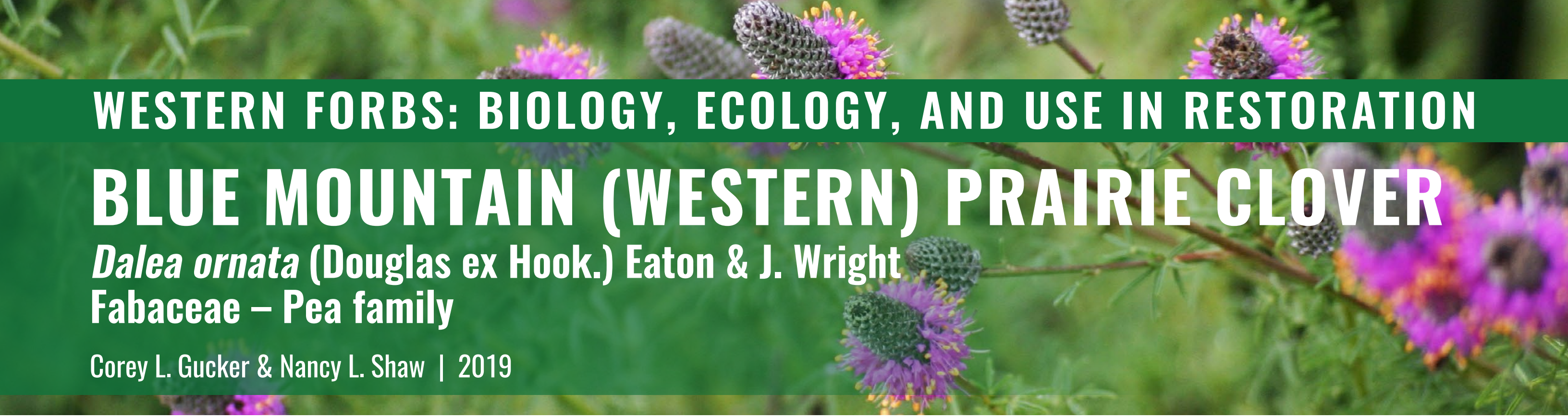

WESTERN FORBS: BIOLOGY, ECOLOGY, AND USE IN RESTORATION

BLUE MOUNTAIN (WESTERN) PRAIRIE CLOVER

Dalea ornata **(Douglas ex Hook.) Eaton & J. Wright**
Fabaceae – Pea family

Corey L. Gucker & Nancy L. Shaw | 2019

ORGANIZATION

NOMENCLATURE

The scientific name of Blue Mountain prairie clover is *Dalea ornata* (Douglas ex Hook.) Eaton & J. Wright. It belongs to the Amorpheae tribe of the Fabaceae family, the legume or pea family (Cane et al. 2012; USDA NRCS 2017).

NRCS Plant Code. DAOR2 (USDA NRCS 2017).

Subtaxa. No subspecies or varieties are currently recognized (USDA NRCS 2017).

Synonyms. *Petalostemon ornatus* Douglas ex Hook (USDA NRCS 2017).

Common Names. Blue Mountain prairie clover, western prairie clover, handsome prairie clover, ornate dalea (Barneby 1989; Hickman 1993; Pavek et al. 2012; USDA NRCS 2017).

Chromosome Number. Chromosome number is commonly 2n = 14, although 2n = 16 may also occur (Barneby cited in Bhattarai et al. 2010).

Hybridization. Hybrids were not reported in the literature.

DISTRIBUTION

Blue Mountain prairie clover is widespread, though generally infrequent, over a relatively large portion of the Interior West including southeastern Washington, eastern Oregon, northern California, northwestern Nevada, and western Idaho (Barneby 1989; Scheinost et al. 2009b). It occurs in the Columbia Plateau, Blue Mountains, Snake River Plain, and in the Northern Basin and Range ecoregions (Lambert 2005).

Habitat and Plant Associations. Dry rocky or sandy sites in sagebrush (*Artemisia* spp.) and pinyon-juniper (*Pinus-Juniperus* spp.) communities where average annual precipitation is 12 inches or more (≥305 mm) are typical Blue Mountain prairie clover habitats. (Fig. 1) (Lambert

2005; Ogle et al. 2011; Cane et al. 2012; Pavek et al. 2012). Habitats also include river terraces, lake shores, washes, and sandy plains (Barneby 1989).

Elevation. Blue Mountain prairie clover occurs at low to moderate elevations from 330 to 6,000 feet (100-1,830 m) (Barneby 1977; Pavek et al. 2012). Seed collections made by the BLM SOS project occurred over an elevation range of 2,223-3,950 feet (678-1,204 m) in Oregon (USDI BLM SOS 2017).

Soils. Soft clay and sandy soils from weathered basalt and volcanic ash are typical of Blue Mountain prairie clover habitats (Barneby 1977). Plants often occur on ash outcrops in Idaho and Oregon (DeBolt and Barrash 2013).

Figure 1. Blue Mountain prairie clover growing in sagebrush habitat in Idaho. Photo: USDI BLM ID931, SOS.

DESCRIPTION

Blue Mountain prairie clover is a tap-rooted perennial legume with clusters of stout stems 12 to 24 inches (30-61 cm) tall (Fig. 2) (Barneby 1977; Lambert 2005; Pavek et al. 2012). Taproots are brown and tough from a short caudex (Barneby 1977). Plants resemble some clover species (*Trifolium* spp.) and give off a strong scent when bruised (Barneby 1989). Stems and leaves are glabrous and gland dotted (Barneby 1989; Pavek et al. 2012). Dried stems from the previous year's growth are often present (Scheinost et al. 2009b). Leaves are alternate and pinnately compound with five or seven, thick, oval leaflets and small stipules (Barneby 1989; Johnson et al. 2011; Cane et al. 2012; Pavek et al. 2012). Leaves are 1.6 to 2 inches (4-5 cm) long; individual leaflets are 0.4 to 0.8 inch (1-2 cm) long (Scheinost et al. 2009a) with the terminal leaflet being the largest (Barneby 1977).

Figure 2. Blue Mountain prairie clover growing in the Succor Creek area of Oregon. Photo: M. Fisk, USFS.

Figure 3. Blue Mountain prairie clover beginning to flower. Photo: G.A. Monroe, hosted by the USDA-NRCS PLANTS Database.

Inflorescences are dense, congested, cylindrical spikes that are generally 0.5 to 0.6 inch (1-2 cm) in diameter. Flowers are perfect and tubular with five light pink to purple petals (Fig.3) (Barneby 1989; Hickman 1993; Pavek et al. 2012). One petal is broadly clawed and attached to the calyx. The other four petals have narrow claws. They alternate with the five stamens and are attached to the staminal tube (Barneby 1989; Scheinost et al. 2009a; Pavek et al. 2012). Flower petals are 7 to 9 mm long and come together at the base in the calyx tube, which is thin and papery with 10 ribs and long silky hairs (Hickman 1993; Scheinost et al. 2009a). Fruits are indehiscent pods, each 3 to 3.5 mm long, that contain a single seed. Fruits produce two ovules, but one is aborted (Barneby 1977).

Below-Ground Relationships/Interactions. As is common with legumes, Blue Mountain prairie clover fixes nitrogen in association with rhizobial symbionts (Fig. 4) (Bushman et al. 2015).

Figure 4. Root nodules on *Dalea* roots. Photo: J. Cane, USDA Agriculture Research Service (ARS).

Reproduction. Blue Mountain prairie clover reproduces from seed. In an agricultural setting, plants flowered and produced seed in their second year (Shock et al. 2018). In an outdoor nursery setting, plants flowered in their first growing season (DeBolt and Barrash 2013). Flowering progresses upwards from the base to the tip of the inflorescence over a 3- to 4-week period, usually beginning in late May or June. Flowers near the tip of the inflorescence may just be opening as the lower portion of the inflorescence is maturing seeds (Johnson et al. 2011).

Seed production of Blue Mountain prairie clover plants can be prolific. In a USDA Agricultural Research Service (ARS) research garden (Logan, UT), 17 plants averaged 117 spikes each, and each spike averaged 151 flowers (Cane et al. 2012). At 1 seed per flower, estimated average seed production per plant would be almost 18,000. This number is slightly lower than the estimated yield of 22,000 seeds/plant for an equivalent number of flowering spikes reported for purple prairie clover (*D. purpurea*) grown in the same garden (Cane et al. 2012). Blue Mountain prairie clover plants grown in two nearby ARS research gardens averaged 36 spikes (range of 12-82) in sandy, mesic silt loams and 61 spikes in coarse, mesic silt loams (Bhattarai et al. 2010). Similar numbers of spikes per plant (25-115) were also reported in a research garden in southeastern Oregon (Love and Cane 2019).

Pollination. Insect pollination is required to maximize seed production (Cane et al. 2012). Pollination of Blue Mountain prairie clover was evaluated for several years at the ARS' Pollinating Insect-Biology, Management, Systematics Research (ARS PIBMSR). Manually outcrossed flowers produced four times more seed than manually selfed flowers and 10 times more seed than auto-pollinated flowers (caged and without insect contact) ($P < 0.05$). Hence, the species is largely self-incompatible, requiring cross-pollination between plants for good seed production. Bee visitors were net-collected in wild populations of Blue Mountain prairie clover and Searls' prairie clover (*D. searlsiae*) in Elmore County, Idaho; Malheur County, Oregon; and Benton, County, Washington. Researchers collected 114 bees representing 22 species at 847 plants sampled. The most prevalent bee visitors were carder or potter bees (*Anthidium* spp.), bumblebees (*Bombus* spp.), long-horned bees (*Eucera* and *Melissodes* spp.), and a specialist plasterer bee (*Colletes* spp.) (Cane et al. 2012). Another study compared floral guilds of bees across the Great Basin and adjoining regions. Researchers collected 13 bee genera in eight surveys of Blue Mountain prairie clover and Searls' prairie clover, including seven bumblebee species (Cane and Love 2016). Blue Mountain prairie clover is considered a fire-tolerant species and provides an important nectar source for recovering bee populations by the first or second post-fire year (Love and Cane cited in Shock et al. 2018).

Predation. Seed production can be dramatically reduced by seed-feeding insects. In wildland stands in Washington, Oregon, and Idaho, tiny seed-feeding beetles (*Acanthoscelides oregonensis* and *Apion amaurum*) were found in 14 of 23 Blue Mountain prairie clover stands sampled (Cane et al. 2012). In another survey of

Blue Mountain prairie clover seed predators in sagebrush-steppe in Washington, Idaho, and Oregon, these seed-feeding beetles were found in 19 of 22 seed collections. Larvae of these beetles feed within a single seed, then pupate there and later emerge as adults. It is not clear if they winter in the seed or exit the seed in the fall and winter underground or in leaf litter (Cane et al. 2013).

ECOLOGY

Blue Mountain prairie clover is a long-lived perennial. Stems sprout from crowns in early spring, and by early July, flowering and seed set are generally complete. Stems die back in fall, and plants are dormant through the winter (Johnson et al. 2011; Shock et al. 2018). This pattern of growth suggests plants should be fire and grazing tolerant, especially in late summer and fall.

An experimental burning study found that Blue Mountain prairie clover was quite fire tolerant. Fire response was evaluated by experimentally burning seed production plots near Ontario, Oregon. Senescing plants were burned between August 21 and 30 in 2012 at various heat intensities using a propane burn barrel. Plant mortality was evaluated the following spring (Love and Cane 2019). Mortality was less than 10% at very low 212 °F (100 °C) and medium 572 °F (300 °C) burn intensities. Mortality increased to 10 to 20% with high 932 °F (500 °C) and very high 1,112 °F (600 °C) burn intensities (Cane 2014). Overall survival of burned plants was 93% and all but one survivor flowered the first year after burning. Burned plants produced 25 to 115 inflorescences/plant, and the average sum of inflorescence lengths did not change with increasing fire intensity ($P = 0.08$) (Love and Cane 2019).

Wildlife and Livestock Use. Blue Mountain prairie clover is not toxic to herbivores (Bhattarai et al. 2010), however direct use by wildlife and livestock is rarely reported in the available literature. In the PIBMSR common garden, cattle pushed through a fence to graze on planted purple prairie clover (*Dalea purpurea*) (J. Cane, USDA ARS, personal communication, January 2019). Blue Mountain prairie clover was noted as a component of greater sage-grouse (*Centrocercus urophasianus*) habitats (Lambert 2005), and prairie clover (*Dalea* spp.) can comprise 2% of Ord's kangaroo rat (*Dipodomys ordii*) diets (Martin et al. 1951).

Nutritive value. Only small differences in forage quality traits were found in 22 accessions of Blue Mountain prairie clover (Bhattarai et al. 2010). Growing-season acid detergent fiber averaged 34% (range: 30-37%), neutral detergent fiber averaged 43% (range: 39-47%), and crude protein averaged 18% (range: 17-19%). This forage quality together with the lack of swainsonine, selenium, or nitrotoxin concentrations that are toxic to livestock makes Blue Mountain prairie clover a good quality forage (Bhattarai et al. 2010; Johnson et al. 2011).

Current medicinal uses. Extracts of Blue Mountain prairie clover reduced the motility and increased the mortality of human pathogenic hookworms (*Ancylostoma ceylanicum*), which cause anemia and malnutrition in resource-limited regions worldwide. This represents just part of the on-going research for potential treatments (Deardorff et al. 2016).

REVEGETATION USE

Blue Mountain prairie clover has been shown to be broadly adaptable. In a common garden study, seed collected over a broad range of elevations, temperature gradients, precipitation regimes, and from several different ecoregions was grown successfully at sites in northern Utah (Bhattarai et al. 2010). It has many traits making it an attractive revegetation choice at sites with medium to coarse soils receiving 12 inches or more (≥305 mm) of annual precipitation. In a guide to conservation plantings for encouraging pollinators in the Intermountain West, prairie clovers are described as having a moderate growth rate and providing excellent wildlife forage including pollen and nectar for bees (Ogle et al. 2011). It is beneficial to both native and managed agricultural pollinators (Fig. 5) and produces attractive flowers, making it useful for planting along roadsides, in rest areas, parks, campgrounds, and other low maintenance landscapes (Johnson et al. 2011). A legume, it provides biologically fixed nitrogen and increases wildlife and livestock forage quality (Shock et al. 2018). It is also fire tolerant. Blue Mountain prairie clover has persisted in dense stands of uninterrupted cheatgrass (*Bromus tectorum*) near Hanford, Washington, and King Hill, Idaho, where it is likely important to post-fire pollinator populations (Love and Cane 2019).

Figure 5. Hunt's bumblebee (*Bombus huntii*) visiting Blue Mountain prairie clover flowers in a common garden in Hyde Park, Utah. Photo: K. Connors.

DEVELOPING A SEED SUPPLY

For restoration to be successful, the right seed needs to be planted in the right place at the right time. This involves a series of steps that require coordinated planning and cooperation among partners to first select appropriate species and seed sources and then properly collect, grow, certify, clean, store, and distribute seed for restoration.

Developing a seed supply begins with seed collection from native stands. Collection sites are determined by current or projected revegetation requirements and goals. Production of nursery stock requires less seed than large-scale seeding operations, which may require establishment of agricultural seed production fields. Regardless of the size and complexity of any revegetation effort, seed certification is essential for tracking seed origin from collection through use.

Seed Sourcing. Empirical seed zones are not currently available for Blue Mountain prairie clover, however, generalized provisional seed zones developed by Bower et al. (2014) may be used to select and deploy seed sources. These provisional seed zones identify areas of climatic similarity with comparable winter minimum temperature and aridity (annual heat:moisture index). In Figure 6, Omernik Level III Ecoregions (Omernik 1987) overlay the provisional seeds zones to identify climatically similar but ecologically different areas. For site-specific disturbance regimes and restoration objectives, seed collection locations within a seed zone and ecoregion may be further limited by elevation, soil type, or other factors.

The Western Wildland Environmental Threat Assessment Center's (USFS WWETAC 2017) Threat and Resource Mapping (TRM) Seed Zone application provides links to interactive mapping features useful for seed collection and deployment planning. The Seedlot Selection Tool (Howe et al. 2017) can also guide restoration planning, seed collection, and seed deployment, particularly when addressing climate change considerations.

Although broadly adapted and widely distributed as a species, genetic and phenotypic differences can exist among populations. When 22 Blue Mountain prairie clover populations from Idaho, Oregon, and Washington were compared, researchers determined that two distinct, genetically differentiated groups and one admixed group were represented. Flowering date played a significant role in distinguishing the groups. Although phenotypic characteristics were correlated with differences in precipitation and elevation differences, genetic distance was not. Genetic distance did, however, correlate to differences in mean annual temperature (P = 0.004) (Bhattarai et al. 2010).

In two common gardens in Utah, winter survival and growth differences were apparent for Blue Mountain prairie clover accessions from north-central Oregon growing in North Logan and Kaysville, Utah (Table 1). Nearly all plants (92-100%) transplanted in spring 2008 survived the summer without irrigation, but winter survival was generally lower for Oregon accessions growing in North Logan than in Kaysville, which is about 65 miles south of North Logan. By late summer 2009, Oregon plants grew taller at the southern garden but wider at the northern garden. The two upper elevation Oregon and L & H plants reached 35 to 50% bloom, but the bloom for northernmost Oregon accession (Sherman County) was less than 20% (Kratsch et al. 2010). L & H plants were obtained from the L & H Seed Company based in Connell, Washington (origin unknown).

Table 1. Growth characteristics of Blue Mountain prairie clover plants from seed collected in north-central Oregon and seed obtained from L & H Seed Company when planted in northern Utah (North Logan and Kaysville) (Kratsch et al. 2010).

Accession	North Logan, UT (4,692 ft)			Kaysville, UT (4,357 ft)			Average
	Winter survival (%)	Height (tallest shoot, in)	Width (widest point, in)	Winter survival (%)	Height (tallest shoot, in)	Width (widest point, in)	Percent bloom[2]
Sherman Co, OR 1,150 ft	78	15.4a	30.4a	100	17.0ab	22.8a	17.2b
Jefferson Co, OR 3,100 ft	72	13.6b	16.6c	100	15.2c	16.5b	35.6ab
Wheeler Co, OR 3,280 ft	89	12.2b	23.2b	100	16.4ab	19.1ab	48.9a
L & H Seed Company	94	16.2a	30.3a	94	13.0d	16.0bc	49.7a

[1] Values within a column followed by different letters are significantly different (P < 0.05).
[2] Percent bloom averaged for both common garden sites and evaluated on June 9, 2009.

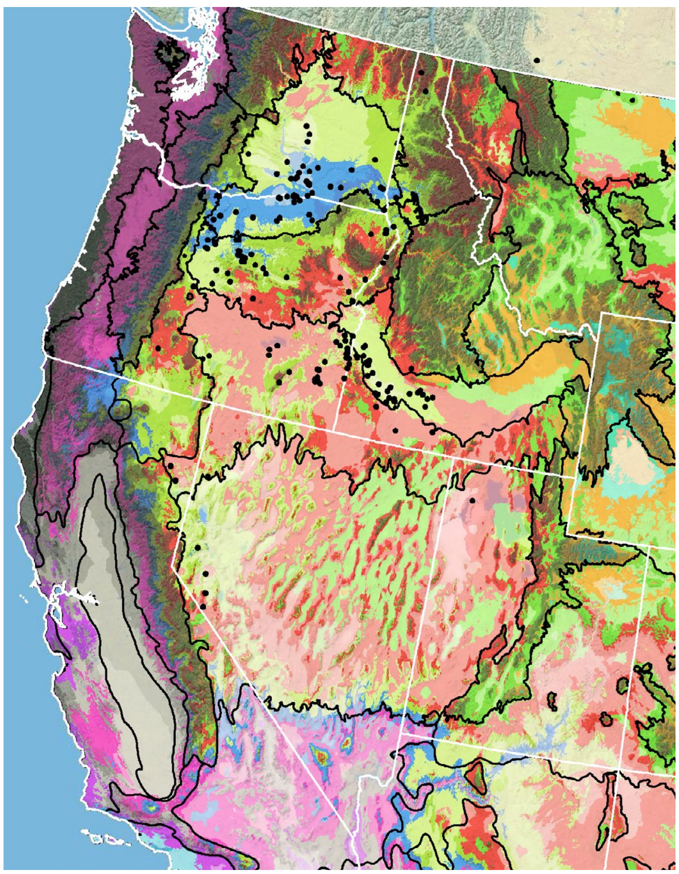

Figure 6. Distribution of Blue Mountain prairie clover (black circles) based on geo-referenced herbarium specimens and observational data from 1885-2013 (CPNWH 2017; SEINet 2017; USGS 2017). Generalized provisional seed zones (colored regions) (Bower et al. 2014) are overlain by Omernik Level III Ecoregions (black outlines) (Omernik 1987; USDI EPA 2018). Interactive maps, legends, and a mobile app are available (USFS WWETAC 2017; www.fs.fed.us/wwetac/threat-map/TRMSeedZoneMapper2.php?). Map prepared by M. Fisk, USGS.

Releases. Two Blue Mountain prairie clover germplasms were approved for release in 2010 (Johnson et al. 2011). The releases (Majestic [Do-09] and Spectrum [Do-04]) were selected after monitoring growth at two common gardens in northern Utah and conducting genetic analyses (using amplified fragment length polymorphism [AFLP] markers) on plants from 22 seed collections made at sites ranging from 360 to 3,680 feet (110-1,120 m) in Washington, Oregon, and Idaho (Johnson et al. 2011).

Majestic germplasm was selected to represent the genetically distinct group from the Deschutes River Watershed, as well as the genetic diversity found within the western regions of the Columbia Plateau (MLRA 8) and Blue Mountain ecoregions (MLRA 10). Selection was based on dry matter yield, which was significantly higher ($P \leq 0.1$) in both gardens, total inflorescence weight, and flowering date, which was latest for the Deschutes genetic group (Johnson et al. 2011).

Spectrum germplasm was selected to represent the geographically diverse genetic group from sites outside of the Deschutes Watershed, as well as the central and eastern Columbia Plateau (MLRA 8), central and eastern Blue Mountains (MLRA 10), Northern Basin and Range (MLRA 1), and Snake River Plain (MLRA 11) ecoregions. In at least one of the common gardens, Spectrum produced some of the tallest plants and the greatest number and heaviest inflorescences (Johnson et al. 2011).

Wildland Seed Collection. Hand stripping the inflorescences is the most effective method of collecting wildland seed of Blue Mountain prairie clover (Fig. 7). Seed that is not easily stripped is often immature or insect infested. Hand-stripped seed is typically easy to clean (M. Fisk, USGS, personal communication, 2018).

Figure 7. Blue Mountain prairie clover setting seed in Oregon. Photo: USDI BLM SOS OR030.

Wildland seed certification. Wildland seed collected for direct sale or for establishment of agricultural seed production fields should be Source Identified through the Association of Official Seed Certifying Agencies (AOSCA) Pre-Variety Germplasm Program that verifies and tracks seed origin (Young et al. 2003; UCIA 2015). For seed that will be sold directly for utilization in revegetation, collectors must apply for certification prior to making collections. Applications and site inspections are handled by the state where collections will be made. For seed that will be used for planting agricultural seed fields or nursery propagation, additional details of the collection site and procedures are required. Seed collected by most public and private agencies following established protocols may enter the certification process directly without certification agency site inspections when protocols include collection of all data required for Source Identified certification (see Agricultural Seed Field Certification section). Wildland seed collectors should become acquainted with state certification agency procedures, regulations, and deadlines in the states where they collect. Permits or permission from public or private land owners are required for all collections.

Collection timing. Flowering of Blue Mountain prairie clover generally occurs over a 2- to 4-week period in May or June (Johnson et al. 2011; Shock et al. 2018). Seed is generally mature in mid-summer (DeBolt and Barrash 2013; USDI BLM SOS 2017). BLM Seeds of Success (SOS) field crews reported details from 10 seed collections made over a period of 4 years, primarily in Oregon at elevations from 2,223 to 3,950 feet (678-1,204 m). The earliest collection date was July 5, 2010 at 2,661 feet (811 m) in Malheur County, Oregon, and the latest collection date was August 5, 2010, also in Malheur County, at an elevation of 3,742 feet (1,141 m) (USDI BLM SOS 2017).

Flowering begins at the base of the inflorescence and progresses upward, thus the tip of the inflorescence may be flowering as the lower portion is producing mature seed (Johnson et al. 2011). Mature seed detaches rapidly from the plant (Shock et al. 2018), thus monitoring seed ripening is important for proper collection timing. Considerable ripe seed can be lost during rain or wind storms. Plants are typically ready for harvest when some inflorescences are dispersing or have dispersed a small amount of seed and a portion of the seed comes off easily when the inflorescence is stripped (M. Fisk, USGS, personal communication, 2018).

In common garden studies, the flowering date for Blue Mountain prairie clover was positively correlated with temperature ($P < 0.0001$) and negatively correlated with elevation ($P = 0.0079$) of the seed collection site. Collections from high elevation, low temperature sites flowered earlier than those from warmer, low-elevation sites. Plants from high elevations generally grow and flower at relatively lower ambient temperatures than plants from low elevations (Bhattarai et al. 2010).

Collection methods. Field crews collecting seed for the Great Basin Native Plant Project harvested seed by hand-stripping inflorescences (M. Fisk, USGS, personal communication, 2018). Field crews collecting seed for the SOS project stripped or clipped inflorescences directly into paper bags (DeBolt and Barrash 2013).

Standardized collection guidelines and methods should be followed to maximize the genetic diversity of wildland collections at a given site: collect seed from a minimum of 50 randomly selected plants; collect from widely separated individuals throughout a population without favoring the most robust or avoiding small stature plants; and collect from all microsites including habitat edges (Basey et al. 2015). General collecting recommendations and guidelines are provided in online manuals (e.g. ENSCONET 2009; USDI BLM SOS 2016). As is the case with wildland collection of many forbs, care must be taken to avoid inadvertent collection of weedy species, particularly those that produce seeds similar in shape and size to those of Blue Mountain prairie clover.

Post-collection management. Blue Mountain prairie clover is host to several seed-feeding insects. Measures to protect seed lots (Fig. 8) from insect damage are generally initiated immediately following harvest. Insecticidal strips are often placed in collection bags to reduce insect damage (Bhattarai et al. 2010). The SOS collection crews placed insecticide strips in each seed collection bag for 2 to 3 days while seed dried in open bags at room temperature (DeBolt and Barrash 2013). Seed-feeding beetles have been found in wildland and agricultural seed collections. Infestations can be detected by digital X-radiography of seed samples. There are several methods to treat insects without harming live seed. These include mechanical cleaning, fumigation, and abrupt freezing. For small wildland-collected seed lots (average size 22,800 seeds) beetles were killed with a conventional insecticide fumigant treatment of dichlorovos, which did not harm the seed (Cane et al. 2013).

Figure 8. Bulk seed collection of prairie clover seed. Photo: J. Cane, ARS PIBMSR.

Seed Cleaning. The process for cleaning hand-stripped Blue Mountain prairie clover seed is usually simple and quick (M. Fisk, USGS, personal communication, 2018). Wildland seed collected from Washington, Oregon, and Idaho was threshed, then cleaned with sieves and a seed blower (Bhattarai et al. 2010). A seed lot from Owyhee County, Idaho, was cleaned by the USFS Bend Seed Extractory using the following procedure: 1) processing seed through a dewinger with a hopper feed setting of 15, a black liner, a tilt of 3, and speed of 5 for about 1 hour; 2) fine cleaning seed through a blower set to low (or a 300 setting) for 40 minutes (Rauch cited in DeBolt and Barrash 2013).

For field harvests, cleaning seed with a gravity table or separator reduced the abundance of seed infested with seed-feeding beetles. Uncleaned seed harvested from a central Washington farm was 4 to 5% infested. Seed cleaned using a gravity table was 2% infested (Cane et al. 2013).

Seed Storage. Seed used in common garden experiments that led to the selection of the two Blue Mountain prairie clover releases was stored in the dark at 37 °F (3 °C) where relative humidity was 20 to 25% (Bhattarai et al. 2010). Seed stored at 72 °F (22 °C) for 7 to 12 months averaged 88% viability based on tetrazolium (TZ) tests (Jones et al. 2016). Seed longevity with longer periods of storage was not reported in the available literature.

Seed Testing. The Association of Seed Analysts (AOSA) developed procedures for tetrazolium (TZ) tests of Blue Mountain prairie clover (AOSA 2010). Seed is imbibed at 68 to 77 °F (20-25 °C). Seed coats of seed failing to imbibe are nicked or clipped. Seed is then soaked for 2 to 72 hours in a 1% TZ solution at 86 to 95 °F (30-35 °C). Viability is assessed based on staining patterns; immature seed may stain unevenly (AOSA 2010).

Germination. Blue Mountain prairie clover produces hard seeds that are physically dormant due to water impermeable seed coats. Low levels of germination (11-22%) can be expected without mechanical (Fig. 9) or acid scarification (Scheinost et al. 2009b; Bushman et al. 2015; Jones et al. 2016).

Figure 9. Apparatus used to mechanically scarify prairie clover seed with sand paper. Photo: S. Bushman, ARS.

In tests of stratification, scarification, seeding depth, and substrate on Majestic and Spectrum seed germination and seedling establishment obtained from BFI Native Seed, acid scarification resulted in the greatest increases in germination, followed by mechanical scarification (Table 2). Seed that imbibed water and stained with TZ without seed coat manipulations were considered viable. Those that required nicking of the seed coat to imbibe water and stain were considered viable and hard. Acid scarification resulted in significantly greater germination than mechanical scarification, however, both methods resulted in significantly greater and more rapid germination than untreated seeds ($P < 0.05$; Bushman et al. 2015; Johnson and Bushman 2016).

Table 2. Percentages of viable seed, viable hard seed, and germination for two Blue Mountain prairie clover selected germplasms (Majestic and Spectrum) with and without scarification (Bushman et al. 2015).

Source	Majestic germplasm			Spectrum germplasm		
Treatment	Acid scarification[1]	Mechanical scarification[2]	Untreated	Acid scarification	Mechanical scarification	Untreated
Viable (%)	68	43	11	72	34	16
Viable hard (%)	14	48	73	16	40	81
Germination[3] (%)	84	60	11	85	61	22

[1] Seeds soaked for 5 minutes in 98% sulfuric acid, rinsed for 3 minutes, and air dried. Note: Ransom (2014) found soaking seed longer than 5 minutes produced significant reductions in germination.

[2] Seeds hand rubbed between two pieces of 120 grit sand paper for 30 seconds.

[3] Germination adjusted based on percentage of total viable seed (viable % + viable hard %). Emergence monitored in soil in glasshouse (77/68 °F [25/20 °C] 12 hr day/12 hr night) (Bushman et al. 2015).

Planting depth (0.2 vs. 0.7 in [0.6 vs. 1.9 cm]) did not significantly impact total emergence of Blue Mountain prairie clover in glasshouse experiments, but deeper planting did significantly slow the rate of emergence ($P < 0.05$). For wildland-collected Majestic seed, there were significant decreases in total emergence of scarified seed as clay content of soils increased. Emergence was more rapid in sandy soils than in soils with greater clay content. Less than 11% of untreated Majestic seed emerged regardless of soil composition (Bushman et al. 2015; Johnson and Bushman 2016).

Physical dormancy or hard seededness was the primary barrier to germination of Spectrum seed when effects of eight treatments were evaluated. As expected from other studies, scarification was necessary for germination, and cool, moist stratification treatments alone did not increase germination. Seed came from plots growing near Millville, Utah, and was stored at room temperature for up to 12 months. Treatments were a factorial combination of 1) scarification, 2) sand or paper substrate, 3) 3-weeks at 41 °F (5 °C) in the dark. Treated and untreated seeds were germinated at 72 °F (22 °C) and ambient daylight conditions. Scarification significantly increased germination ($P < 0.0001$). Neither prechilling nor substrate affected germination. Seed viability averaged 88%, and scarification did not impact viability. For all treatment combinations, the number of seeds germinating increased over time and had not plateaued after 10 weeks (Jones et al. 2016).

When 22 different treatments from freezing to near boiling temperatures and various types and times of abrasion were evaluated, only abrasion resulted in large increases in Blue Mountain prairie clover germination. Seed permeability, imbition, and germination were evaluated after treatments of wet heat (5-300 s in 194 °F [90 °C] water), freezing + wet heat (2 hr at -112 or -4 °F [-80 or -20 °C] then 5 or 30 s in 194 °F [90 °C] water), freeze-thaw cycles (2 hr at -112 or -4 °F [-80 or -20 °C] then 2 hr at 73 °F [23 °C] repeated 1-6 times) and six abrasion-based treatments: pneumatic scarification (10-160 s in a Mater seed scarifier, Corvallis, OR), and manual scarification (120-grit sand paper). Only the abrasion treatments were highly effective for improving water uptake or increasing germination. Seed responded across the range of scarification durations and 10 s was sufficient for producing germination of 99% (Kildisheva et al. 2018).

Wildland Seed Yield and Quality. Post-cleaning seed yield and quality of seed lots collected in the Intermountain region are provided in Table 3 (USFS BSE 2017). The results indicate that Blue Mountain prairie clover can be cleaned to high levels of purity and seed fill and that viability of fresh seed is generally high.

Table 3. Seed yield and quality of Blue Mountain prairie clover seed lots collected in the Intermountain region, cleaned by the Bend Seed Extractory, and tested by the Oregon State Seed Laboratory or the USFS National Seed Laboratory (USFS BSE 2017).

Seed lot characteristic	Mean	Range	Samples (no.)
Bulk weight (lbs)	3.4	0.55-9.6	13
Clean weight (lbs)	0.6	0.03-2.25	13
Clean-out ratio	0.2	0.06-0.37	13
Purity (%)	98	92-99	13
Fill (%)1	86	70-95	13
Viability (%)2	88	79-94	11
Seeds/lb	163,194	135,000-187,433	13
Pure live seeds/lb	141,353	112,455-167,340	11

[1] 100 seed X-ray test

[2] Tetrazolium chloride test

Similar numbers of seeds/lb (128,367-154,227 [282,996-340,006/kg]) have been reported (Scheinost et al. 2009a; Ogle et al. 2011; USFS GBNPP 2014). The Forage and Range Research laboratory in Logan, Utah, indicated that seed weight varied with environmental factors and genotype (Scheinost et al. 2009a). Weights of 22 wildland seed collections growing in common gardens in northern Utah ranged from 256,410 to 467,290 seeds/lb (565,280-1,030,180/kg), and Majestic and Spectrum seed from a production field averaged 270,270 seeds/lb (595,830/kg) (Johnson et al. 2011).

Marketing Standards. Marketing Standards are not available for Blue Mountain prairie clover, however, acceptable seed purity, viability, and germination specifications typically vary with revegetation plans. Purity needs are highest for precision seeding equipment used in nurseries, while some rangeland seeding equipment will handle less clean seed. Viability of seed collected from two production fields ranged from 88% to 92% (Johnson et al. 2011; Jones et al. 2016), and seed can easily be cleaned to purities of 90% or more (Table 3).

AGRICULTURAL SEED PRODUCTION

Production plots of Blue Mountain prairie clover have been grown and evaluated in Utah and Oregon (Fig. 10). Harvestable seed is generally produced in the second year and stands can be harvested for 6 years or more (Shock et al. 2017, 2018). Pollination by bees greatly improves seed yields when seed-feeding beetle populations are kept in check (Cane et al. 2012, 2013).

Figure 10. Blue Mountain prairie clover seed production plots growing at Oregon State University's Malheur Experiment Station near Ontario, OR. Photo: USFS.

Agricultural Seed Certification. It is essential to maintain and track the genetic identity and purity of native seed produced in seed fields. Tracking is done through seed certification processes and procedures. State seed certification offices administer the Pre-Variety Germplasm (PVG) Program for native field certification for native plants, which tracks geographic source, genetic purity, and isolation from field production through seed cleaning, testing, and labeling for commercial sales (Young et al. 2003; UCIA 2015). Growers should plant certified seed (see Wildland Seed Certification section) and apply for certification of their production fields prior to planting. The systematic and sequential tracking through the certification process requires pre-planning, understanding state regulations and deadlines, and is most smoothly navigated by working closely with state certification agency personnel.

Site Preparation. At the Oregon State University Malheur Experiment Station (OSU MES) near Ontario, Oregon, seed fields were grown in silt loam soils with a pH of 8.3 and 1.1% organic matter. Plots were weed-free at the time of seeding. Seed was fall planted using a custom small plot grain drill with disk openers. Seed was deposited on the soil surface and subsequently covered with sawdust at rate of 7 g/foot (24 g/m) of row and then covered with row cover, which was removed the following April (Shock et al. 2018).

Seed Pretreatments. A large proportion of untreated Blue Mountain prairie clover seed is hard or dormant. Mechanical or acid scarification can be used to promote even and rapid germination (see Germination section). In glasshouse emergence tests, acid scarification resulted in significantly greater total emergence than mechanical scarification and either scarification method resulted in significantly greater and more rapid emergence than untreated seed ($P < 0.05$) (Bushman et al. 2015).

Weed Management. At OSU MES, weeds were controlled in seed production research plots primarily with cultivation or hand rouging (Shock et al. 2018). Many pre- and post-emergent herbicides have been tested on Blue Mountain prairie clover (Ransom 2012, 2014). Herbicides are not registered for Blue Mountain prairie clover, and the results discussed here do not constitute an endorsement of specific companies or products or recommendations for use. The research, however, could contribute to future registration efforts.

Germination, root and shoot production, and seedling biomass were unaffected by pre-emergent applications of imazapic or rimsulfuron herbicides. Evaluating seed germination and seedling growth on plates with these herbicides added to the agar was not a viable testing method for herbicide tolerance, at least not as conducted in this report (Ransom 2014). When pre-emergent herbicides were applied one day after seeding, plant densities were not significantly different between herbicide treatments (type and rate) or between herbicide treatments and controls. Density ranged from a low of 137 plants/plot in untreated to 200 plants/plot on pendimathalin-treated plots. These results suggest further testing of pre-emergent herbicides to aid establishment of Blue Mountain prairie clover in seed production fields is needed (Ransom 2012).

At OSU MES, there was no evidence of post-emergent herbicide damage to seed production plots sprayed in early spring with pendimethalin (Ransom 2014). About 4 pounds (1.8 kg) of seed was collected from a 0.125-acre (0.05 ha) plot treated with when buds were present on the plants. Plant injury ranged from 4 to 18% after post-emergent herbicides were sprayed in August 2011 on plots drill seeded in mid-June (Ransom 2012). Injury was least for plants sprayed with imazamox + crop oil concentrate (COC) and greatest for those treated with dichlorophenoxy butric acid + broxynil, however, injury differences were not significantly different compared to untreated plants. Plant densities increased between pre- and post-treatment evaluations (22 days). Density increases for herbicide-treated plots ranged from a low of 3% for imazamox + COC treatments to a high of 31% for bentazon + COC treatments, while density increased 22% on untreated plots. Post-emergent herbicide application did not reduce the number of flowers produced per plot. Flower production ranged from 136/plot in bomoxynil treated, 200/plot in bentazon + COC treated, and 169/plot for controls (Ransom 2012).

In other post-emergent herbicide testing, several herbicides applied in May caused significant injury to 3-year-old Blue Mountain prairie clover plants. Oxyfluorfen and flumioxazin herbicides caused severe tissue burn 5 days after treatment (DAT), but considerable recovery occurred by 35 DAT. Injury from clopyralid was high initially with little to no recovery by 35 DAT. Injury from aminopyralid was moderate at 5 DAT and increased significantly compared to untreated by 35 DAT ($P < 0.05$). Bromoxynil, clopyralid, and aminopyralid herbicide treatments significantly reduced seed head biomass compared to controls. When the same herbicide treatments were applied in early spring before much re-growth, no injury was observed. This suggests that herbicide applications to control winter annual weeds prior to spring re-growth of Blue Mountain prairie clover may warrant further testing (Ransom and Edvarchuk 2008, 2009).

Seeding. Scheinost et al. (2009a) recommended a seeding rate of 25 to 30 pure live seed (PLS)/linear foot (82-98/m) for Blue Mountain prairie clover seed production fields. At OSU MES, Blue Mountain prairie clover stands were established by dropping seed on the soil surface at a rate of 20 to 30 seeds/foot (65-100/m) in the fall and covering it with sawdust (Shock et al. 2018). Research plots for herbicide tolerance were established at Utah State University's Utah Agricultural Experiment Station (USU UAES) in North Logan, Utah, by drill seeding scarified seed at a rate of 8 lbs PLS/acre (9 kg/ha) in mid-June (Ransom 2012). Blue Mountain prairie clover can be established successfully with spring seeding, which is rare for many Great Basin forb species.

At USU UAES, Blue Mountain prairie clover plot establishment for herbicide tolerance research was attempted in fall 2010 and summer 2011 (Ransom 2012). Aridlands germplasm seed was scarified and fungicide treated prior to seeding in Millville silt loam soils. Seed was drill seeded using a Hege cone-seeder. Seeds were drilled 0.25 inch deep (0.6 cm) in rows spaced 14 inches (36 cm) apart at a rate of 8 lbs PLS/acre (9 kg/ha). Seed planted in mid-November 2010 emerged in early spring 2011, but seedlings were killed by late spring frost events. Seed was planted again in mid-June following the same methods, and establishment was adequate to permit implementation of the planned herbicide treatments (Ransom 2012).

In glasshouse experiments at Logan, Utah, planting depths of 0.25 and 0.75 inch (0.6-1.9 cm) did not significantly affect emergence of wild-collected scarified Majestic seed, but deeper planting resulted in significantly slower emergence rates ($P < 0.05$). Total emergence decreased significantly as clay content of soils increased. Emergence of scarified seed was more rapid in sandy soils than in soils with greater clay content. Untreated seeds showed little to no response to soil composition (Bushman et al. 2015).

Establishment and Growth. In seed production research plots at OSU MES, Blue Mountain prairie clover plants began flowering and produced seed the second year after fall planting and seed was harvested for 6 years, although it may be harvested longer (Fig. 11) (Shock et al. 2016, 2018).

Strong positive correlations have been reported between dry matter yield (DMY) and weight, and the number of inflorescences per plant, suggesting that selecting for high DMY would lead to greater seed yields (Bhattarai et al. 2010). For more on this common garden study, see Seed Sourcing section.

Figure 11. Blue Mountain prairie clover flowering in seed production plots growing at Oregon State University's Malheur Experiment Station near Ontario, OR. Photo: USFS.

Irrigation. Seed yield and plant water relations were evaluated at OSU MES over a 6-year period (2011-2015) (Shock et al. 2017, 2018). Maximum seed yield occurred when irrigation and precipitation totaled 12 to 16 inches (300-400 mm)/year. Studies tested additions of 0, 4, and 8 inches (0-200 mm) of subsurface drip irrigation delivered 12 inches (30 cm) deep in four bi-weekly increments starting at time of flower bud formation (Table 4). Over the course of the study, annual precipitation averaged 9.8 inches (249 mm) (range: 7-11 inches [179-292 mm]). Blue Mountain prairie clover seed yield was maximized by 4 to 8 inches (100-200 mm) of irrigation in warmer, drier years (2012-2016) and without irrigation in cooler, wetter years (2011). In 2011 fall, winter, and spring precipitation were greatest and there were the fewest number of growing-degree days (Table 5). Researchers concluded that water requirements for Blue Mountain prairie clover seed production were low and natural precipitation in Ontario, Oregon provided a substantial amount of the water needed for maximum seed yields. Seed yield showed a quadratic response to irrigation in 2012 through 2015 with maximum seed yields at 7.7 inches (196 mm) in 2012, 8.1 inches (206 mm) in 2013, 6.9 inches (175 mm) in 2014, and 4.3 inches (109 mm) in 2015 (Table 6; Shock et al. 2017, 2018).

Table 4. Flowering phenology as related to timing of irrigation of Blue Mountain prairie clover seed production plots growing at Oregon State University's Malheur Experiment Station in Ontario, OR (Shock et al. 2017).

Year	Flowering			Irrigation		
	Start	Peak	End	Start	End	Harvest
2011	June 8	June 20	July 20	May 27	July 6	July 22
2012	May 23	June 10	June 30	May 11	June 21	July 11
2013	May 13	May 21	June 15	May 8	June 19	June 28
2014	May 15	June 4	June 24	May 6	June 17	July 1
2015	May 5	May 26	June 22	May 5	June 17	June 25
2016	May 3	May 26	June 10	May 3	June 14	June 13

Table 5. Maximum seed yield of Blue Mountain prairie clover seed production plots by irrigation amount applied based on quadratic response. Plots growing at Oregon State University's Malheur Experiment Station in Ontario, OR (Shock et al. 2018).

Year	Highest yield (lbs/acre)	Fall + Winter + Spring (in)	Growing degree days (50-86 °F) Jan-June	Additional water (in/season) applied for highest seed yield
2011	454.6	14.4	476	0.0
2012	431.5	8.4	682	7.6
2013*	130.3	5.3	733	7.9
2014	486.2	8.1	741	6.7
2015	398.6	10.4	895	4.4
2016	392.7	10.0	810	4.5
Average	353.4	9.1	665**	5.9

*Seed pods had extensive damage from seed beetles in 2013 (Shock et al. 2017).
** 22-year average.

Table 6. Seed yield (kg/ha) for fall-seeded (November 2009) Blue Mountain prairie clover in response to no additional irrigation and supplemental irrigation (4 and 8 inches [100-200 mm]/season) at Oregon State University's Malheur Experiment Station in Ontario, OR (Shock et al. 2018).

Year	Supplemental irrigation (inches/season*)		
	0	4	8
	---------Seed yield (lbs/acre)---------		
2011	451.5a	410.5a	351.4a
2012	145.0a	364.8b	431.1b
2013	28.5a	104.6b	130.2b
2014	119.3a	422.5b	476.0b
2015	212.7a	396.4b	267.0ab
2016	246.1a	307.7a	312.2a
Average	201.3a	325.9b	331.7b

*Irrigation season was from bud to seed set and water was delivered through a drip irrigation system.

Numbers within a row followed by different letters are significantly different ($P < 0.05$).

Pollinator Management. Seed production is limited by the extent of outcrossing. Manually outcrossed flowers produced significantly more seed (4-10 times) than self-pollinated flowers ($P < 0.05$) (Cane et al. 2012). At five cultivated stands growing near Logan, Utah, and Ontario, Oregon, the natural bee fauna was mostly bumblebees and sweat bees (*Dialictus* spp. and *Halictus tripartitus*). Common managed bees were alfalfa leafcutter bees (*Megachile rotundata*) and mason bees (*Osmia bruneri*) (Cane et al. 2012). Currently managed pollinators such as honey bees (*Apis mellifera*) and alfalfa leafcutter bees should be effective pollinators for Blue Mountain prairie clover seed production operations (Cane 2011).

Pest Management: In wildland and seed field surveys, Melissa blue butterflies (*Lycaeides melissa*), a flower predator, and seed weevils (*Achanthoscelides* spp., *A. oregonensis*, *A. daleae*, and *Apion* spp.), seed predators, were found feeding at Blue Mountain prairie clover plants (Hammon and Cane 2005). Powdery mildew (*Leveillula papilionacearum*) was found on plants in research plots at OSU MES (Mohan and Shock 2013).

Apion amaurum was widespread in seed collected from 12 populations of Blue Mountain prairie clover. In a few cases, the majority of sampled seed was infested (Cane 2006). Seed weevils (*Apion* spp.) occurred in densities of greater than 10 adults/flowering inflorescence in a commercial seed production field (Cane 2010). One or more adult seed-feeding beetles (*Acanthoscelides* spp.) were found on many of the early-flowering racemes of Blue Mountain prairie clover growing at a 5-acre seed production farm in central Washington (Cane et al. 2013). Larvae of these insects develop within the seed from which adults later emerge (Cane et al. 2012). Larvae are protected inside the seeds and seed pods and cannot be controlled by conventional surface insecticides but may be susceptible to systemic insecticides. Conventional surface sprays are not recommended for adult beetles because of the damage to bees and other pollinators, which are needed for high seed yields (Cane et al. 2013). In research plots at OSU MES, Blue Mountain prairie clover seed was damaged extensively by seed-feeding beetles in 2013. Seed damage also occurred in 2014 and 2015 but to a much lesser degree. In 2015, bifenthrin (0.04 lb/acre [0.05 kg/ha]) and novaluron insecticides (0.03 lb/acre [0.04 kg/ha]) were applied to plants in May. Insecticides were applied at night to minimize harm to pollinators. Effectiveness of the treatments was not determined (Shock et al.

2018). There is evidence that night insecticide applications may minimize harm to bees (J. Cane, ARS, personal communication, January 2019). Mosquito adulticides were sprayed on alfalfa (*Medicago* spp.) at night without apparent harm to bees the following morning . Early detection of seed-feeding beetles is possible by placing greenhouse-grown (and thus more physiologically advanced) potted Blue Mountain clovers in seed production fields (J. Cane, ARS, personal communication, January 2019).

Seed Harvesting. Blue Mountain prairie clover grows relatively upright, a good trait for commercial seed production (Johnson et al. 2011), but flowering is somewhat indeterminate. Flowering progresses up the inflorescence, and plants are still flowering near the top of the inflorescence as seed is maturing near the bottom (Scheinost et al. 2009a). This flowering pattern makes multiple harvests or ideal timing of single pass manual or mechanical harvests necessary to maximize seed yields (Johnson et al. 2011; Shock et al. 2018).

Blue Mountain prairie clover can be harvested by hand or with a leaf blower in vacuum mode. In northern Utah, plants flowered in early and mid-June, and seed was harvested on July 15 using a leaf blower in vacuum mode. Seed was harvested from the plants and the soil when seed tufts began to shatter (Ransom 2014). In later years at the same location, seed was harvested multiple times between late July and early August (Jones et al. 2016). At OSU MES, seed was harvested in a single, once-over, manual harvest. Timing of the harvest represented a compromise between immature, mature, and dehiscing seed. Seed ripening occurred over a 2-week period, and seeds detached soon after maturing (Shock et al. 2018).

Seed Yields and Stand Life. At OSU MES, the first harvestable crop was produced 2 years following fall seeding. Stands produced harvestable crops for 6 years, but they may be harvestable for longer periods (Shock et al. 2017, 2018). Blue Mountain prairie clover's highest annual seed yields (cleaned seed bulk) ranged from 130 to 486 lbs/acre (146-545 kg/ha) and averaged 353 lbs/acre (396 kg/ha) over 6 years of irrigation experiments. Average seed yield was greatest when irrigation plus precipitation levels totaled 12 to 16 inches (300 to 400 mm)/year (Shock et al. 2018). At study plots growing at the ARS PIBMSR in Logan, Utah, 17 small plants averaged 117 inflorescences and 151 flowers/inflorescence for an estimated 18,000 seeds/young plant (Cane 2006). In northern Utah, about 4 lbs (1.8 kg) of seed was collected from a 0.125-acre (0.05 ha) plot. Seed was harvested by vacuuming the plants and soil surface (Ransom 2014). In seed production fields in Moses Lake, Washington, it was estimated that 600 to 700 lbs/acre (673-785 kg/ha) of Majestic and 163 lbs/acre (183 kg/ha) of Spectrum seed could be produced if seed was harvested by hand every few days over a 3- to 4-week period (Johnson et al. 2011).

NURSERY PRACTICE

Production of nursery stock was described for two small-scale experiments. For establishment of Blue Mountain prairie clover seed production study plots in northern Utah, seeds were germinated on moist blotter paper, transferred to plugs, and then transferred to cone-tainers. Growing conditions in the greenhouse were set to an 86/59 °F (30/15 °C) day/night regime. Seedlings were grown 90 days before field transplanting (Bhattarai et al. 2010).

DeBolt and Barrash (2013) scarified Blue Mountain prairie clover seed with one swipe across a fingernail file and soaked scarified seed in distilled water at room temp for 20 hours, by which time more than half of the 600 seeds germinated. Two to three seeds were sown per container. Nine-inch deep containers filled with a 2:1:5 mix of lava fines, perlite, and nursery soil mix were used to accommodate the long taproots. Containers were placed outdoors in full sun on April 16 and hand watered when dry. Between 40 and 50% of the planted seed produced established seedlings. The establishment phase was about 2 months. A weak fish fertilizer was applied 2 times each month from April through June. Any flower stalks produced were removed. The active growing phase was about 4 months and some seedlings were dormant by mid-September. Plants remained outdoors until outplanting, which occurred in early October. This process yielded 255 plants from 600 seeds (DeBolt and Barrash 2013).

Experimental stands at the ARS PIBMSR, were established from nursery stock grown from seed collected from Deschutes Basin, Oregon. Plants (15-20) were transplanted 3 feet (1 m) apart in clay loam field soils amended with compost to improved drainage. Plants received periodic drip irrigation and were grown for up to 3 years (Cane et al. 2012).

WILDLAND SEEDING AND PLANTING

Use of Blue Mountain prairie clover in wildland restoration is rarely reported in the available literature, but it has many traits making it an attractive revegetation choice at sites with medium to coarse soils that receive 12 inches or more (≥305 mm) of annual precipitation. In a guide to conservation plantings for encouraging pollinators in the Intermountain West, prairie clovers are described as having a moderate growth rate, providing excellent wildlife forage, and being attractive to bees (Ogle et al. 2011).

A firm, weed-free, seed bed is recommended for Blue Mountain prairie clover. (Scheinost et al. 2009b). In field experiments at dryland sites in Oregon, 120 of 250 acid-scarified Majestic seeds emerged after early spring sowing, which was at least 12 times greater than emergence of acid-scarified seed sown in fall and non-scarified seeds sown in fall or spring (Johnson and Bushman 2016).

Seed production is limited by the extent of outcrossing. Manually outcrossed flowers produced significantly more seed (4-10 times) than self-pollinated flowers ($P < 0.05$) (Cane et al. 2012). If Blue Mountain prairie clover is seeded sparsely as a minor seed mix component, plants will likely be spaced too widely to be sequentially visited during the foraging trip of a given bee, which would result in rare outcrossing and poor seed set. The spacing issue can be addressed by planting seed more thickly in limited areas (Cane et al. 2012).

Recommended pure stand seeding rates range from 4 to 10 PLS lbs/acre (4.5-11.2 kg/ha), the lower rates for drill seeding and the higher rates for broadcast seeding (Scheinost et al. 2009b; Ogle et al. 2011). When seeding Blue Mountain prairie clover as part of a mix, adjust the rates according to the proportion of the stand desired (Scheinost et al. 2009b). Seeding depth should be 0.25 to 0.5 inch (0.6-1.3 cm) (Scheinost et al. 2009b; Ogle et al. 2011), and rows should be spaced 1 to 3 feet (0.3-1 m) apart (Ogle et al. 2011). Inoculating seed with *Rhizobium* bacteria may improve establishment. Weed management for several years is important for establishment and persistence of Blue Mountain prairie clover, and seedling damage by rodents and insects should be anticipated, monitored, and controlled (Scheinost et al. 2009b). Planting both scarified and non-scarified seed in rangeland revegetation seedings may allow for production of an immediate stand and provide for delayed germination with later precipitation events (Bushman et al. 2015; Johnson and Bushman 2016).

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AOSCA NATIVE PLANT CONNECTION

https://www.aosca.org/wp-content/uploads/Documents///AOSCANativePlantConnectionBrochure_AddressUpdated_27Mar2017.pdf

BLM SEED COLLECTION MANUAL

https://www.blm.gov/sites/blm.gov/files/programs_natural-resources_native-plant-communities_native-seed-development_collection_Technical%20Protocol.pdf

ENSCONET SEED COLLECTING MANUAL

https://www.publicgardens.org/resources/ensconet-seed-collecting-manual-wild-species

HOW TO BE A SEED CONNOISSEUR

http://www.utahcrop.org/wp-content/uploads/2015/08/How-to-be-a-seed-connoisseur20May2015.pdf

OMERNIK LEVEL III ECOREGIONS

https://www.epa.gov/eco-research/ecoregions

CLIMATE SMART RESTORATION TOOL

https://climaterestorationtool.org/csrt/

SEED ZONE MAPPER

https://www.fs.fed.us/wwetac/threat-map/TRMSeedZoneMapper.php

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