BARESTEM BISCUITROOT

Lomatium nudicaule (Pursh) J.M. Coult. & Rose
Apiaceae – Carrot family

Corey L. Gucker and Nancy L. Shaw | 2021

ORGANIZATION

NOMENCLATURE

Barestem biscuitroot (*Lomatium nudicaule*) (Pursh) J.M. Coult. & Rose belongs to the Apiaceae family (USDA NRCS 2020).

NRCS Plant Code. LONU2 (USDA NRCS 2020).

Subtaxa. No varieties or subspecies are currently recognized.

Synonyms. *Cogswellia nudicaulis* (Pursh) J.M. Coult. & Rose (ITIS 2020).

Common Names. Barestem biscuitroot, Indian celery, Indian consumption plant, naked-stem lomatium, pestle lomatium (Turner and Bell 1971; Blackwell 2006; Welsh et al. 2016).

Chromosome Number. Chromosome number is: 2n = 22 (Hitchcock et al. 1961; Welsh et al. 2016).

Hybridization. There is no documentation of hybridization for the *Lomatium* genus (Hitchcock and Cronquist 2018).

DISTRIBUTION

Barestem biscuitroot occurs in the Pacific Northwest of the United States and southern British Columbia (Hitchcock et al. 1961; Lesica 2012). Populations occur on both sides of the Cascade Mountain Range, as far south as central California and Nevada, and as far east as western Utah and Idaho (Hermann 1966; Munz and Keck 1973; Welsh et al. 2016; Hitchcock and Cronquist 2018). Barestem biscuitroot appeared west of the Cascade Range about 4,500 years ago and was likely brought from the high desert interior by the Salish peoples. On Washington's Waldron Island, barestem biscuitroot is found only in association with known Salish settlements (Drum 2006).

Habitat and Plant Associations. Barestem biscuitroot is common in meadow and grassland vegetation (Fig. 1). Its frequency can be as high as 87% in native grasslands dominated by

Roemer's fescue (*Festuca roemeri*), large camas (*Camassia leichtlinii*), and western buttercup (*Ranunculus occidentalis*) on the Yellow Island in Washington's San Juan Islands (Dunwiddie 2002). Barestem biscuitroot occurs in summer-dry subalpine meadows in Olympic National Park, Washington (del Moral 1983). It is also common in grassy meadows dominated by needlegrass (*Achnatherum* spp.) in the mixed-conifer zone in Washington and Oregon (Franklin and Dyrness 1973). In Nevada, barestem biscuitroot cover exceeds 25% in a community where cover of forbs exceeds that of Sandberg bluegrass (*Poa secunda*), squirreltail (*Elymus elymoides*), and bluebunch wheatgrass (*Pseudoroegneria spicata*) (Peterson 2008).

Sagebrush (*Artemisia* spp.) and mountain shrublands are also common barestem biscuitroot habitats (Munz and Keck 1973; Blackwell 2006; Welsh et al. 2016). Barestem biscuitroot grows throughout the sagebrush steppe except for its eastern extremes (Taylor 1992). Cover of barestem biscuitroot exceeds 5% in threetip sagebrush/Sandberg bluegrass-onespike danthonia (*A. tripartita*/*P. sandbergii*-*Danthonia unispicata*) communities at 5,170 feet (1,580 m) in the southern Blue Mountains of Oregon (Johnson and Swanson 2005). In eastern Oregon, eastern Washington, and extreme western Idaho, barestem biscuitroot is part of the sparse forb layer in the scabland sagebrush (*A. rigida*) rangeland cover type (Shiflet 1994). On the western margin of the Great Basin, barestem biscuitroot occurs in low sagebrush (*A. arbuscula*) communities dominated by native species but not those dominated by medusahead (*Taeniatherum caput-medusae*) (Young and Evans 1970).

Figure 1. Barestem biscuitroot (scattered yellow flowers) growing in a sagebrush grassland. Photo: USFS, Rocky Mountain Research Station (RMRS), Provo Shrub Sciences Laboratory (PSSL).

Barestem biscuitroot occurs in openings in pinyon-juniper (*Pinus*-*Juniperus* spp.) woodlands and pine forests (Fig. 2) (Hermann 1966; Munz and Keck 1973; Hickman 1993; Welsh et al. 2016; Hitchcock and Cronquist 2018). It is also common in Oregon white oak (*Quercus garryana*) woodlands and prairies in Oregon, Washington, and British Columbia (Pfeifer-Meister and Bridgham 2007; Marsico and Hellmann 2009). It was dominant in white oak remnant prairies at Mt. Pisgah southeast of Eugene, Oregon (Pfeifer-Meister and Bridgham 2007).

Figure 2. Barestem biscuitroot growing in an opening in a pinyon-juniper woodland in Oregon. Photo: USDI, BLM ID931, Seeds of Success (SOS).

Elevation. Barestem biscuitroot is common at low to moderate elevations throughout its western range (Hermann 1966). It occurs at elevations of up to 8,000 feet (2,440 m) in the Great Basin (Blackwell 2006), from 5,200 to 8,300 feet (1,585-2,530 m) in Utah (Welsh et al. 2016), and 590 to 6,560 feet (180-2,000 m) in California (Munz and Keck 1973; Hickman 1993).

Soils. Barestem biscuitroot grows in fine- to coarse-textured soils with high gravel or rock content (Johnson and Swanson 2005; Shock et al. 2016). In Olympic National Park, it grew in subalpine meadows that fell in the middle to wet range of a drought stress gradient, where early September soil moisture ranged from 20 to 52% (del Moral 1983). In grasslands in the mixed-conifer zone in Oregon and Washington, barestem biscuitroot occurred on shallow, stony soils that were warm and extremely dry in summer (Franklin and Dyrness 1973). In the southern Blue Mountains, it grew on andesite soils in threetip sagebrush communities where 65% of the ground was covered with rock and gravel (Johnson and Swanson 2005). Barestem biscuitroot is common on shallow soils (usually <10 inches [25 cm] deep) over basalt in the scabland sagebrush rangeland cover type where it occurs. These soils have low moisture holding capacity, are typically saturated in early spring, and dry rapidly as the growing season progresses (Shiflet 1994).

DESCRIPTION

Barestem biscuitroot is a glabrous perennial from a long, thick taproot (Hickman 1993; Welsh et al. 2016). At 4 to 8 years old, taproots can exceed 12 inches (30 cm) in length and are about 1 inch (2.5 cm) thick. Older plant roots growing in very sandy soils may be 3 feet (1 m) long and 6 inches (15 cm) wide (Drum 2006). Plants produce stout blue-green stalks up to 28 inches (70 cm) tall with swollen bases just below the inflorescences (Hermann 1966; Blackwell 2006). Plants in California reach greater heights (up to 28 inches [70 cm]) (Munz and Keck 1973; Hickman 1993) than those in Utah (up to 18 inches [45 cm]) (Welsh et al. 2016). Leaves are entirely or chiefly basal and rarely persistent (Hermann 1966; Welsh et al. 2016). Barestem biscuitroot produces pinnately (ternate or biternate) compound leaves with 3 to 30 distinct leaflets (Fig. 3) (Welsh et al. 2016; Hitchcock and Cronquist 2018). Leaves are petiolate and may have a dilated sheath. Petioles are up to 2.4 inches (6 cm) long for plants in Utah (Welsh et al. 2016) and up to 10 inches (25 cm) long for plants in California (Hickman 1993). Leaflets are oval to almost round, up to 2 inches (5 cm) wide, and nearly equal or up to 3 times as wide as they are long (USDA FS 1937; Taylor 1992; Welsh et al. 2016). Leaflets are often prominently veined with entire margins or with coarse teeth near the blunt tips (Hitchcock and Cronquist 2018).

Figure 3. Barestem biscuitroot plants with petiolate pinnate leaves and oval leaflets. Photo: USDI, BLM OR090A, SOS.

Flowers are produced in compound umbels (Fig. 4) at the ends of the tallest and stoutest flowering stems (USDA FS 1937; Lesica 2012). Umbels have 7 to 27 rays measuring 2 to 8 inches (6-20 cm) long sit atop swollen peduncles without bracts (USDA FS 1937; Hitchcock et al. 1961; Munz and Keck 1973; Blackwell 2006; Welsh et al. 2016). Rays terminate in secondary umbellets with a whorl of leafy bracts and clusters of tiny 5-petaled, yellow flowers (USDA FS 1937; Hickman 1993; Blackwell 2006; Hitchcock and Cronquist 2018). Longer outer rays generally support bisexual flowers, and shorter inner rays support primarily male flowers (Hitchcock and Cronquist 2018). Bisexual flowers produce slender, often curved or coiled styles (1-2 mm long) (Welsh et al. 2016). Fruits are schizocarps (Fig. 5) that contain two seeds (mericarps) (Welsh et al. 2016). Schizocarps are oblong, strongly flattened, 0.4 to 0.6 inch (1-1.4 cm) long, and 2 to 5 mm wide, with thin wings (USDA FS 1937; Welsh et al. 2016). The lateral wings (~0.5 mm) are narrower than the seed body. Mericarps have dorsal equal, threadlike ribs with one to several oil tubes per rib interval (USDA FS 1937; Hickman 1993; Welsh et al. 2016).

Figure 4. Barestem biscuitroot's compound umbels and tiny yellow flower clusters. Photo: USDA, PSSL.

Reproduction. Flowers are produced from April to June and seed is typically mature in July (Munz and Keck 1973; Blackwell 2006; Tilley and St. John 2012; USDI BLM SOS 2017). Barestem biscuitroot reproduces from seed. Plant size was positively associated with reproduction and amount of plant damage was negatively associated with reproduction in upland prairies on Mount Pisgah near Eugene, Oregon (Roy et al. 2014).

Figure 5. Barestem biscuitroot with fruits (schizocarps). Photo: USDI, BLM ID931 SOS.

Breeding system and pollination. Barestem biscuitroot produces male and bisexual flowers. The bisexual flowers develop female parts before male parts. Flowers are primarily pollinated by bees, but because there in an overlap in the timing of sexual function between and within umbels, self-pollination is possible (Schlessman 1982; Cruden 1988). Fruit set for flowers freely visited by pollinators was 60 times that of flowers protected from pollinators for other *Lomatium* species (Cane et al. 2020).

Mining bees (*Andrena* and *Micrandrena* spp.) are important barestem biscuitroot pollinators (Cane and Love 2016; Wray and Elle 2016). Both genera were collected from barestem biscuitroot flowers in pollinator surveys conducted in the Great Basin (Cane and Love 2016). In Oregon white oak savannahs on Vancouver Island, British Columbia, mining bees (*A. angustitarsata* and *A. auricoma*) are associated with spring blooming Apiaceeae, specifically barestem biscuitroot, common lomatium (*Lomatium utriculatum*), and Pacific black snakeroot (*Sanicula crassicaulis*). In northern Oregon white oak savannahs of Cowichan Valley, almost 90% of *A. angustitarsata* were collected from *Lomatium* flowers, and in more southern savannahs on the Saanich Peninsula, 95% of *A. angustitarsata* were collected from *Lomatium* flowers. Nearly 60% of *A. auricoma* were collected from *Lomatium* flowers in the northern and 70% from *Lomatium* flowers in the southern savannahs (Wray and Elle 2016).

ECOLOGY

Barestem biscuitroot is a long lived (Hitchcock and Cronquist 2018), shade-intolerant, early maturing species (Marsico and Hellmann 2009). In all but high-elevation populations, vegetative growth, flowering, and seed set typically occurs by early summer (USDA FS 1937; Shock et al. 2016). Plants are dormant from late summer through the winter and do not green-up with fall rains (Shock et al. 2016).

Seed and Seedling Ecology. Studies evaluating barestem biscuitroot seedling establishment found that seed germination is improved when seeds occurred in the openings of intact vegetation (Marsico and Hellmann 2009, Reagan 2014). Germination of seeds still attached to the umbellet, without soil contact was observed in January on Waldron Island, Washington. Seeds making it to the soil surface establish by developing long thin taproots 5 to 12 inches (13-30 cm) deep and up to 0.25 inch (0.6 cm) in diameter in their first 1 to 3 years (Drum 2006).

In a field experiment on Vancouver Island, British Columbia, barestem biscuitroot seed germination was compared at sites within the species' range and at sites to the north of its range to determine limitations on range expansion with climate change. Seed germination was evaluated in plots where existing vegetation was reduced or left intact (Marsico and Hellmann 2009). Seed (86 wild-collected) was planted in 10 feet^2 (1 m^2) plots in July 2006, and germination was assessed in April 2007. Where vegetation was reduced prior to seeding, germination was close to 60% within the range and 50% at northern sites. Where vegetation was left intact, germination was about 45% within the range and 50% at northern sites. Second-year emergence was the same (~ 45%) inside and north of the range where vegetation was reduced but 35% inside and almost 50% north of the range where vegetation was intact. Researchers concluded that the distribution of barestem biscuitroot was dispersal limited, and vegetation reduction did confer an advantage within the species' range but not outside the species' range. At these experimental field sites, seed predation and herbivory were limited, but when deer and elk (*Odocoileus* spp. and *Cervus canadensis*) were excluded, barestem biscuitroot germination was significantly ($P < 0.05$) better (Marsico and Hellmann 2009).

Barestem biscuitroot recruitment generally increased with availability of bare ground and following seed additions in Oregon white oak savannahs in western Washington (Reagan 2014). Seed treatments ranged from 0 to 200 seeds/10 ft^2 [1m^2] plot) and bare ground ranged from 0 to more than 40% with increasing fire severity. No recruitment occurred on burned or unburned sites without seed additions, and recruitment was generally greatest at the highest seeding densities. Severe burns exposed more than 40%, moderate burns more than 20%, and light burns more than 10% bare ground. Recruitment on severely burned sites (~25 seedlings/plot) seeded at the highest density was about half that on moderately burned sites (about 50 seedlings/plot) also seeded at the highest densities (Reagan 2014).

In another field study, researchers found that recruitment of barestem lomatium or common lomatium was higher at sites where estimated stress was higher and lower at sites where stress was lower (Reagan 2014). This conclusion came after monitoring recruitment with seed inputs and vegetation manipulation (focused on removing non-native dominant species) across a latitudinal stress gradient, so that site stress represented a combination of abiotic conditions and presence of non-native species. The 10 sites occurred across a 310-mile (500 km) latitudinal stress gradient in Oregon white oak savannahs from Vancouver Island, British Columbia, to Corvallis, Oregon (Reagan 2014).

Disturbance Ecology. Barestem biscuitroot produces a long, thick taproot (Hickman 1993; Welsh et al. 2016) and typically tolerates aboveground disturbance (Rossman et al. 2018) but is susceptible to belowground herbivory or disturbances (del Moral 1984).

Frequency of barestem biscuitroot was relatively unchanged following thinning and burning treatments in dry ponderosa pine (*Pinus ponderosa*) and Douglas-fir forests (*Pseudotsuga menziesii*) in the Mission Creek Watershed in Washington's Cascade Mountains. Thinning treatments reduced forest basal area by a half to a third (23-42 m^2/ha to 10-14 m^2/ha [139-183 ft^2/acre to 43-61 ft^2/acre), and the prescribed fire scorched 30 to 80% of the remaining overstory trees. Frequency of barestem biscuitroot was 33% before the thinning and burning treatments, 25% in the second or third post-treatment years, and 29% ten to 13 years following treatments (Rossman et al. 2018).

Umbel production was higher on burned than unburned sites 2 years following an October prescribed fire in an upland prairie on Mt. Pisgah near Eugene, Oregon. In the first postfire year, barestem biscuitroot produced about six umbels/plant on burned and eight umbels/plant on unburned plots. Two years following the fire, about 11 umbels/plant were produced on burned sites and about 6 umbels/plant on unburned sites. Plant size was positively associated with reproduction and increasing sources of damage were negatively associated with reproduction (Roy et al. 2014).

In a subalpine meadow in Washington's Olympic Mountains, biomass of barestem biscuitroot decreased with the removal of Idaho fescue (*Festuca idahoensis*) (del Moral 1983). In the same meadow, barestem biscuitroot cover was significantly greater ($P < 0.05$) on transects without marmot (*Marmota* spp.) mounds (1.3%) than on those with mounds (0.2%) (del Moral 1984).

Wildlife and Livestock Use. Barestem biscuitroot is an important spring and summer food for native ungulates, livestock, birds, and insects. Elk and deer feed on barestem biscuitroot (Cowan 1945; Boltz 1979), and pronghorn (*Antilocapra americana*) relish *Lomatium* species (USDA FS 1937). In the Teton Range in Wyoming and Idaho, *Lomatium* species are important forage for bighorn sheep (*Ovis canadensis*), making up more than 5% of their diets (Courtemanch and Kauffman 2009). On the Kluhhane Ridge, Olympic National Park, Washington, mountain goats (*Oreamnos americanus*) preferred barestem biscuitroot. Plants showed evidence of grazing on more than 50% of mountain goat grazed quadrats (Pfitsch and Bliss 1985).

Cattle and domestic sheep feed on barestem biscuitroot. Palatability is good to poor for cattle and excellent for sheep, which readily consume leaves, flowers, and green seeds (USDA FS 1937; Hermann 1966).

Barestem biscuitroot and other *Lomatium* species are also important to birds and insects. On Oregon's Hart Mountain National Antelope Refuge, *Lomatium* species provide cover and food for greater sage-grouse (*Centrocercus urophasianus*) juveniles and adults (Pennington et al. 2016). In south-central Owyhee County in Idaho, *Lomatium* species were common in greater sage-grouse brood-rearing plots and especially important during the early brood rearing period (Wik 2002). Indra, anise, and black swallowtail butterflies (*Papilio indra*, *P. zelicaon*, and *P. polyxenes*) and moths (*Agonopterix oregonensis*) use barestem biscuitroot as a host plant (Pelinia et al. 2009; James and Nunnallee 2011; CA Native Plant Society 2020).

Nutritive value. The nutrient content of barestem biscuitroot was reported for ungulate and human users. Barestem biscuitroot growing in sagebrush communities in Haney Meadow in the Wenatchee National Forest received elk use of 0.71% in June and July and 0.17% in August. At this site, moisture was not limited in the summer. Barestem biscuitroot nutrition was highest early in the season and declined over time (Table 1; Boltz 1979).

Table 1. Nutritional content of barestem biscuitroot growing in the Wenatchee National Forest.

Date (1977)	Gross moisture	Oven-dry moisture	Crude protein	Ash	CS*	Fiber**
	----------------------------%----------------------------					
6/22	74.2	7.4	21.3	9.8	80.3	19.0
7/11	70.4	7.0	15.7	8.7	72.0	27.7
8/1	58.5	2.7	12.6	9.4	69.5	30.2
9/3	14.1	5.4	7.0	6.5	48.4	50.7

*CS: Cell solubles; **Fiber: hemicellulose, cellulose, and lignin-cutin combined. In all months, cellulose was the major fiber.

Ethnobotany. Barestem biscuitroot is used as food and medicine by Indigenous populations. Young barestem biscuitroot plants are high in vitamin C, and one cup contains more than the recommended adult dietary intake (Hilty et al. 1980). Norton et al. (1984) reported levels of ascorbic acid as 43.2 mg/g in a 100 g edible portion.

Barestem biscuitroot was and remains an important food, medicine, and good luck charm for western Indigenous people. It is used as a vegetable, a flavor for meats and stews, a treatment for respiratory and other ailments, and is thought to provide safety or luck (Turner and Bell 1973; Turner et al. 1990; Turner and Cocksedge 2001; Welsh et al. 2016).

Food. Young stems and leaves of barestem biscuitroot are eaten fresh and cooked. Harvesting commonly occurs in the spring just as flowers are developing (Garth 1953; Turner et al. 1990, 2000). Salish children dug and ate the pencil-sized roots like candy and referred to seedlings as Indian candy or licorice root (Drum 2006). Oregon Paiutes ate barestem biscuitroot like celery. They gathered stems in May before seeds matured and ate the stems after removing the outer tissue (Mahar 1953). Warm Springs Indians ate fresh stems from April to June and considered the first leaves pushing through the ground a delicacy (Hilty et al. 1980). Thompson Indians of British Columbia ate young barestem biscuitroot leaves as greens and used seeds to flavor teas, soups, and tobacco (Turner et al. 2011).

The annual root feast of the Yakima Nation at their Longhouse at White Swan, Washington, begins by naming all culturally important foods. The list includes water, salmon (*Oncorhynchus* spp.), venison, barestem biscuitroot, bitterroot (*Lewisia rediviva*), and other foods (Schuster 1975 cited in Winthrop 2014).

Medicine. Stems, leaves, and seeds (Fig. 6) are used to treat fevers, respiratory illnesses, and other aches and pains (Drum 2006). Along the West Coast of British Columbia and into the US, barestem biscuitroot was known by the same name and commonly traded among various tribes (Turner and Bell 1973). The Thompson Indians of British Columbia used a strong decoction of whole plants or stems and leaves for colds, fevers, and colic (Steedman 1928; Turner et al. 1990). Barestem biscuitroot greens mixed with strawberry (*Fragaria* spp.) leaves and ginger root (*Zingiber* spp.) are taken as a vitamin supplement to ward off colds (Turner et al. 1990).

The Salish of southern Vancouver Island considered barestem biscuitroot one of their most powerful medicines. The Saanich and Songish chewed seeds for colds and sore throats and burned them to fumigate houses and drive away ghosts. For headaches, seeds were inhaled like smelling salts while a poultice was placed on the head. The Songish burned seeds with "red paint" and cattails (*Typha* spp.) as an offering in First Salmon ceremonies (Turner and Bell 1971).

Seeds were also a highly valued medicine of the southern Kwakiutl Indians of British Columbia. Carbuncles were treated with chewed barestem biscuitroot seeds, which were covered with warm American skunkcabbage (*Lysichiton americanus*). Headaches were treated by having someone chew seeds and blow on the forehead. Chewed seeds were also applied to aches in the stomach, back, breasts, knees, or any body part. Seeds were eaten to cure constipation and sucked on to ease coughs and sore throats. Barestem biscuitroot was used with twinberry honeysuckle (*Lonicera involucrata*) and tobacco (*Nicotiana* spp.) in a steam bath for general sickness, and this water was drunk by pregnant woman to insure an easy delivery (Turner and Bell 1973).

Figure 6. Barestem biscuitroot with mature schizocarps. Photo: USDA, PSSL.

Other uses. Barestem biscuitroot was also used as a deodorant, perfume, and a good luck, love, or protection charm (Van Allen Murphey 1990; Drum 2006). Southern Kwakiutl sea hunters kept barestem biscuitroot seeds in their canoe boxes to protect against evils and bring good luck (Turner and Bell 1973). The Ditidaht of Vancouver Island, British Columbia, burned seeds to protect them from illness and bad spirits (Turner cited in Turi and Murch 2013). Salish people used seeds as a house fumigant and deodorant and to keep mosquitos away (Drum 2006).

Current medicinal uses. Barestem biscuitroot is used by herbalists today. Seeds are considered as therapeutically effective as medicines from the roots of fernleaf biscuitroot (*Lomatium dissectum*) and can be harvested without killing the plant (Drum 2006).

Horticulture. Barestem biscuitroot is recommended for butterfly and herbal gardens (CA Native Plant Society 2020; Klamath-Siskiyou Native Seeds 2020). It grows well in dry, open habitats, flowers early in the growing season (April-June), produces clusters of yellow flowers on stalks up to 2 feet (0.6 m) tall, and provides food for wildlife (Klamath-Siskiyou Native Seeds 2020), making it a good choice for low-maintenance landscaping at visitor centers, campgrounds, rest areas, etc.

REVEGETATION USE

Barestem biscuitroot and other *Lomatium* species are used for revegetation of sites receiving 14 inches (350 mm) or more annual precipitation (Tilley and St. John 2012). It is a mid-seral species (Walker and Shaw 2005) that grows early in the spring from a deep taproot, which allows it to be competitive with non-native annuals once established (Tilley and St. John 2012; Shock et al. 2016). It also provides valuable food and cover for wildlife and pollinators (see Wildlife and Livestock Use section).

DEVELOPING A SEED SUPPLY

For restoration to be successful, the right seed needs to be planted in the right place at the right time. Coordinated planning and cooperation is required among partners to first select appropriate species and seed sources and then properly collect, grow, certify, clean, store, and distribute seed for restoration (PCA 2015).

Developing a seed supply begins with seed collection from native stands (Fig 7). 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 (UCIA 2015).

Figure 7. Barestem biscuitroot seed collection with many schizocarps and detached umbellets. Photo: USDI BLM OR014 SOS.

Seed Sourcing. Because empirical seed zones are not currently available for barestem biscuitroot, 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 8, 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 Climate Smart Restoration Tool (Richardson et al. 2019) can also guide revegetation planning, seed collection, and seed deployment, particularly when addressing climate change considerations.

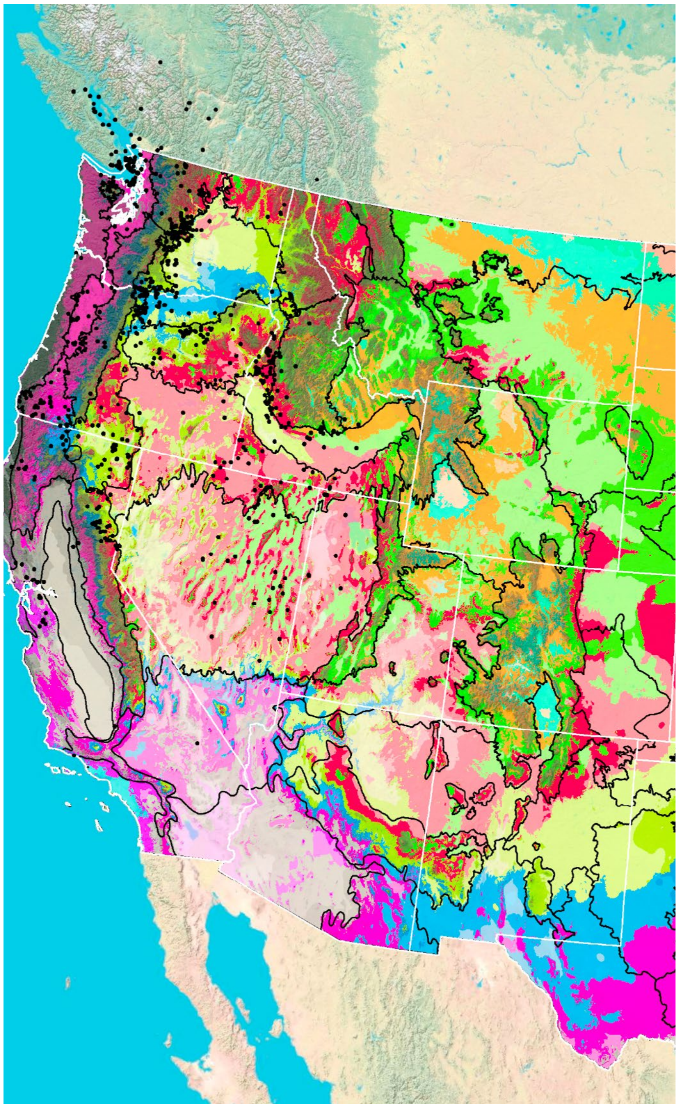

Figure 8. Distribution of barestem biscuitroot (black circles) based on geo-referenced herbarium specimens and observational data from 1881-2016 (CPNWH 2017; SEINet 2017; USDI USGS 2017). Generalized provisional seed zones (colored regions) (Bower et al. 2014) are overlain by Omernik Level III Ecoregions (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, USDI USGS.

Releases. As of 2020, there were no barestem biscuitroot germplasm releases.

Wildland Seed Collection. Schizocarps are typically ready for harvest and detach easily when plant leaves and stems are dry. Hand-stripping is a common method for collecting (N. Shaw USFS RMRS [retired], personal communication, May 2020).

Wildland seed certification. Wildland seed collected for either direct sale or to be used as stock seed for establishment of cultivated seed production fields or for nursery propagation should be Source Identified. This is accomplished by following procedures established by the Association of Official Seed Certifying Agencies (AOSCA) Pre-Variety Germplasm Program that verifies species and tracks seed origin (Young et al. 2003; UCIA 2015). Wildland seed collectors should become acquainted with state certification agency procedures, regulations, and deadlines in the states where they collect.

If wildland-collected seed is to be sold for direct use in ecological restoration projects, collectors must apply for Source Identified certification prior to making collections. Pre-collection applications and site inspections are handled by the AOSCA member state agency where seed collections will be made (see listings at AOSCA.org).

If wildland seed collected by a grower is to be used as stock seed for planting cultivated seed fields or for nursery propagation (See Agricultural Seed Field Certification section), detailed information regarding collection site and collecting procedures, including photos and herbarium specimens must be provided when applying for agricultural seed field certification. Germplasm accessions acquired within established protocols of recognized public agencies, however, are normally eligible to enter the certification process as stock seed without routine certification agency site inspections. For contract grow-outs, this information must be provided to the grower to enable certification. Stock seed purchased by growers should be certified.

Collection timing. Schizocarps are commonly harvested in mid-July (Tilley and St. John 2012). The BLM Seeds of Success program made 44 collections over 11 years in California, Idaho, Nevada, Oregon, and Washington (USDI BLM SOS 2017). Most collections were made in July (Fig. 9). Overall, the earliest seed collection was made on May 31, 2013 in Washington County, Idaho, at 2,163 feet (659 m), and the latest collection was made on September 25, 2002 from Lassen County, California, at 4,191 feet (1,277 m). For the single year with the most collections (21 collections in 2010), the earliest harvest was June 25 at 2,505 feet (764 m) in Gem County, Idaho, and the latest was August 20 at a higher elevation site (5,297 feet [1,615 m]) from Klamath County, Oregon (USDI BLM SOS 2017).

Collection methods. Wildland seed is collected by hand-stripping (N. Shaw USFS RMRS [retired], personal communication, May 2020). Researchers reported collecting 394 seeds from 20 plants on Vancouver Island, British Columbia (Marsico and Hellmann 2009).

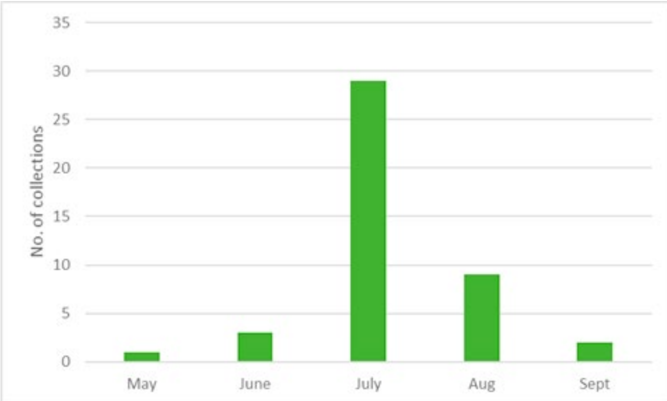

Figure 9. Distribution of barestem biscuitroot seed collections made by the BLM Seeds of Success Program. Seed collections were made in 11 years from 2000-2016 in CA, ID, NV, OR, and WA (USDI BLM SOS 2017).

Several collection guidelines and methods should be followed to maximize the genetic diversity of wildland collections: 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 or related species, particularly those that produce seeds similar in shape and size to those of barestem biscuitroot. Collecting seed from plants retaining their leaves helps to ensure harvests are made from the target species (Camp and Sanderson 2007).

Post-collection management. Seed should be kept in a dry, shaded place until collections can be moved to a controlled short-term storage environment. Short-term storage should be dry, cool, and inaccessible to rodents or other seed predators. If insects are suspected in any collection, seed should be frozen for 48 hours or treated with an appropriate insecticide. The more plant material in the collection, the more ventilation and drying a seed lot will likely need (Gold n.d.; Parkinson and DeBolt 2005; Hay and Probert 2011).

Seed Cleaning. The Bend Seed Extractory shared their procedure for cleaning a 3.5 lb (1.6 kg) harvest of barestem biscuitroot seed. Seed was hand-collected in paper bags from the Umatilla National Forest near Ukiah, Oregon. Seed was first processed using Westrup Model LA-H laboratory brush machine (Slagelse, Denmark) using a #20 mantel and medium speed. Seed (Fig. 10) was then air-screened using an office Clipper (Bluffton, IN) with a 24 round top screen, 8 round bottom screen, medium speed, and low to medium air (Barner 2009).

Figure 10. Barestem biscuitroot mericarps of about 1 cm long and 0.5 cm wide. Photo: USDI, BLM OR030 SOS.

Seed Storage. Dry barestem biscuitroot seeds retained 100% viability after 3 years of storage at -4 °F (-20 °C) and 15% relative humidity (RBG Kew 2020). The Bend Seed Extractory stored dry seed at 33 to 38 °F (0.5-3 °C) (Barner 2009).

Seed Testing. Seed fill can be evaluated be viewing mericarps over a light table (Parkinson and DeBolt 2005). There is no Association of Official Seed Analysts (AOSA) rule for testing germination of barestem biscuitroot.

Viability testing. Because no Association of Official Seed Analysts (AOSA) tetrazolium chloride viability procedure exists for *Lomatium* species, viability procedures should follow those developed for the Apiaceae family. Seed is first imbibed on moist media for 16 hours at 68 to 77 ˚F (20-25 ˚C). Because of deep seed dormancy, barestem biscuitroot seed should be clipped and soaked in giberillic acid (GA_3) overnight before staining. Seed is then cut laterally or longitudinally and exposed to tetrazolium (TZ) concentrations of 0.1 or 1% at 68 to 95 ˚F (20-35 ˚C) for 4 hours or overnight. Staining evaluation varies by species and was not reported for *Lomatium* (AOSA 2010).

Germination. Cold stratification is required for germination of barestem biscuitroot seed. High levels of germination can be achieved with extended periods of stratification, but the duration needed may vary by seed source, after ripening period, or storage conditions (Bartow 2003; Fox 2008; RBB Kew 2020). Karrfalt and Vankus (2012) found that barestem biscuitroot seed germinated best after 8 or more weeks of stratification at 41/50 °F (5/10 °C) under conditions of 16 hours of light and 8 hours of dark. Scarification of the seed did not promote germination. Seed source or storage conditions were not reported. Fox (2008) reported that seed collected in 2005 on Whidbey Island, Washington, and stored at room temperature until testing germinated best (79%) after 6 or 9 weeks of cold stratification. Germination was lower with 12 weeks of stratification (35%), and very low (6%) for untreated seed (Fox 2008).

Researchers at the Royal Botanical Gardens, Kew (RBG 2020) achieved 100% germination for seeds on 1% agar after 140 days at 41 °F (5 °C) in conditions of 8 hours of light and 16 hours of dark. Under the same conditions but with gibberellic acid added to the agar, 100% germination was achieved in 119 days. Using warmer and fluctuating temperatures (68/50 °F [20/10 °C], 8:16 hrs light:dark) resulted in slower or reduced germination (RBG Kew 2020).

Seed from commercial production fields in the Willamette Valley, western Oregon, germinated at 80% after 190 days of cold moist stratification (41 °F [5 °C]). The seed was stored at room temperature for at least 3 months before being tested. Germination was evaluated in a greenhouse with no additional light at 59 to 77 °F (15-25 °C). No germination occurred without stratification or with shorter duration stratifications (61 or 98 days) (Russell 2011).

High levels of germination occurred with 6 weeks of stratification for seed collected from Lane County, Oregon. Seed was sown into cone-tainers filled with Sunshine mix #1 (a soilless peat-based media), micronutrients, and a slow-release fertilizer (14-14-14). Flats were covered with polyethylene bags and placed in a cooler (35 to 40 °F [2-4 °C]) for 6 weeks. Following chilling, flats were placed in the greenhouse (70 °F [21 °C] day and 50 °F [10 °C] night), and germination (90%) occurred within 2 weeks. Seeded flats that were put in the greenhouse without cold stratification showed no germination after 8 weeks, but 90% germination was achieved after these flats were put in the cooler for 6 weeks (Bartow 2003).

Wildland Seed Yield and Quality. Post-cleaning seed yield and quality of seed lots collected in the Intermountain region are provided in Table 2 (USFS BSE 2017). The results indicate that barestem biscuitroot seed can be cleaned to high levels of purity and seed fill but that purity, fill, and viability of pure seed are variable. Average seed weights reported elsewhere in the literature (29,077-55,909 seeds/lb [64,103-123,256/kg]) fell within the range reported in Table 2 (RMRS in-house calculations; Boyer 2008; RBG Kew 2020).

Table 2. Seed yield and quality of barestem biscuitroot 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)	1.64	0.29-6.25	23
Clean weight (lbs)	0.95	0.14-2.78	23
Clean-out ratio	0.63	0.21-0.91	23
Purity (%)	94	78-99	23
Fill (%)[1]	90	73-99	23
Viability (%)[2]	92	82-97	16
Seeds/lb	45,127	24,000-81,000	23
Pure live seeds/lb	35,904	22,037-64,719	16

[1] 100 seed X-ray test

[2] Tetrazolium chloride test

Marketing Standards. Acceptable seed purity, viability, and germination specifications vary with revegetation plans. Purity needs are highest for precision seeding equipment used in nurseries, while some rangeland seeding equipment handles less clean seed quite well. Walker and Shaw (2005) suggest that market seed viability should be 60% to 85%, and purity should be at least 85%.

AGRICULTURAL SEED PRODUCTION

Barestem biscuitroot was grown successfully in seed production fields in Oregon (Boyer 2008; Shock et al. 2016). Heritage Seedlings Inc. reported relatively high seed yields (1,200 lbs/acre [1,345 kg/ha]) and high seed viability for fields grown near Salem (Boyer 2008). At Oregon State University's Malheur Experiment Station, barestem biscuitroot produced seed in the third year and was harvested for 6 years with variable yields (Table 5; Shock et al. 2016, 2018).

Agricultural Seed Certification. It is essential to maintain and track the geographic source and genetic purity of native species produced in cultivated seed fields. This means following Pre-Variety Seed Germplasm (PVG) Certification requirements and standards as administered by state AOSCA offices. The PVG protocols track source and generation of planting stock and require field inspections for compliance. Isolation and control of prohibited weeds or other species are required. Proper seed harvesting, cleaning, sampling, testing, and labeling for commercial sales are monitored (Young et al. 2003; UCIA 2015).

Growers should apply for certification of their production fields prior to planting and plant only certified stock seed of an allowed generation. The systematic and sequential tracking through the certification process requires preplanning, knowing state regulations and deadlines, and is most smoothly navigated by working closely with state certification agency personnel. See the Wildland Seed Certification section for more on stock seed sourcing.

Site Preparation. Barestem biscuitroot should be seeded into a firm, weed-free seed bed (Tilley and St. John 2012).

Fertilization and Weed Management. Almost annual fertilization and herbicide treatments were used at OSU MES to maintain barestem biscuitroot seed production plots (Table 3; Shock et al. 2018).

Table 3. Fertilization and herbicide treatments applied to maintain fernleaf biscuitroot seed production stands seeded in fall 2009 at Oregon State University's Malheur Experiment Station in Ontario, OR (Shock et al. 2018).

Treatment date			Fertilizer			Herbicide			
Year	Fertilizer	Herbicide	N	P	Fe	P	C	G	S
			lbs/acre			lbs/acre			
2012	4/13	11/7	50			10			
2013	3/29	4/3	50	25	0.3		2		
2014	4/2	2/26	20	25	0.3	1	2		
2015	4/15	3/13, 11/6	20	25	0.3	2		1.5	
2016	3/31	10/27	20	25	0.3	1			
2017	4/4	3/28			0.3	1			0.75

*P=pendimenthalin, C=clethodim, G=glyphosate, S=sethoxydim

Seeding. Barestem biscuitroot should be shallowly seeded in the fall. At field sites in Utah, increasing the seeding depth beyond 0.5 inch (1.4 cm) reduced the probability of barestem biscuitroot emergence by up to 31% (Scott Jensen personal communication 2020). Heritage Seedling Inc. used a 10-foot (3 m) wide seed drill to seed barestem biscuitroot. Every other furrow opener was removed providing for 14-inch (36 cm) row spacings. Medium-grade vermiculite was added to the small amounts of barestem biscuitroot seed to provide even distribution (Boyer 2008). At OSU MES, barestem biscuitroot was seeded in silt loam soil using a custom, small-plot, grain drill with disk openers. It was seeded on November 25, 2009 at a rate of 20 to 30 PLS/foot (65-100 PLS/m) of row. Rows were spaced 30 inches (76 cm) apart. Seed was dropped on the soil surface, then covered with a narrow band of sawdust (26 g/m of row) and protected by row cover (N-sulate Deluxe Plus, DeWitt Co., Sikeston, MO) (Shock et al. 2016).

Establishment and Growth. At OSU MES, barestem biscuitroot flowered and produced seed in the third year (2012) after fall planting in 2009 (Table 4; Shock et al. 2016).

Table 4. Timing of flowering and seed harvest dates for barestem biscuitroot seed production fields over a period of 4 years at Oregon State University's Malheur Experiment Station, Ontario, OR. Seed yields are provided in Table 5 (Shock et al. 2016, 2018).

Year	Flower start	Flower end	Harvest
	-----------date---------		
2011	No flowering		
2012	12 Apr	30 May	22 Jun
2013	11 Apr	20 May	10 Jun
2014	7 Apr	13 May	16 Jun
2015	25 Mar	5 May	8 Jun
2016	5 Apr	5 May	6 Jun
2017	12 Apr	15 May	19 Jun

Because barestem biscuitroot produces a taproot and takes years to produce seed, it may be more cost effective to grow plants in densely seeded nursery beds before they reach reproductive age. The first investigation of this propagation method by the Rocky Mountain Research Station's Provo Shrub Sciences Lab (RMRS PSSL), however, failed due to widespread mortality from extensive rodent predation (Jensen et al. 2010).

Irrigation. In trials conducted at OSU MES, barestem biscuitroot seed yield did not respond to irrigation in 5 of 6 years of evaluation (Table 5; Shock et al. 2016, 2018). Irrigation trials delivered 0, 4, or 8 inches (101 or 203 mm) of water through drip tape buried 12 inches (30 cm) deep to assure flowering and limit germination of weed seed. Plots were irrigated four times at about 2-week intervals beginning at the time of bud formation and flowering (Shock et al. 2016). Seed yields ranged from 54 to 701 lbs/acre (60-786 kg/ha), depending on the year (Shock et al. 2016). Interestingly, the one year that seed production was increased with irrigation was a year of above normal precipitation (Shock et al. 2016, 2018). Seed was harvested manually from the middle two rows of each plot and cleaned manually (Shock et al. 2018).

Table 5. Barestem biscuitroot seed yields (lbs/acre) with and without irrigation for 6 years of varied precipitation and growing conditions at Oregon State University's Malheur Experiment Station, Ontario, OR (Shock et al. 2016, 2018).

Year	Ppt. (fall, winter, and spring)	Growing degree (50-86 °F) hours above or below the 25-yr mean	Added irrigation*		
			0 in	4 in	8 in
			Yield (lbs/acre)		
2010	Above normal	0	No flowering		
2011	Above normal	-236	No flowering		
2012	Normal	-351	53.8a	123.8a	61.1a
2013	Below normal	+21	357.6a	499.1a	544.0a
2014	Below normal	+112	701.3a	655.6a	590.9a
2015	Normal	+403	430.6a	406.1a	309.3a
2016	Normal	+251	363.0a	403.7a	332.5a
2017	Above normal	-11	53.7a	159.7b	212.0b
6-yr ave	9.8 inches (fall, winter, and spring)	1,207 hrs	326.7a	374.7a	341.6a

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

Pollinator Management. Barestem biscuitroot is largely pollinated by ground-nesting mining bees (*Andrena* and *Micrandrena* spp.) (Cane and Love 2016; Wray and Elle 2016). Any cultural practices to encourage early emerging pollinators and limit damaging underground nest sites may benefit barestem biscuitroot seed production.

Pest Management. Heavy rodent and bird predation were noted in field studies at the RMRS PSSL and at OSU MES (Jensen et al. 2010; Shock et al. 2015). Leaf miner flies (*Melanagromyza lomatii*) utilize barestem biscuitroot as a host plant. They bore into the upper half of stems (Steyskal 1980). The following fungi use barestem biscuitroot as a host: *Asperisporium peucedani*, *Fusicladium peucedani*, *Phyllosticta* spp., *Pollaccia peucedani*, *Puccinia jonesii*, and *Sphaerella* spp. (Farr and Rossman 2017).

Seed Harvesting. Barestem biscuitroot seed is easily machine harvested (Bartow n.d.; Boyer 2008). The Natural Resources Conservation Service's Plant Materials Center (PMC) in Corvallis, Oregon, ranked barestem biscuitroot as one of the easiest forbs to harvest. Seeds did not shatter when harvested with a small-plot combine (Bartow n.d.). Heritage Seedlings Inc. used a small Allis-Chalmers combine (AGCO Gleaner, Hesston, KS) to harvest barestem biscuitroot seed. The combine is power take-off driven, belt-fed, and used as a stationary combine. It took 2 to 4 hours to harvest 0.15-acre (0.06 ha) plots, and in just 30 minutes, the combine can be cleaned and ready to harvest other plots (Boyer 2008).

Seed Yields and Stand Life. At OSU MES, barestem biscuitroot flowered and produced seed in the third growing season. Seed production was limited in the third year but improved in the following years. Seed can be harvested for 6 years or more (Shock et al. 2018).

NURSERY PRACTICE

Barestem biscuitroot seedlings can be grown successfully in a nursery setting. At the Corvallis PMC, seed collected in Lane County, Oregon, seed was sown into cone-tainers filled with a soilless peat-based media (Sunshine mix #1) with micronutrients and a slow-release fertilizer (14-14-14). Flats were then covered with polyethylene bags and placed in a cooler (35-40 °F [2-4 °C]) for 6 weeks. After stratification, flats were moved to a greenhouse maintained at daytime temperatures of 70 °F (21 °C) and nighttime temperatures of 50 °F (10 °C). Seed germinated at 90% within 2 weeks. One month after coming out of the cooler, flats were moved to a shade house, watered daily, and fertilized (20-20-20) once at mid-growing season. Seedling growth was slow, and it was 5 months before seedlings were considered established (Bartow 2003).

Seedling emergence was lower for seed collected on Vancouver Island, British Columbia. Seed was stratified for 7 weeks (no details), then planted in 6-inch (15 cm) pots (10 seeds/pot) filled with soil and extended release fertilizer (0.09-0.04-0.06). Pots were placed in a greenhouse at 45 to 59 °F (7-15 °C) and given 12 hours of light and dark. After 19 weeks, emergence was 39% (Marsico and Hellmann 2009).

WILDLAND SEEDING AND PLANTING

Barestem biscuitroot can be broadcast or drill seeded for revegetation or restoration of sites receiving (350 mm) or more annual precipitation (Walker and Shaw 2005; Tilley and St. John 2012). Seed should be buried 0.2 to 0.5 inch (0.5-1.2 cm) deep and packed to ensure good seed-soil contact (Tilley and St. John 2012). In wildland restoration, barestem biscuitroot should be a minor component of seed mixes. Although barestem biscuitroot seedlings are slow to establish, plants are competitive once established.

Grazing should be deferred for at least two growing seasons at restoration sites (Tilley and St. John 2012).

In field trials, the use of lightweight N-Sulate fabric was tested in the establishment of forb islands. Researchers found that the density of barestem biscuitroot was slightly greater with cover than without (Gunnell and Summers 2016). Seed mixes were planted in 5-foot × 25-foot (1.5 m × 7.6 m) plots at four sites in the Great Basin region of Utah and one site in the Colorado Plateau where annual precipitation averaged 12 to 14 inches (305-356 mm). Barestem biscuitroot was seeded at 3.6 PLS/feet^2 (39 PLS/m^2), and plots were prepared by using a dixie harrow to remove standing plant material. Across all sites, density of barestem biscuitroot was slightly greater on covered than uncovered sites in year 1 (~0.2 plants ft^2 [2/m^2] more), year 2 (~ 0.04 plants/ft^2 [0.5/m^2] more), and year 5 (~0.14 plants/ ft^2 [1.5/m^2 more). Barestem biscuitroot was one of many species with high survival. In the first year, cover of cheatgrass (*Bromus tectorum*) was also greater in covered than uncovered plots (Gunnell and Summers 2016). When evaluating the Utah sites, barestem biscuitroot density was greater on covered than uncovered plots by almost 0.5 plants/ft^2 (5 plants/m^2) in the first growing season and about 0.3 plants/ft^2 (3 plants/m^2) in the second growing season (Gunnell and Stettler 2015).

In a study to establish barestem biscuitroot on the Tulalip Indian Reservation, survival of barestem biscuitroot was greatest when seedlings were planted in plots where all vegetation was initially cleared. The study compared planting 3-year-old plants into 1) existing vegetation, 2) weeded plots, where all existing vegetation was removed at the time of planting, or 3) weeded plots with a 4- to 6-inch (10-15 cm) layer of wood chips added. Plants obtained from the University of Washington's Center for Urban Horticulture were established in plots in the interior of the Tulalip Reservation, western Snohomish County, Washington. Planting occurred in April, and plots were watered sparingly. First season survival was greater than 80% across all plots, but plants were tallest in the weeded and mulched plots. In the second season, barestem biscuitroot survival was 40% in weeded plots, 30% in weeded and mulched plots, and 20% in vegetated plots (Fox 2008).

ACKNOWLEDGEMENTS

Funding for *Western Forbs: Biology, Ecology, and Use in Restoration* was provided by the USDI BLM Great Basin Native Plant Materials Ecoregional Program through the Great Basin Fire Science Exchange. Great thanks to the chapter reviewers: Amy Bartow, Natural Resources Conservation Service, and Rob Fiegener, Institute for Applied Ecology.

This research was supported in part by the USDA Forest Service, Rocky Mountain Research Station. The findings and conclusions in this publication are those of the authors and should not be construed to represent any official USDA or U.S. Government determination or policy.

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RESOURCES

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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