently, flowers at the top of the spike may still be blooming while seeds at the bottom are mature and beginning to drop. Several passes through seed production fields with a vacuum or soft-brush harvester during seed maturation may be required to maximize seed production. In this way, seeds could be gently manipulated to minimize plant damage and harvested multiple times as they mature.

Beetles (*Acanthoscelides oregonensis* Johnson [Coleoptera: Chrysomelidae] and *Apion amaurum* Kissinger [Coleoptera: Apionidae]) were present in seedpods from 18 of 25 western prairie clover (*Dalea ornata*) collections made across a 3-state region (Cane and others 2012). After seed harvest and prior to seed cleaning, sections of insecticide strips (active ingredient dichlorvos [2, 2-dichlorovinyl dimethyl phosphate] 18.6% and related compounds 1.4 %, Hotshot No-Pest strip, United Industries, St Louis, Missouri) could be placed in seed bags or bins to reduce seed weevil damage (Youtie and Miller 1986; Johnson and others 2011).

ANTICIPATED CONSERVATION USE

Searls' prairie clover is likely to be a beneficial component in conservation plantings to enhance biodiversity, provide forage for wildlife (including sage grouse) and livestock, and fix nitrogen. It also holds promise for use in habitat-enhancement programs for native pollinators and managed agricultural pollinators, as well as for the beautification of roadsides, rest areas, and parks (Cane and others 2012). Primary beneficiaries of this germplasm are expected to be land management agencies, ranchers, landowners enrolled in USDA conservation programs, and the seed industry.

ANTICIPATED AREA OF ADAPTATION

Fanny germplasm was selected to represent the metapopulation that covers the Central Basin and Range Level III Ecoregion, which stretches across central Nevada and southwestern Utah. Carmel germplasm was selected for use in the Colorado Plateau. Bonneville germplasm was selected to represent the genetically distinct metapopulation occurring in northwestern Utah in the vicinity of ancient Lake Bonneville and dry areas in northern and eastern Nevada. (See Table 2.)

AVAILABILITY OF PLANT MATERIALS

G_1 seed of Fanny germplasm and Bonneville germplasm will be maintained by the USDA Agricultural Research Service Forage and Range Research Laboratory, Logan, Utah. G_1 seed of Carmel germplasm will be maintained by the Upper Colorado Environmental Plant Center, Meeker, Colorado. Seed through the G_5 generation will be eligible for certification. Seed of Fanny and Bonneville germplasms will be made available to commercial growers for distribution by the Utah Crop Improvement Association: contact Stanford Young, Utah Crop Improvement Association, Utah State University, Logan, Utah 84322-4820; phone 435.797.2082; e-mail stanford.young@usu.edu. Seed of Carmel germplasm will be made available to commercial growers for distribution by Steve Parr, Upper Colorado Environmental Plant Center, 5538 County Road 4, Meeker, Colorado 81641; phone 970.878.5003; e-mail steve.parr@wreawildblue.org.

Small quantities of seed will be provided to researchers on request to the corresponding author. Appropriate recognition should be made if this material contributes to the development of a new breeding line or cultivar.

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REFERENCES

[AHS] American Horticultural Society. 1997. Plant heat-zone map. Alexandria (VA): American Horticultural Society.

Aydin I, Uzun F. 2005. Nitrogen and phosphorus fertilization of rangelands affects yield, forage quality and the botanical composition. European Journal of Agronomy 23:8–14.

Bailey RG. 1995. Description of the ecoregions of the United States. 2nd ed. Washington (DC): USDA Forest Service Miscellaneous Publication 1391 (rev.).

Barneby RC. 1977. *Dalea* imagines. Memoirs of the New York Botanical Garden 27:1–892.

Bhattarai K, Johnson DA, Jones TA, Connors KJ, Gardner DR. 2008. Physiological and morphological characterization of basalt milkvetch (*Astragalus filipes*): basis for plant improvement. Rangeland Ecology and Management 61:444–455.

Bhattarai K, Bushman BS, Johnson DA, Carman JG. 2010. Phenotypic and genetic characterization of western prairie clover collections from the western United States. Rangeland Ecology and Management 63:696–706.

Bhattarai K, Bushman BS, Johnson DA, Carman JG. 2011. Searls' prairie clover (*Dalea searlsiae*) for rangeland revegetation: phenotypic and genetic evaluations. Crop Science 51:1–12.

Brown CS, Anderson VJ, Claassen VP, and 6 others. 2008. Restoration ecology and invasive plants in the semiarid West. Invasive Plant Science Management 1:399–413.

Bushman BS, Larson SL, Peel MD, Pfrender ME. 2007. Population structure and genetic diversity in North American *Hedysarum boreale* Nutt. Crop Science 47:1281–1286.

Bushman BS, Bhattarai K, Johnson DA. 2010. Population structure of *Astragalus filipes* collections from western North America. Botany 88:565–574.

Bushman BS, Johnson DA, Connors KJ, Jones TA. 2015. Germination and seedling emergence of three semiarid western North American rangeland legumes. Rangeland Ecology and Management 68:501–506.

Cane JH, Weber M, Miller S. 2012. Breeding biologies, pollinators, and seed beetles of two prairie-clovers, *Dalea ornata* and *Dalea searlsiae* (Fabaceae: Amorpheae), from the Intermountain West, USA. Western North American Naturalist 72:16–20.

Cherney JH, Allen VG. 1995. Forages in a livestock system. In: Barnes RF, Miller DA, Nelson CJ, editors. Forages: the science of grassland agriculture. Volume I. Ames (IA): Iowa State University Press. p 175–188.

Falush D, Stephens M, Pritchard JK. 2007. Inference of population structure using multilocus genotype data: dominant markers and null alleles. Molecular Ecology Notes 7:574–578.

Haring DA, Huber MJ, Suter D, Edwards PJ, and Luschier A. 2008. Plant enemy-derived elicitors increase the foliar tannin concentration of *Onobrychis viciifolia* without a trade-off to growth. Annals of Botany (London) 102:979–987.

Hobbs RJ, Harris JA. 2001. Restoration ecology: repairing the earth's ecosystem in the new millennium. Restoration Ecology 9:239–246.

[ITIS] Integrated Taxonomic Information System. 2015. URL: http://www.itis.gov/index.html (accessed 11 Jun 2015). Washington (DC): National Museum of Natural History.

Johnson DA, Jones TA, Connors KJ, Bhattarai K, Bushman BS, Jensen KB. 2008. Notice of release of NBR-1 germplasm basalt milkvetch. Native Plants Journal 9:127–132.

Johnson DA, Bushman BS, Bhattarai K, Connors KJ. 2011. Notice of release of Majestic germplasm and Spectrum germplasm western prairie clover. Native Plants Journal 12:249–256.

Jones TA, Larson SR, Wilson BL. 2008. Genetic differentiation and hybridization among *Festuca idahoensis, F. roemeri,* and *F. ovina* detected from AFLP, ITS, and chloroplast DNA. Botany 86:422–434.

Larson SR, Jones TA, Jensen KB. 2004. Population structure in *Pseudoroegneria spicata* (Poaceae: Triticeae) modeled by Bayesian clustering of AFLP genotypes. American Journal of Botany 91:1789–1801.

Liao C, Peng R, Luo Y, Zhou X, Wu X, Fang C, Chen J, Li B. 2008. Altered ecosystem carbon and nitrogen cycles by plant invasion: a meta-analysis. New Phytologist 177:706–714.

Madison LA, Robel RJ. 2001. Energy characteristics and consumption of several seeds recommended for northern bobwhite food plantings. Wildlife Society Bulletin 29:1219–1227.

McKay JK, Christian CE, Harrison SP, Rice KJ. 2005. "How local is local?" A review of practical and conceptual issues in the genetics of restoration. Restoration Ecology 1:432–440.

Moscow Forestry Sciences Laboratory. 2009. Custom climate data requests. URL: http://forest.moscowfsl.wsu.edu/climate/customData/ (accessed 6 Oct 2009). Moscow (ID): Moscow Forestry Sciences Laboratory, Rocky Mountain Research Station.

Omernik JM. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,000). Annals of the Association of American Geographers 77:118–125.

Oviatt CG. 1997. Lake Bonneville fluctuations and global climate change. Geology 25:155–158.

Peakall R, Smouse PE. 2012. GenAlEx 6.5: genetic analysis in Excel. Population genetic software for teaching and research—an update. Bioinformatics 28:2537–2539.

Pfisterer AB, Joshi J, Schmid B, Fischer M. 2004. Rapid decay of diversity-productivity relationships after invasion of experimental plant communities. Basic and Applied Ecology 5:5–14.

Phillips NC, Larson SR, Drost DT. 2008. Detection of genetic variation in wild populations of three Allium species using amplified fragment length polymorphisms. HortScience 43:637–643.

Pierson FB, Williams CJ, Hardegree SP, Weltz MA, Stone JJ, Clark PE. 2011. Fire, plant invasions, and erosion events on western rangelands. Rangeland Ecology and Management 64:439–449.

Pokorny ML, Sheley RL, Zabinski CA, Engel RE, Svejcar TJ, Brokowski JJ. 2005. Plant functional group diversity as a mechanism for invasion resistance. Restoration Ecology 13:448–459.

Richards RT, Chambers JC, Ross C. 1998. Use of native plants on federal lands: policy and practice. Journal of Range Management 51:625–632.

Sheley RL, Carpinelli MF. 2005. Creating weed-resistant plant communities using niche-differentiated nonnative species. Rangeland Ecology and Management 58:480–488.

Sheley R, Mangold J, Goodwin K, Marks J. 2008. Revegetation guidelines for the Great Basin: considering invasive weeds. Washington (DC): USDA, Agricultural Research Service. ARS-168. p 1–52.

Tiehm A. 1985. Fanny Searls (1851–1939). Brittonia 37:41–43.

[USDA ARS] USDA Agricultural Research Service. 2012. USDA plant hardiness zone map. URL: http://planthardiness.ars.usda.gov (accessed 5 May 2015). Washington, DC.

[USDA NRCS] USDA Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. Agriculture Handbook 296. Washington (DC): USDA NRCS.

[USDA NRCS] USDA Natural Resources Conservation Service. 2015a. The PLANTS database. URL: http://www.plants.usda.gov (accessed 5 May 2015). Greensboro (NC): National Plant Data Team.

[USDA NRCS] USDA Natural Resources Conservation Service. 2015b. Web soil survey. URL: http://websoilsurvey.sc.egov.usda.gov/app/HomePage.htm (accessed 5 May 2015). Washington (DC): USDA NRCS Headquarters.

[US EPA] US Environmental Protection Agency. 2013. Level III ecoregions of the continental United States. URL: http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm (accessed 5 May 2015). Corvallis (OR): National Health and Environmental Effects Research Laboratory.

Walker SC, Shaw NL. 2005. Current and potential use of broadleaf herbs for reestablishing native communities. In: Shaw NL, Pellant M, and Monsen SB, editors. Proceedings, Sage Grouse Habitat Restoration Symposium. Fort Collins (CO): USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-38. p 46–61.

Youtie BA, Miller RF. 1986. Insect predation on *Astragalus filipes* and *A. purshii* seeds. Northwest Science 60:42–46.

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