

Fernleaf biscuitroot (*Lomatium dissectum*)

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Nomenclature

Fernleaf biscuitroot (*Lomatium dissectum* [Nutt.] Math. & Const.) belongs to the Apiaceae or carrot family, Apioideae subfamily, and *Leptotaenia* subgenus (Hickman 1993; Sun et al. 2004).

Family

Apioideae – Carrot family

Genus

Lomatium

Species

dissectum

NRCS Plant Code

LODI (USDA NRCS 2020).

Subtaxa

Lomatium is a taxonomically difficult genus (Hermann 1966). The following varieties are recognized by USDA NRCS (2020): *Lomatium dissectum* var. *dissectum*; *Lomatium dissectum* var. *multifidum*.

Synonyms

Leptotaenia dissecta Nutt. (USDA NRCS 2020).

Common Names

Fernleaf biscuitroot, carrotleaf biscuitroot, chocolate tips, fernleaf desert-parsley, giant lomatium, lace-leaved leptotaenia, wild carrot (Franklin and Dyrness 1973; Andersen and Holmgren 1976; LBJWC 2015; Hitchcock and Cronquist 2018; USDA NRCS 2020).

Chromosome Number

2n = 22 (Bell and Constance 1960; Crawford and Hartman 1972; Munz and Keck 1973).

Hybridization

No hybridization has been documented for *Lomatium* (Hitchcock and Cronquist 2018).

Distribution

Fernleaf biscuitroot is widespread with scattered populations throughout the western US and adjacent parts of southwestern Canada. Populations occur from British Columbia to Saskatchewan and south to New Mexico and California (Tilley et al. 2010; Welsh et al. 2016; BONAP 2017). Variety *dissectum* occurs primarily west of the Cascade Mountains where the average annual precipitation typically exceeds 39 in (1,000 mm). Variety *multifidum* is most common east of the Cascade Mountains in semiarid habitats (Scholten et al. 2009; Serpe and Novak 2011). Though common, populations can be small, scattered, or disjunct (Hermann 1966; USDA NRCS 2020).

Habitat And Plant Associations

Fernleaf biscuitroot occurs in a variety of plant communities and environments ranging from rocky outcrops and dry open slopes to riparian habitats (Craighead et al. 1963; Hermann 1966; Andersen and Holmgren 1976; Crawford 2003). It is common in grasslands (Fig. 1), mountain meadows, sagebrush (*Artemisia* spp.) steppe (Fig. 2) and is also found in desert shrublands, woodlands, and forests. In the Inland Northwest, fernleaf biscuitroot is common in meadow steppe, shrub steppe, and mountain meadow vegetation (Fig. 3) (Pavek et al. 2012). In the Columbia Basin of Washington, it is common in streamside Oregon white oak (*Quercus garryana*)- and white alder (*Alnus rhombifolia*)-dominated woodlands that experience temporary flooding (Crawford 2003).



Figure 1. Fernleaf biscuitroot growing in a dry grassland near Craters of the Moon National Monument in south-central Idaho. Photo: USFS, RMRS.



Figure 2. Fernleaf biscuitroot growing with big sagebrush, rabbitbrush, and cheatgrass near Homedale, ID. Photo: USFS, RMRS.

In California, fernleaf biscuitroot occurs in rocky places in oak (*Quercus* spp.) woodlands, pinyon-juniper (*Pinus-Juniperus* spp.) woodlands, and mixed-conifer forests (ponderosa pine [*P. ponderosa*], California red fir [*Abies magnifica*], lodgepole pine [*P. contorta*]) (Munz and Keck 1973). In a study of soil, plant community, and climate relationships in south-central Idaho, fernleaf biscuitroot was a uniformly distributed, dominant species in basin big sagebrush (*Artemisia tridentata* subsp. *tridentata*) and antelope bitterbrush (*Purshia tridentata*) shrublands at Craters of the Moon National Monument. Here fernleaf biscuitroot production ranged from 394 to 513 lbs/ac (442–575 kg/ha) over 4 years (Passey et al. 1982). In a survey of low sagebrush (*A. arbuscula*) and black sagebrush (*A. nova*) communities in northern Nevada, fernleaf biscuitroot constancy was 100% in low sagebrush-Thurber's needlegrass (*Achnatherum thurberianum*) communities and 40% in low sagebrush-Idaho fescue (*Festuca idahoensis*) communities. Fernleaf biscuitroot did not occur in black sagebrush-dominated shrublands (Zamora and Tueller 1973).

In Utah, fernleaf biscuitroot occurs in many of the aforementioned communities but also in oak-maple (*Acer* spp.), aspen-fir (*Populus-Abies* spp.), mountain shrub, and ponderosa pine vegetation (Fig. 4) (Welsh et al. 2016). In Jackson Hole Wildlife Park, Wyoming, fernleaf biscuitroot was abundant in big sagebrush (*Artemisia tridentata*) vegetation but also common in willow (*Salix* spp.)-dominated shrub swamps (Reed 1952). In the Gunnison National Forest in Colorado, fernleaf biscuitroot occurs in Gambel oak-Saskatoon serviceberry (*Q. gambelii-Amelanchier alnifolia*) communities (Komarkova et al. 1988). Understory species often associated with fernleaf biscuitroot include bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue, brome grasses (*Bromus* spp.), arrowleaf balsamroot (*Balsamorhiza sagittata*), poison hemlock (*Conium maculatum*), cow parsnip (*Heracleum maximum*), and other *Lomatium* species (Thompson 1986; USU Ext 2017).

Elevation

Fernleaf biscuitroot occupies low-elevation to subalpine sites (Hitchcock and Cronquist 2018). Across its range, it occurs at elevations from 490 to 10,700 ft (150–3,250 m). In Utah, the elevation range is 4,200 to 10,660 ft (1,280–3,250 m) (Welsh et al. 2016). In California, variety *dissectum* generally occupies a narrower and lower elevation range (2,000 to 6,600 ft [600–2,000 m]) than variety *multifidum* (500–9,800 ft [150–3,000 m]) (Munz and Keck 1973; Hickman 1993).



Figure 3. Fernleaf biscuitroot growing in a moist shrubland at the base of a scree slope. Photo: USDI BLM ID931 Seeds of Success (SOS).



Figure 4. Fernleaf biscuitroot growing with grasses and arrowleaf balsamroot at the edge of a ponderosa pine forest in Oregon. Photo: BLM OR135, SOS.

Soils

Fernleaf biscuitroot grows in a variety of soil types, including rocky to fine-textured and acidic to alkaline soils (USU Ext 2017; Hitchcock and Cronquist 2018). While a variety of soil conditions are tolerated, including high CaCO₃ levels (LBJWC 2015), it is most common in well-drained, dry, rocky soils particularly those on talus slopes (Craighead et al. 1963; Taylor 1992). Fernleaf biscuitroot grows well in soils with pH of 6.5 to 7.5 (Tilley et al. 2010).

More specific soil conditions were described for fernleaf biscuitroot growing in grasslands and shrublands in Idaho and Wyoming. In Fendler threeawn (*Aristida*

purpurea var. *longiseta*) and bluebunch wheatgrass grasslands in central Idaho's Snake and Salmon river drainages, fernleaf biscuitroot occurred on steep south and west slopes with skeletal colluvial soils but not on gentle alluvial fans and terraces. On the steep slopes, soils were old with shallow A and well-developed B horizons. Soils were very stony loams to silt loams, 1.6 to 3.3 ft (0.5–1 m) deep with 3 to 4% organic matter. Moisture holding capacity on the steep slopes was low. On the fans and terraces, soils were 5 to 6.5 ft (1.5–2 m) deep loams to sandy loams with weak profile development and 1.8 to 3.5% organic matter. At both topo-edaphic sites, moisture content up to 4 in (10 cm) deep was below the wilting point by early July (Evans and Tisdale 1972). In Jackson Hole Wildlife Park, Wyoming, fernleaf biscuitroot occurred in big sagebrush communities where soils were fine to coarse sandy loams, 10 ft (3 m) or deeper, with high gravel content and an inch (2.5 cm) or more of soil surface litter. In the Park, fernleaf biscuitroot also occurred in willow-dominated shrub swamps with a water table near the soil surface (Reed 1952).

Description

Fernleaf biscuitroot is a sturdy, large, long-lived perennial (Fig. 5) from a stout caudex and thick, sometimes branching, woody taproot (Fig. 6). Plants can reach 5 ft (1.5 m) tall with roots up to 2 in (5 cm) thick and extending more than 2 ft (0.6 m) deep (Marshall 1977; Tilley et al. 2010; Hitchcock and Cronquist 2018). Stems are ascending and hollow. Herbage is aromatic and glabrous to puberulent or minutely scabrous (Andersen and Holmgren 1976; Hickman 1993; Lesica 2012; LBJWC 2015; USU Ext. 2017). Basal and stem leaves are produced, but stem leaves are less common and much smaller than basal leaves (Taylor 1992; Pavék et al. 2012). Leaves are often somewhat rough-textured or scabrous (Hitchcock and Cronquist 2018). Leaves are pinnately or ternate-pinnately dissected into fern-like leaflets (Hickman 1993; USU Ext 2017). Large mature leaves are 4 to 12 in (10–30 cm) long with petioles up to 12 in (30 cm) long (Welsh et al. 2016). Terminal leaflets are 0.1–0.3 in (2–7.5 mm) long (Hitchcock and Cronquist 2018). Petioles are lacking on stem leaves (Welsh et al. 2016).



Figure 5. Fernleaf biscuitroot with bright green, heavily dissected leaves and tiny yellow flowers in a compound umbel. Photo: BLM ID230 SOS.



Figure 6. The thick, sometimes branching taproots of fernleaf biscuitroot support a stout caudex. Photo: USFS RMRS.

Flowers are produced in large compound umbels (Fig. 5) (Craighead et al. 1963). Peduncles (6–24 in [15–60 cm]) support umbels that are usually solitary (Welsh et al. 2016). Umbels produce 10 to 30 rays that vary in length from 1 to 5 in (3–13 cm) long and are topped by umbellets (Munz and Keck 1973; Hickman 1993). Compound umbels are comprised of a combination of 50 to 200 male and bisexual flowers (Thompson 1998). All flowers are small, lack sepals, have five stamens, and five greenish yellow, yellow, or purple petals (Fig. 7) (Taylor 1992). Male flowers lack pistils and are common on the central, shorter rays (see Reproduction section) (Andersen and Holmgren 1976; USU Ext 2017). Bisexual flowers produce dry, two-seeded fruits (schizocarps) (Fig. 8) (Taylor 1992). Schizocarps are flattened dorsally, oblong to oval, 0.4 to 0.6 in (1–1.6 cm) long, 0.2 to 0.4 in (0.4–1 cm) wide, and have flat-winged edges (Munz and Keck 1973; Hitchcock and Cronquist 2018). Schizocarps include two mericarps (seeds) that remain attached along their midlines until ripe. A single umbel can produce hundreds of seeds (Thompson 1985).



Figure 7. *Lomatium dissectum* var. *dissectum* with purple flowers, although they can be yellow. Photo: USFS RMRS.

Variety *dissectum* leaves are generally smaller (segments 2–8 mm long and 1.5–3 mm wide) than those of variety *multifidum* (2–22 mm long and 0.5–2 mm wide). Variety *dissectum* often produces maroon to purple flowers with 0.04 to 0.1-in (1–3 mm) pedicles (Fig. 7),

flowers can be yellow, but this is less common. Variety *multifidum* produces yellow flowers with 0.2 to 0.6-in (5–15 mm) pedicles (Hickman 1993).



Figure 8. Fernleaf biscuitroot umbels with immature schizocarps. Photo: BLM ID230 SOS.

Reproduction

Fernleaf biscuitroot reproduces from seed. High levels of seed production are possible with pollination. Under optimal conditions, Cane et al. (2020) estimated that 25 plants could produce 21,675 seeds, but flowering and seed production can be highly erratic and diminished with predation (Thompson 1998). Large plants may produce umbels with all perfect flowers (Thompson 1998), but in a research garden near Logan, Utah, umbels averaged 17 umbellets, each with some male flowers (Cane et al. 2020). Bisexual flowers had receptive pistils before stamens matured. Bisexual umbellets averaged 21 flowers, 16.8 of which were bisexual and 4.5 were male. Almost a third (27%) of umbellets, primarily the innermost ones on shorter rays, were entirely staminate (Cane et al. 2020).

Multiple years of observations at Smoot Hill Biological Research Area (SHBRA) north of Pullman, Washington, revealed important information concerning fernleaf biscuitroot life history and ecology (Thompson 1983, 1986, 1998). Flowering of fernleaf biscuitroot was highly erratic. When 103 fernleaf biscuitroot plants in the SHBRA were monitored for 10 years, most did not flower every year (Thompson 1983). The proportion of plants to flower in any year ranged from 4 to 34% (Thompson 1998). Because plants were at least 2 years old when marked (Thompson 1998), and because fernleaf biscuitroot plants do not produce flowers until age 3 or 4 (Shock et al. 2016), failure to flower may have been related to plant age. The number of umbels produced per flowering plant also varied greatly during these studies. Some produced just one while others produced five or more umbels. Germination and establishment were also highly erratic (Thompson 1983, 1998).

A study of moth larvae (*Greya subalba*) feeding on fernleaf biscuitroot was also conducted at SHBRA. Fernleaf biscuitroot plants produced one to several umbels comprised of 20 to 30 umbellets. Female moths laid eggs in a few schizocarps on each umbellet visited, and larva emerged in most umbels. Over 3 years of observations,

female moths probed an average of 2.7 schizocarps/umbellet, leaving 8.3 unprobed (Thompson 1986).

Phenology

Fernleaf biscuitroot flowers in spring or early summer often at the same time as arrowleaf balsamroot (Craighead et al. 1963; Eldredge et al. 2013). Phenology was earlier as winter precipitation decreased and spring temperature increased in a 14-year study (1995–2008) of grassland vegetation in Missoula, Montana (Lesica and Kittelson 2010). The average date of earliest flowering for fernleaf biscuitroot was April 20. The earliest flower date advanced over the course of study, although not significantly. Average March temperature and December and January precipitation were explanatory variables in the best-supported multiple linear regression model for average earliest flowering date. Over the course of the study, December plus January precipitation declined an average of 0.2 in (4.8 mm)/year, and March temperature increased 0.36°F (0.2°C)/year (Lesica and Kittelson 2010).

Pollination

Fruit set for fernleaf biscuitroot flowers depends on pollination, particularly from bees (unpublished data cited in Cane and Love 2016). In experiments, only 3 of 20 bagged umbels produced fruits, compared to 27 of 35 unrestricted umbels (Cane et al. 2020). Although manipulated crossing treatments showed that fernleaf biscuitroot is self-compatible, pollinator access to flowers increased fruit production by 60 times. Given adequate pollination, mature fernleaf biscuitroot plants have exceptional seed production capacity. Of 25 plants evaluated, each plant averaged three bisexual umbels composed of 10 umbellets, each with 17 bisexual flowers, for a total of 510 bisexual flowers/plant. Pollinated flowers averaged 1.7 seeds/bisexual flower. With complete pollination, 25 plants could produce 21,675 seeds (Cane et al. 2020).

Bees are important fernleaf biscuitroot pollinators, especially mining bees (*Andrena* spp.), some of which specialize on *Lomatium* species (Cane and Love 2016). In a survey of bees and their floral associations at 219 locations covering over 130,000 mi² (340,000 km²) in Idaho, Nevada, Utah, and Wyoming, bees were swept from 295 fernleaf biscuitroot plants from late April to June. Sweeps captured 82 bees representing 5 genera: 55.2% nonsocial, ground-nesting, mining bees (*Andrena* spp.), 40% mini-mining bees (*Micrandrena* spp., an *Andrena* subgenus), 2.2% sweat bees (*Lasioglossum* spp.), 1.5% cuckoo bees (*Nomada* spp.), and 0.7% sweat bees (*Halictus* spp.). The predominant fernleaf biscuitroot visitors were pollen specialists (Cane and Love 2016). Of the 16 mining bee species visiting *Lomatium* species, only one was found visiting another species (arrowleaf balsamroot). Complete segregation of mining bees by floral host is common (Cane and Love 2016).

Ecology

Fernleaf biscuitroot is a long-lived (>10 years), perennial that completes its annual life cycle early in the growing season (Thompson 1998; Hitchcock and Cronquist 2018). Growth begins just after snow melts in the spring and ends before hot summer weather arrives (Skinner et al. 2005; Tilley et al. 2010). Plants tolerate partial shade but are most common in full sun or in forest and woodland openings (Pavek et al. 2012; LBJWC 2015; USU Ext 2017). Their large taproot allows them to survive fire and heavy aboveground predation (Love and Cane 2019).

Seed And Seedling Ecology

Controlled studies suggest that fernleaf biscuitroot may produce a seed bank (Fig. 9) (Scholten et al. 2009), although a proportion will likely be lost to predation (Thompson 1985, 1986). In experiments, viability was reduced but not lost to dehydration (Scholten et al. 2009). In this study, dehydration of imbibed seed was used to simulate spring drying of seeds to test the potential survival of ungerminated seed. Dehydration of seeds that were cold stratified for 10 weeks reduced seed viability from 96% to 61%. Seeds surviving dehydration did not germinate after being rehydrated but did germinate after 7 weeks of cold moist stratification. While final germination of dehydrated seed (33%) was much lower than that of control seeds (97%), 29% of ungerminated dehydrated seed remained viable but had deep dormancy, suggesting the potential for persistence in the seed bank. When fernleaf biscuitroot seeds were buried in mesh bags in mid-November, 31% of seed germinated by early March and 50% germinated by 2 June. Of the seed that remained ungerminated in the soil, 81% were viable. Viability decreased to 52% a month later, and to 30% by the start of fall (Scholten et al. 2009).



Figure 9. Single fernleaf inflorescence with some schizocarps attached but others dispersed. Photo: BLM/RMRS, SOS.

A proportion of developing and dispersed fernleaf biscuitroot seed is lost to predation. Losses to seed-feeding insects and small mammals likely vary from year to year. Researchers collected 13 adult *Smicronyx* weevils from

umbels bearing developing seeds in a natural fernleaf biscuitroot population growing near Logan, Utah (Cane et al. 2013). Umbellets produced an average of 11 schizocarps over a 3-year period. Female moths (*G. subalba*) laid eggs in an average of 2.7 schizocarps in each umbellet, which left an average of 8.3 schizocarps per umbellet unaffected over 3 years of observations at SMBR (Thompson 1986).

Disturbance Ecology

Fernleaf biscuitroot is fire tolerant, and its abundance is typically unchanged or increased after fire. Following an extremely hot winter fire in a rough fescue (*Festuca campestris*) grassland in southwestern Alberta, fernleaf biscuitroot cover was relatively unchanged in the first post-fire year in both the interior and perimeter areas of the fire. In this study, post-fire precipitation was considered favorable for vegetation recovery (Bork et al. 2002). Fernleaf biscuitroot cover increases were considerable following a low-severity August fire in canyon grasslands in northern Idaho. Before the fire fernleaf biscuitroot cover was less than 0.05% and by the third post-fire year it was 0.84%. Again, post-fire moisture conditions were favorable (Gucker and Bunting 2011).

Seven-year old fernleaf biscuitroot plants were very fire resistant, and burned plants produced more flowers than unburned plants when controlled burning was evaluated at Oregon State University's Malheur Experiment Station (Love and Cane 2019). Individual plants were burned using a propane burner in mid- to late August, when the air temperature range was 64 to 97°F (18–36°C) and plants were well into senescence. Burning achieved very low 120°F (49°C), low 135°F (57°C), moderate 151°F (66°C), high 24 °F (102°C), and very high 264°F (129°C) temperatures at 0.8 in (2 cm) below the soil surface. Of the 125 burned and control plants, 96% of unburned and 93% of burned survived the first post-fire year, and all survivors flowered. Burned plants produced double or triple the number of umbels produced by unburned plants, but fire temperature did not affect per plant umbel production. Taproot crowns were buried 1.4 to 3 in (3.5–8 cm) deep in a natural population of mature fernleaf biscuitroot growing naturally near Logan, Utah, suggesting good insulation from high fire temperatures. Because fernleaf biscuitroot survives fire and its primary miner bee pollinator is a ground-nester with a spring flight season, this specialized plant-pollinator relationship is nearly fireproof (Love and Cane 2019).

Predation. Many insects and other animals feed on fernleaf biscuitroot (Thompson 1998; Karban et al. 2004). While aboveground herbivory can severely impact reproduction, belowground herbivory has a more immediate negative affect on survival (Thompson 1998). Levels of herbivory were monitored for 3 years from mid-June until plants senesced in a big sagebrush community near Mammoth Lakes, California (Karbon et al. 2004). In 2000, there was little herbivory on fernleaf biscuitroot leaves and almost no flowering. Most plant damage was caused by grasshoppers and a specialist web-building caterpillar (*Depressaria leptotaeniae*). Herbivory was greater in 2001. Many flowers and fruits were produced, but they were heavily attacked by mule deer (*Odocoileus hemionus*), black-tailed jackrabbits (*Lepus californicus*), or mountain beavers

(*Aplodontia rufa*). In 2002, leaf herbivory by mammals was again high, and there was little seed production (Karbon et al. 2004).

Fernleaf biscuitroot seed was taken by small mammals (*Peromyscus* spp.), darkling beetles (*Eleodes nigrina*), and others in field experiments at Smoot Hill Biological Reserve (Thompson 1985). Piles of 5 and 10 fernleaf biscuitroot and nineleaf biscuitroot [*Lomatium triternatum*] seed were placed at 6.6-ft (2 m) intervals along three transects in mid-July 1981 and checked monthly. After 43 weeks (May 1982), just 9.1% of the seeds remained, and less than 2% of these seeds were intact, suggesting few seeds survive more than one winter. In experiments to determine if seed predators showed a preference between fernleaf and nineleaf biscuitroot species, piles of 300 seeds of both species were set out in mid-July 1983. All but 2 of 300 piles were discovered within the first month of trials. Significantly more fernleaf biscuitroot seed than nineleaf biscuitroot seed was taken ($P < 0.001$). Seeds were taken more rapidly from pure fernleaf biscuitroot piles than from pure nineleaf biscuitroot piles and fernleaf biscuitroot was preferentially taken from mixed-species seed piles ($P < 0.0001$) (Thompson 1985).



Figure 10. Fernleaf biscuitroot umbel covered with aphids at the USFS Lucky Peak Nursery near Boise, ID. Photo: USFS RMRS.

Pocket gophers (*Thomomys talpoides*) caused the most severe injury to fernleaf biscuitroot in a 10-year study of attacks on tagged plants at Smoot Hill Biological Reserve (SMBR) (Thompson 1998). Attacks on leaves, flowers, and roots from major enemies (rust [*Puccinia*], gall flies [*Contarinia*], leaf miners [*Phytomyza*], moth larva [*Depressaria*], and grazing mammals (white-tailed deer [*Odocoileus virginianus*], eastern cottontail [*Sylvilagus floridanus*], and northern pocket gophers [*Thomomys talpoides*]) were monitored on 103 plants that were at least 2 years old. Survivorship between years was 90%. After 10 years, 35% of tagged plants were still alive. Average life span of tagged plants was an estimated 6.3 years. At least 43% of deaths were attributed to root feeding by pocket gophers. Nearly 70% of the plants were attacked by at least one of the five aboveground herbivores or pathogens. Plants surviving until the end of the study had been affected by most of these species. Rust and leaf miners were the most consistent, infecting 30% or more of plants in at least half of the years. Anise swallowtail butterflies

(*Papilio zelicaon*) and tortricid moths (*Sparganothis* spp.) that consume leaves and flowers, aphids (*Aphis* spp.) that cluster on the flowering stalks just below the inflorescence (Fig. 10), and moths (*Greya subalba*) that oviposit in developing seeds (Fig. 10) were rare in this study (<1% observations) (Thompson 1998).

Wildlife And Livestock Use

Fernleaf biscuitroot is a food source for a variety of wildlife from bears to bees. It is crucial early season forage for many wildlife species and domestic grazers due to its high biomass production (Craighead et al. 1963; Tilley et al. 2010). Fernleaf biscuitroot is also an important component of greater sage-grouse habitat (Lambert 2005) and chick diets (Drut et al. 1994).

Large mammals. Bear (*Ursus* spp.), mule deer, pronghorn (*Antilocapra americana*), mountain goats (*Oreamnos americanus*), and other large mammals feed on fernleaf biscuitroot. In a literature review of grizzly bear (*U. arctos*) food habits in the US Northern Rocky Mountains and southern British Columbia, fernleaf biscuitroot stems were a highly preferred food (Mace and Bissell 1986). Fernleaf biscuitroot was one of the seven plants most frequently associated with black bears (*U. americanus*). It was considered a very important food in black bear habitats in and adjacent to the Middle Fork Weiser River, east of Council, Idaho (Amstrup and Beecham 1976).

Feeding habitats of a total of 10,174 mule deer were observed and monitored from June 1983 to April 1985 on the Umatilla Reservation in northeastern Oregon. Mule deer preferred habitats with high cover of fernleaf biscuitroot and mule-ears (*Wyethia amplexicaulis*) in bluebunch wheatgrass-Sandberg bluegrass (*Poa secunda*) communities (Bodurtha et al. 1989). Deer also clipped fernleaf biscuitroot flowers, costing researchers their pollination experiments in a common garden near Logan, Utah (Cane 2007). In a feeding trial to assess the accuracy of fecal analysis, fernleaf biscuitroot made up 33% of the five species diet fed to captive pronghorn. Fernleaf biscuitroot was 22% of pronghorn diets based on fecal analysis (Smith and Shandruk 1979). In the Swan Mountains of western Montana, fernleaf biscuitroot was eaten by mountain goats in May, June, and early July and was most important in May diets (Chadwick 1974).

Birds. *Lomatium* species are commonly consumed by greater sage-grouse and were found in dissected crops (Pennington et al. 2016). In southeastern Oregon, average frequency of fernleaf biscuitroot in the crops of greater sage-grouse chicks ranged from 3 to 33% at three sagebrush-antelope bitterbrush sites. Frequency of fernleaf biscuitroot in crops was greatest at the site with the largest and most productive greater sage-grouse populations (Drut et al. 1994).

Insects. Fernleaf biscuitroot is important to many insects including native bees, moths, butterflies, and predatory or parasitoid insects (La Berge 1977; Thompson 1983; James and Nunnallee 2011; LBJWC 2015). *Lomatium* species are host plants for Anise swallowtail (*Papilio zelicaon*), and Indra swallowtail (*P. indra*) feeds on *Lomatium* nectar (James and Nunnallee 2011). Larvae of *Greya subalba* moths feed on fernleaf biscuitroot seed

(Thompson 1986). Female moths (*Depressaria leptotaeniae*) oviposit in leaf petioles surrounding unopened umbels in early spring. Early instar larvae develop and feed on flower buds and petiole tissue. Later instar larvae feed either in the umbels or on the leaves (Thompson 1983). Native bees, especially mining bees collect fernleaf biscuitroot pollen (La Berge 1973; Ribble 1974; La Berge 1977, 1985, 1989). At a total of 15 western sagebrush steppe and juniper woodland locations, eight bees were collected for every 100 flowering fernleaf biscuitroot plants inspected. Bee abundance ranged from 3 to 109 per 100 umbels (Cane et al. 2020).

Ethnobotany

Fernleaf biscuitroot was and continues to be used for food, medicine, and ceremonies by Indigenous peoples of the western US and southwestern Canada. Some American Indian men carried the seed of *Lomatium* species as a love charm (Van Allen Murphey 1990). The pulverized root was also burnt as incense by tribes in Utah (USU Ext 2017).

Foods. Roots and early shoots of fernleaf biscuitroot were an important food for some tribes (Salish [Mullin et al. 1997] and Sanpoil [Turner et al. 1980]) but considered a starvation food by others (Nez Perce [Marshall 1977] and Southern Okanogan [Turner et al. 1980]). Okanogan-Colville people harvested and ate young fernleaf biscuitroot shoots before they emerged and before they turned purple (Turner et al. 1980). The shoots, about 2 in (5 cm) long, were found by searching for dead stalks from the previous year. New white shoots were eaten as a relish alone or with meat and said to have a dill flavor. These shoots were thought to aid in adapting to the coming summer heat (Turner et al. 1980). Indigenous peoples commonly harvested and ate the roots. They were eaten raw, baked, roasted, and dried and made into a flour (Craighead et al. 1963). Fernleaf biscuitroot roots were regularly pit cooked by the interior Salish people of the British Columbia plateau (Mullin et al. 1997). Sanpoil people held a First Roots ceremony that featured fernleaf biscuitroot and arrowleaf balsamroot (Turner et al. 1980). Sacajawea reportedly showed Lewis and Clark how and when to dig *Lomatium* roots (Van Allen Murphey 1990). Roots dug from plants that had produced seed had improved storage life.

Technological uses. Mature stems and roots were considered poisonous by Okanogan-Colville tribe. Roots were pounded and steeped in water overnight to make an infusion used to poison fish. Ten mature roots in a bucket of water would kill fish in a section of the creek. Poisoned fish were safe to eat (Turner et al. 1980).

Traditional medicinal uses. American Indians used and continue to use the roots of fernleaf biscuitroot to treat various internal and external ailments (Zigmond 1981; Park and Fowler 1989). Fernleaf biscuitroot was used as an inhalant, tea, and poultice to treat respiratory issues, skin ailments, and skin wounds. During the influenza pandemic of 1917, it was used with reportedly good results, especially in the southwestern US (USU Ext 2017).

The Kawaiisu people of California roasted roots then peeled them to expose the white interior of the root, which was mashed on rocks and kneaded in hot water. This mash was used to treat cuts, wounds, and sore muscles

(Zigmond 1981). Shoshone people collected oil that oozed from cut roots to treat trachoma (Johnston 1970). The Northern Paiute of western Nevada boiled fernleaf biscuitroot roots and rubbed the oily broth on joints for rheumatism, pimples, sores, and aches (Park and Fowler 1989). The Okanogan-Colville made a tea from roots to treat tuberculosis and arthritis, but tea made too strong was poisonous (Turner et al. 1980). The northern Cheyenne and Blackfoot Indians of Montana used fernleaf biscuitroot tea to ease chest pains and aid people in a weakened condition (Johnston 1970; Hart 1981). To treat dandruff an inch-long (2.5 cm) piece of root was pounded and soaked in cold water for at least 12 hours, then applied multiple times to the scalp. Lakes Okanogan-Colville tribes used roots in a “steam bath” for rheumatism, pains, pneumonia, and other issues. Hot rocks were placed in a trench, then covered with a layer of dirt, then a layer of crushed, roasted roots. The patient lay on the roots, covered with a blanket until the bed cooled (Turner et al. 1980). The Northern Paiute placed cut pieces of fernleaf biscuitroot roots on a fire and inhaled the fumes to treat colds (Park and Fowler 1989).

Veterinary uses. Fernleaf biscuitroot was used to treat livestock illnesses. Blackfeet used smoke from burning roots as an inhalant or in decoction to treat distemper in horses (Johnston 1970). Mature fernleaf biscuitroot stems and roots were used by Okanogan-Colville to kill lice on cattle and horses (Turner et al. 1980).

Current Medicinal Use

Laboratory screenings indicate that fernleaf biscuitroot has antiviral and antibacterial properties. Fernleaf biscuitroot inhibited the cytopathic effects of bovine rotavirus (Reoviridae), which causes gastroenteritis, a major infection of the world's population today (McCutcheon et al. 1995; Castle et al. 2014). Of the plant species tested, fernleaf biscuitroot had some of the greatest activity against the pathogenic bacteria evaluated. At 20 mg, fernleaf biscuitroot greatly inhibited growth of *Mycobacterium tuberculosis* and *M. avium*, and at 100 mg strength completely inhibited growth (McCutcheon et al. 1997).

Fernleaf biscuitroot and other *Lomatium* species are sold as herbal medicines. *Lomatium* species are part of an herbal tincture to treat herpes simplex virus (Conroy and Milkis 2013). Fernleaf biscuitroot is marketed as LDM-100 and recommended for treating influenza. However, whole body rashes lasting up to 7 days were reported by some taking high doses of LDM-100 (Marshall and Thornton 2018).

In a study evaluating the risk of overharvesting medicinal plants, fernleaf biscuitroot ranked in the top 11 of 40 species potentially overharvested. The ranking tool took into consideration demand, habitat, population size, harvest effects on individual plants and populations, and life history (Castle et al. 2014).

Horticulture

Fernleaf biscuitroot plants are marketed as drought tolerant, medicinal, native plants. Low water use, conspicuous flowers, and tolerance of high CaCO₃ and partial shade, make fernleaf biscuitroot a desirable plant for native home landscaping, public use recreation areas, and other low-maintenance landscaping situations (LBJWC 2015). Fernleaf biscuitroot seed can be sown outdoors in pots or in the ground in late August or early September. Plants grow readily from seed when provided extremely long stratification, but even then, some seed may not germinate until the following growing season. Seedling growth is slow, and it takes 2 years for plants to reach transplant size and 2 or more years to flower (Skinner et al. 2005).

Revegetation Use

Fernleaf biscuitroot is a valuable addition to wildland restoration seed mixes because it is long-lived, competitive with weeds once established, provides important early season forage, and attracts pollinators (Tilley et al. 2010, 2013; Ogle et al. 2011, 2012a). Early phenology and development of a large taproot makes fernleaf biscuitroot competitive with invasive annual grasses. It is recommended for fine- to coarse-textured silt to clay soil sites receiving at least 12 in (30 cm) annual precipitation (Ogle et al. 2011, 2012a; Tilley et al. 2013). Seedlings grow slowly, and plants are mid- to late-seral (Walker and Shaw 2005; Tilley et al. 2013). These traits need to be taken into consideration when evaluating revegetation goals and planning restoration.

Fernleaf biscuitroot is recommended for planting on public lands and small farms and gardens in the Intermountain semi-desert region to attract bees and butterflies (Ley et al. 2007). It not only attracts bees, flies, beetles, and butterflies but also serves as a host plant for Anise and Indra swallowtail butterflies (Ogle et al. 2011). Fernleaf biscuitroot may also prove useful as a conservation biological control plant, because it attracts a variety of parasitoid insects that prey on other insects (LBJWC 2015).

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. 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).

Seed Sourcing

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 11, Omernik Level III Ecoregions (Omernik 1987) overlay the provisional seed 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. 2020) can also guide revegetation planning, seed collection, and seed deployment, particularly when addressing climate change considerations.

Occurrence Map

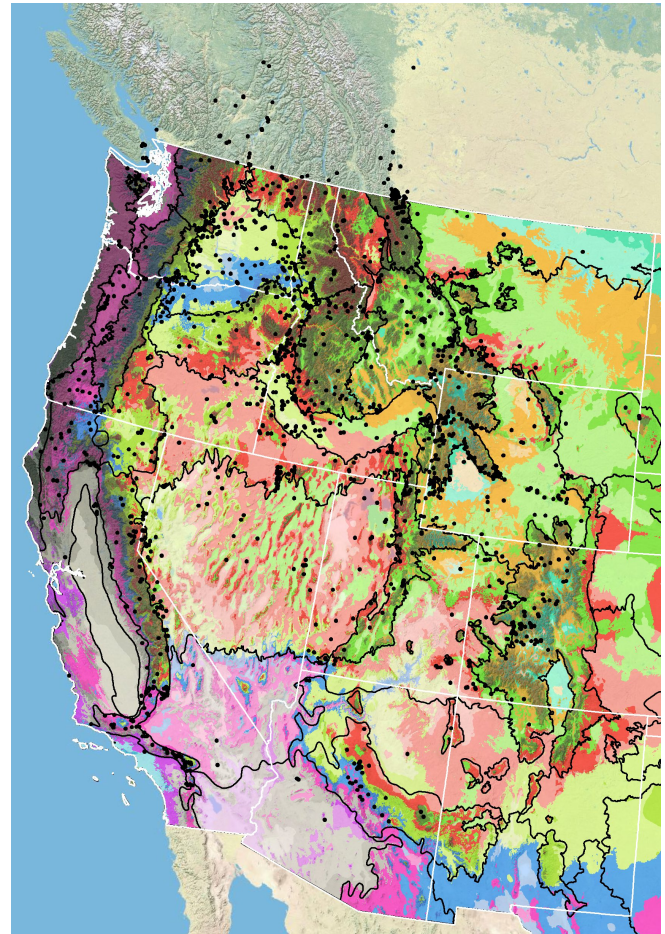


Figure 11. Distribution of fernleaf biscuitroot (black circles) based on geo-referenced herbarium specimens and observational data from 1882-2016 (CPNWH 2017; SEINet 2017; USDI USGS 2017). Generalized provisional seed zones (colored regions) (Bower et al. 2014) are overlain by Omernik Level III Ecoregions (black outlines) (Omernik 1987; USDI EPA 2018). Interactive maps, legends, and a mobile app are available (USFS WWETAC 2017; research.fs.usda.gov/pnw/products/dataandtools/seed-zone-webmap). Map prepared by M. Fisk, USDI USGS.

Releases

As of 2020, there were no fernleaf biscuitroot germplasm releases. As of 2010, commercial growers were producing source-identified seed representative of the Snake River Plain and Northern Basin and Range Omernik regions (Tilley et al. 2010). Current availability of these materials is unknown.

Wildland Seed Collection

Fernleaf biscuitroot seed is collected when the schizocarps are dark brown and easily detach from the umbel (Fig. 12) (Skinner 2004; Parkinson and DeBolt 2005).



Figure 12. Hand collection of wild fernleaf biscuitroot seed. Photo: USFS RMRS.

Wildland Seed Certification

Verification of species and tracking of geographic source is necessary whether wildland seed is collected for immediate project use or as stock seed for cultivated increase. This official Source Identification process can be accomplished by following procedures established by the Association of Official Seed Certifying Agencies (AOSCA) Pre-Variety Germplasm Program (Young et al. 2020; 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, site inspections, and species and seed amount verification 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 or private collector 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 must be provided when applying for certification. Photos and herbarium specimens may be required. 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, however, this collection site information must be provided to the grower to enable certification.

Collection Timing

Seed is ready to harvest when fernleaf biscuitroot inflorescences are dry and schizocarps are brown and easily detached (Fig. 13). This typically occurs 5 to 8 weeks after flowering, which can occur as early as March and as late as July depending on location and weather conditions (Skinner 2004; Parkinson and DeBolt 2005; USDI BLM SOS 2017). Fruits on open-grown plants mature sooner than those on plants growing beneath canopy cover (Parkinson and DeBolt 2005). Based on data from Bureau of Land Management's Seeds of Success (SOS) collections, fernleaf biscuitroot seed was collected as early as May and as late as August (USDI BLM SOS 2017). A total of 46 SOS collections were made over 12 years between 2002 and 2015 in Washington, Oregon, California, Nevada, and Idaho. Harvest sites ranged from 1,050 to 7,255 ft (320–2,211 m) elevation. The earliest collection was made on May 22, 2013. At 3,431 ft (1,046 m) in Malheur County, Oregon. The latest collection was made on August 25, 2011 at 3,286 ft (1,002 m) in Boise County, Idaho. In the single year with the greatest number of harvests (18 collections in 2011) the earliest was June 14 at 3,143 ft (958 m) in Malheur County, Oregon, and the latest was August 25 at 3,286 ft (1,002 m) in Boise County, Idaho (USDI BLM SOS 2017), suggesting factors other than elevation are important to consider when estimating harvest dates. Regular monitoring of fernleaf biscuitroot populations is necessary for planning and maximizing fernleaf biscuitroot seed harvests.



Figure 13. Hand-collected fernleaf biscuitroot seed. Schizocarps containing two seeds are visible. Photo: BLM CA370 SOS.

Collection Methods

Wildland seed is hand collected by stripping, shaking, or clipping ripened inflorescences over and into a container (Figs. 13 and 14) (Skinner 2004; Parkinson and DeBolt 2005; Ogle et al. 2012a). Collections are cleanest when schizocarps are collected by shaking ripened inflorescences over the container (Ogle et al. 2012a). Clipping ripe inflorescences makes for more post-harvest cleaning.

Several collection guidelines and methods should be followed to maximize the genetic diversity of wildland collections: 1) collect seed from a minimum of 50 randomly selected plants; 2) collect from widely separated individuals throughout a population without favoring the most robust or avoiding small stature plants; and 3) 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 2021).

It is critical that wildland seed collection does not impact the sustainability of native plant populations. Collectors should take no more than 20% of the viable seed available at the time of harvest (USDI BLM SOS 2021). Additionally, care must be taken to avoid the inadvertent collection of weedy species, particularly those that produce seeds similar in shape and size to those of fernleaf biscuitroot.



Figure 14. Bulk collection of fernleaf biscuitroot seeds. Photo: BLM NV030 SOS.

Post-Collection Management

Seed should be kept in a dry, shaded place until it 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 may need (Gold n.d.; DeBolt and Parkinson 2005; Hay and Probert 2011).

Seed Cleaning

At the USFS Bend Seed Extractory, the following procedure was used to clean a 3.8-lb (1.7 kg) lot of hand-collected fernleaf biscuitroot seed. Seed was processed using a Westrup Model LA-H laboratory brush machine (Hoffman Manufacturing, Corvallis, OR) with #20 mantel at medium speed. Seed was then air-screened using an 18 round top screen and 1/18 round bottom screen with medium speed and medium air. Any remaining non-seed material was hand removed. The Bend Seed Extractory cleaning process yielded 41,884 seeds/lb (46,946 seeds/kg) with 98% purity and 94% fill (from X-ray of 100 seeds) (Barner 2007). Seed collected from production plots grown at the Aberdeen, Idaho, Plant Materials Center (PMC) had greater than 95% purity. Using an air screen cleaner, seed purities reached almost 100% (Ogle et al. 2012a).

Very small harvests collected by shaking inflorescences or by hand stripping inflorescences can be processed using an air-screen cleaner or air column separator, if any cleaning

is necessary (Skinner 2004; Ogle et al. 2012a). The air column separator works well to remove insect-damaged seed (Skinner 2004).

DeBolt and Parkinson (2005) rubbed fernleaf biscuitroot schizocarps through 0.5-in (1.3 cm) square openings to remove fine debris and then processed the collection through a sieve with 3.4-mm square openings (No. 6 USA STS) (Fig. 15). Seed can be sorted over a light table to remove empty mericarps if necessary for nursery plantings.



Figure 15. Fernleaf biscuitroot seed size variability. Scale is mm. Photo: BLM OR030 SOS.

Seed Storage

Fernleaf biscuitroot seed is orthodox. Dry seed stored at -4°F (-20°C) and 15% relative humidity was 80% viable after 3.4 years (RBG Kew 2017). Skinner (2004) stored fernleaf biscuitroot seed at 40°F (4°C) and 40% humidity, but viability over time under these storage conditions was not reported.

Seed Testing

Seed fill can be evaluated by viewing schizocarps over a light table (DeBolt and Parkinson 2005).

Viability Testing

Because no Association of Official Seed Analysts (AOSA) tetrazolium chloride viability procedure exists for *Lomatium* species, viability testing 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, fernleaf biscuitroot seed should be clipped and soaked in gibberillic acid (GA3) overnight before staining. Seed is then cut laterally or longitudinally and exposed to tetrazolium concentrations of 0.1 or 1% at 68 to 95 °F (20–35 °C) for 4 hours or overnight. Seeds with stained embryos and endosperm are viable (AOSA 2010).

Germination Testing

Vankus (2006) found that fresh fernleaf biscuitroot seed requires 28 to 63 days of prechilling at 37 to 41°F (3–5°C) to relieve dormancy. Seeds are then incubated on moist blotter paper at 59 to 77°F (15–25°C). First germination counts are made at 7 days and the last at 28 days. There is no AOSA procedure for germination testing of fernleaf biscuitroot.

Germination Biology

Fernleaf biscuitroot seed is dormant when dispersed. An extended period of cold stratification is required to break dormancy following long after-ripening periods (Shaw et al. 2007). Buhler and Hoffman (1999) reported seed dormancy was not broken by 18 months of dry storage at 64°F (18°C). Mechanical, chemical, warm stratification and hot water treatments also failed to promote germination (Pelton 1956; Shaw et al. 2007). Germination was unaffected by smoke treatments using smoke water concentrations of 1:10, 1:100, 1:1000 (Cox 2016).

Fernleaf biscuitroot seed is dormant because of underdeveloped embryos. Scholten et al. (2009) found that small differences in temperatures below 50°F (10°C) had large impacts on embryo growth with stratification requirements varying among populations. Fernleaf biscuitroot seed collected near Harper, Oregon, had embryos that were 15% of seed length. After 14 weeks of cold stratification 41°F (5°C), embryo size increased 7 times. Final germination was higher (87%) and quicker (13 wks) at 38°F (3.4°C) than at 42°F (5.5°C) (64% and 15.5 wks). Few seeds germinated at 33°F (0.5°C) and 48.4°F (9.1°C) (Scholten et al. 2009).

High levels of germination (80–98%) are possible with cold stratification, and temperatures that break dormancy are adequate for seed germination. Parkinson and DeBolt (2005) collected fernleaf biscuitroot seed (85% viability) in Ada County, Idaho, and stored it a room temperature for 18 months. Seed was then stratified for 60 days at 39°F (4°C). Germination began during stratification and totaled 98% after 66 days. Cold stratification promoted embryo growth in experiments by Shaw et al. (2007). Embryo growth occurred at 34, 43, and 52°F (1, 6, and 11°C) and was greatest (80%) at 43°F (6°C) after 15 weeks. After 14 weeks, germination was significantly greater for seed stratified at 34°F (1°C) and 43°F (6°C) than seed stratified at 52°F (11°C). Germination occurred while seeds were being cold stratified before being transferred to warmer temperatures (Shaw et al. 2007).

In field experiments (Boise, Idaho) initiated in mid-November 2005, minimal embryo growth occurred in the first month when average daily soil temperatures were 21 to 80°F (-6 to 27°C) at 0.8 to 10.6 in (2-7 cm) deep (Scholten et al. 2009). The largest increases in embryo length occurred in the second month when temperatures were mostly 32 to 43°F (0–6°C) and soil moisture content was high (>10%). Though differences were not significant, germination was 31% for seed retrieved from the field in early March 2006, 48% for seed retrieved on March 17, 60% for seed retrieved on April 21, and 50% for seed retrieved

on June 2. Germination percentages were not significantly different for any of the retrieval dates. Seed required fewer hours of stratification under field conditions than in growth chambers. Seeds in growth chambers were exposed to light and constant temperatures while those in the field experienced ambient conditions (Scholten et al. 2009).

When seed burial experiments were repeated using seed collected from the same populations but in different years (2005 and 2007), embryos grew more rapidly in 2007, and germination was about 30% better in 2007 than in 2005. Because seed came from the same population and storage conditions prior to the experiments were the same, embryo growth and germination differences were attributed to the environmental conditions occurring as seeds were developing. At the time of seed development, May and June precipitation was higher in 2005 (3.1 in [78.2 mm]) than in 2007 (1.1 in [27.2 mm]) suggesting that fernleaf biscuitroot seed produced in drier conditions required less stratification than seed developed in wetter conditions. This hypothesis was supported by comparing germination of fernleaf biscuitroot varieties collected at various elevations.

Variety *multifidum* seed collected from various sites in southeastern Idaho and southwestern Oregon (elevations of 4,222–5,577 ft [1,287–1,700 m]) began to germinate after 8 weeks. Variety *multifidum* seeds from Moore's Mountain, Idaho (7,218 ft [2,200 m]) and variety *dissectum* seeds collected from Oregon's Willamette Valley (intermediate elevations) began to germinate after 10 weeks. Mean germination time for variety *multifidum* from southeastern Idaho and southwestern Oregon was between 10.5 to 11 weeks, which was significantly ($P < 0.05$) shorter than the 14.4 to 16 weeks for variety *dissectum*. Mean germination time for the high-elevation variety *multifidum* was in between (about 13 weeks). Quicker germination for variety *multifidum* is likely an adaptation to the short growing seasons with dry summer conditions in southern Idaho and Oregon, whereas early germination is not critical for variety *dissectum* growing in the Willamette Valley where temperatures and precipitation allow for plant growth through most of the spring and summer (Scholten et al. 2009).

Wildland Seed Yield And Quality

Post-cleaning seed yield and quality of fernleaf biscuitroot seed lots collected in the Intermountain region are provided in Table 1 (USFS BSE 2017). The results indicate that fernleaf biscuitroot seed can generally be cleaned to high levels of purity but that seed fill and viability of fresh seed is variable. Average seed weights reported elsewhere in the literature (23,510–45,031 seeds/lb [26,351–50,473 seeds/kg]) generally fall within the ranges reported in Table 1 (Skinner 2004; Lambert 2005; Parkinson and DeBolt 2005; Ogle et al. 2011, 2012a; RBG Kew 2017). Others suggested upper limit seed weights can be as high as 134,000 seeds/lb (150,193 seeds/kg) (Parkinson and DeBolt 2005; Walker and Shaw 2005), which exceeds those reported in Table 1.

Table 1. Seed yield and quality of fernleaf 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)	2.42	0.25–9.05	25
Clean weight (lbs)	1.06	0.12–4.24	25
Clean-out ratio	0.49	0.07–0.81	25
Purity (%)	92	75–99	25
Fill (%)¹	84	56–95	25
Viability (%)²	89	54–97	21
Seeds/lb	31,687	3,660–66,704	25
Pure live seeds/lb	25,245	1,739–54,679	21

¹100 seed X-ray test

²Tetrazolium 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% (Walker and Shaw 2005)

Agricultural Seed Production

Trials for growing fernleaf biscuitroot for seed production were conducted at the Aberdeen, Idaho, Plant Materials Center (PMC) (Ogle et al. 2012a) and Oregon State University's Malheur Experiment Station (OSU MES) (Shock et al. 2016). Plants at both locations grew slowly in the first 3 years. Although some plants produced a minimal number of flowers and seeds in the third growing season, first harvests were made in year 4 (Ogle et al. 2012a; Shock et al. 2016). At OSU MES, fernleaf biscuitroot stands were maintained and harvested for 9 years. Seed yield ranged from 300 to 1,200 lbs/ac (336–1,345 kg/ha), and seed yield increased with irrigation (see Irrigation section below; Shock et al. 2016).

Agricultural Seed Certification

In order to minimize genetic changes in specific accessions of native species when increased in cultivated fields, it is essential to track the geographic source and prevent inadvertent hybridization or selection pressure. This is accomplished by following third party seed certification protocols for Pre-Variety Germplasm (PVG) as established by the Association of Official Seed Certification Agencies (AOSCA). AOSCA members in the U.S., Canada, and other countries administer PVG requirements and standards that track the source and generation of planting stock. Field and cleaning facility inspections then monitor stand establishment, proper isolation distances, control of prohibited weeds, seed harvesting, cleaning, sampling, testing, and labeling for commercial sales (Young et al. 2020; UCIA 2015).

Seed growers apply for certification of their production fields prior to planting and plant only certified stock seed of an allowed generation (usually less than four). 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 information on stock seed sourcing.

Site Preparation

Fernleaf biscuitroot should be seeded in firm, weed-free soil (Fig. 16). At the Pullman PMC, fernleaf biscuitroot was seeded in early fall (mid-September), dormant fall (late October), and early spring (mid- to late April) in retired grain fields, where stubble was chiseled and disked (Scheinost et al. 2010). Fields were then cultivated using a Glencoe cultivator (Gonzales, LA) and packed with Brillion roller (Marysville, KS) just before seeding. Fernleaf biscuitroot was seeded no more than 0.5 in (1.3 cm) deep in four 20-ft (6 m) long rows using a Hege 1000 plot drill seeder (Waldenberg, Germany). Initial establishment was poor, and no seedlings emerged when spring seeded. Fewer than 1.5 plants/linear ft (5/linear m) established in fall-seeded plots. Survivability of plants that did establish was good, and stand density increased substantially over time from seed produced by the initially established plants. After 2 to 3 years, cover of fernleaf biscuitroot was moderate to high, even though initial seedling establishment was low (Scheinost et al. 2010).

Weed Management

A variety of weed control methods were tested and used in combination in seed production plots at the Aberdeen PMC and OSU MES. Good weed control was achieved using weed barrier fabric and hand rouging at the Aberdeen PMC (Ogle et al. 2012a). Non-selective foliar herbicide applications were used to control weeds after summer senescence of fernleaf biscuitroot (St. John and Ogle 2008; Ogle et al. 2012a).



Figure 16. Site preparation for seeding fernleaf biscuitroot at USFS Lucky Peak Nursery (near Boise, ID). Beds at the center and on the right have already been seeded and covered with a thin layer of sand. Photo: USFS RMRS.

Trials at OSU MES evaluated emergence following preemergent herbicide treatments. Most preemergent herbicide treatments had minimal effect on emergence which was low overall (Table 2; Shock et al. 2011). For the preemergence herbicide trials, fernleaf biscuitroot was seeded at 30 PLS/ft of row [98 PLS/m] on December 1, 2009. Seed was placed on the soil surface then covered with a thin layer of sawdust (0.18 oz/ft [0.6/m] of row) and row cover until April 7, 2010. Preemergence herbicides (20 gal/ac [187 l/ha]) were applied on November 30, 2009 using a CO2 sprayer at 30 PSI (Shock et al. 2011).

Table 2. Emergence of fernleaf biscuitroot in spring 2010 following preemergence herbicide treatments in fall 2009 in experimental plots at Oregon State University's Malheur Experiment Station, Ontario, OR (Shock et al. 2011).

Control	Bensulide	Pronamide	Trifluralin
-----% emergence-----			
6.8	10.3	4.7	4.3
Pendimethalin*	Benefin	Dimethenamid	Linuron
8.5	10.8	12.0	6.3

*There were no significant differences between treatments of pendimethalin with and without activated charcoal (Shock et al. 2011).

Seed yield of fernleaf biscuitroot was relatively unaffected by annually repeated post-emergent herbicide treatments (Table 3). Herbicides were applied in the spring for 4 consecutive years. Researchers caution that seed yields came from small, one-row plots without borders (Shock et al. 2011).

Table 3. Seed yield of fernleaf biscuitroot following the third and fourth years of post-emergent herbicide treatments in experimental plots at Oregon State University's Malheur Experiment Station, Ontario, OR (Shock et al. 2011).

Herbicide	Application rate	Mar 20, 2009	Apr 7, 2010
lb ia/ac		Seed yield (lbs/ac)	
Control	NA	83.4	475.3
Bromoxynil	0.125	83.3	462.8
Oxyfluorfen	0.125	88.0	421.6
Clethodim	0.094	78.1	449.1
Pendimethalin	1	85.6	488.7
Prometryn	0.8	66.1	449.1
Dimethenamid	0.656	80.9	413.4
Linuron	0.5	104.5	533.3

Regular fertilization (N, Fe, P) and herbicide (pendimethalin) treatments were applied to maintain fernleaf biscuitroot seed production stands seeded for evaluation of irrigation treatments (Table 4). Nitrogen and other nutrients were delivered through the buried drip irrigation system, except for the November 11, 2006 application which was broadcast. All herbicide treatments were broadcast (Shock et al. 2018).

Table 4. Fertilization and herbicide treatments applied (per ac) to maintain fernleaf biscuitroot seed production stands seeded in fall 2005 at Oregon State University's Malheur Experiment Station in Ontario, OR (Shock et al. 2018). *P=pendimethalin, C=clethodim, G=glyphosate, S=sethoxydim

Treatment date			Fertilizer				Herbicide*			
Year	Fertilizer	Herbicide	N	P	Zn	Fe	P	C	G	S
			lbs/ac				lbs/ac			
2006	10/27 11/11	11/17	100	50	2		1			
2007		11/9					1			
2008		4/15					1			
2009	4/8	3/18, 12/4	50	10			2	0.5		
2010		11/17					1			
2011	5/3	11/9	50				1			
2012	4/13	11/7	50	10		0.3	1			
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

Seeding

Fernleaf biscuitroot requires an extended period of cold moist stratification to germinate (Ogle et al. 2012a). Planting trials conducted at the Pullman, Washington PMC showed that seed planted immediately after harvest germinated the following spring, but seed planted in the fall often required two winters to germinate (Skinner 2004). At OSU MES, seeding on December 1, 2009 resulted in poor stand emergence (Shock et al. 2018), but seeding on October 26, 2005 resulted in excellent stands (Shock et al. 2016), though the seeding methods were slightly different for the two seedings.

Several seeding methods were used at the Aberdeen PMC and OSU MES, with drill seeding being most common and resulting in good stands. Seeding methods, however, were not directly compared. Ogle et al. (2012a) suggest drill seeding fernleaf biscuitroot at rates of 25 to 30 PLS/ft (82–98 PLS/m). If seeding into weed barrier fabric, seeds should be spaced 18 to 24 in (45–60 cm) apart (Ogle et al. 2012a). At OSU MES, fernleaf biscuitroot was seeded on October 26, 2005 in Nyssa silt loam soil using a custom, small-plot, grain drill with disk openers. Seed was planted 0.5 in (1.3 cm) deep at 20 to 30 PLS/ft of row (65–100/m) of row. In spring 2006, stands were “excellent” (Shock et al. 2016). In other trials at OSU MES, fernleaf biscuitroot was placed on the soil surface and then covered with sawdust on December 1, 2009. Seeds were covered with sawdust applied in narrow band over the seed (rate of 0.26 oz/ft [0.85 oz/m] of row). Spring seed emergence was poor (Shock et al. 2018) but this may have had more to do with seeding timing than seeding method, since seed planted late in the fall may take two growing seasons to germinate (Skinner 2004).

Establishment And Growth

Fernleaf biscuitroot produces little above-ground growth in its first years (Fig. 17). Only a few leaves are produced in the first year, and plants do not typically flower or produce seed adequate for harvest until the fourth year. Plants emerge early in the spring and go dormant and senesce by mid-summer (Ogle et al. 2012a). At OSU MES, first flowering of seedlings made in fall 2005 occurred in 2009. Over a 7-year period, initiation of flowering occurred from late March through mid-May. Seed matured in June (Table 5). Fungal infections can further delay fernleaf biscuitroot's maturation. At other trials at OSU MES, plants from fall 2005 seedings produced very little vegetative growth from 2006 to 2008 and few flowers in 2013, likely because of an *Alternaria* fungal infection (Shock et al. 2018).

Preliminary experimentation at the Aberdeen PMC suggests that fernleaf biscuitroot can be grown at high densities in compact rooting beds for 1 to 2 years and then be transplanted into larger seed production plots. Taproots were not damaged, and plants survived transplanting well, suggesting this production method may be used by seed growers looking to minimize the area devoted to the species in its non-productive years (Tilley et al. 2010).



Figure 17. Fernleaf biscuitroot seedling growing at the Tom Day Farm in Layton, UT. Photo: Stanford Young, emeritus Utah State University.

Table 5. Timing of flowering and seed harvest dates for fernleaf biscuitroot seed production fields over a period of 7 years at Oregon State University's Malheur Experiment Station, Ontario, OR (Shock et al. 2018). Seed yields are provided in Table 6.

Year	Flower start	Flower peak	Flower end	Harvest
	----- Date -----			
2009	10 Apr		7 May	16 Jun
2010	25 Apr		20 May	21 Jun
2011	8 Apr	25 Apr	10 May	20 Jun
2012	9 Apr	16 Apr	16 May	4 Jun
2013	10 Apr		25 Apr	4 Jun
2014	28 Mar		21 Apr	2 Jun
2015	1 Apr		24 Apr	26 May, 1 Jun

Irrigation

Although emergence of fernleaf biscuitroot at OSU MES occurred without supplemental irrigation (Shock et al. 2012), plant size and seed yields were significantly greater with irrigation ($P < 0.05$) (Table 6; Shock et al. 2012, 2016, 2018). Irrigation trials began in March 2006 in plots seeded in late October 2005. Irrigation treatments of 0, 4, or 8 in (101 or 203 mm) of water were delivered four times at about 2-week intervals beginning at the time of bud formation and flowering (Table 3). Water was delivered through drip tape buried 12 in (30 cm) deep, so as not to affect flowering and to limit germination of weed seed (Shock et al. 2016). Fernleaf biscuitroot seed yields increased significantly with irrigation ($P < 0.05$). Seed yields averaged over 7 years were 360 lbs/ac (403 kg/ha) with 0 in, 767 lbs/ac (860 kg/ha) with 4 in (100 mm), and 710 lbs/ac (796 kg/ha) with 8 in (200 mm) of supplemental irrigation (Shock et al. 2016). Seed yield differences were even greater between irrigated and non-irrigated plants after 9 years (Table 6). Regression analysis estimates showed that a maximum fernleaf biscuitroot seed yield of 999 lbs/ac/year (1,120 kg/ha/yr) was possible with 9.5 in (24 cm) of irrigation (Shock et al. 2018).

Table 6. Seed yields (lbs/ac) for fernleaf biscuitroot growing with and without supplemental irrigation at Oregon State University's Malheur Experiment Station near Ontario, OR. Fernleaf biscuitroot was seeded in fall 2005 (Shock et al. 2018).

Year	0 inch	4 inches	8 inches
	Seed yield (lbs/ac)		
2009	50.6a	320.5b	327.8b
2010	265.8a	543.8a	499.6b
2011	567.5a	1342.8b	1113.8b
2012	388.1a	460.3a	444.4a
2013	527.8a	959.8b	1166.7b
2014	353.4a	978.9b	1368.3b
2015	591.2a	1094.7b	1376.0b
2016	1039.4a	1612.7b	1745.4b
2017	488.2a	713.1b	674.4ab
Mean	474.7a	923.3b	968.5b

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

The years with large differences between the seed yield of non-irrigated and irrigated plots were not obviously linked to dry years or years with a longer or shorter growing season (Table 7). However earlier flowering and harvest dates (Table 5) were associated with years with longer growing seasons (Shock et al. 2016, 2018).

At OSU MES, effects of irrigation treatments were evaluated for three fernleaf biscuitroot ecotypes over 3 to 4 years. Seed yields varied by ecotype with and without irrigation (Table 8; Shock et al. 2018). Annual seed yields showed a quadratic response to irrigation. Average seed yield estimates were maximized by 9.3 in (236 mm) of irrigation plus spring precipitation for the fernleaf biscuitroot seed collected near Riggins, Idaho, and 7.7 in (196 mm) of irrigation plus spring irrigation for seed collected in Washington County, Idaho (ecotypes 38 and 41) (Shock et al. 2018).

Table 7. Precipitation (in) and growing degree hours (°F) at Oregon State University's Malheur Experiment Station in Ontario, OR (Shock et al. 2018).

Year	Spring	Winter + Spring	Fall + Winter + Spring	Growing degree hrs (50-86 °F) Jan-June
2006	3.4	10.1	14.5	1273
2007	1.9	3.8	6.2	1406
2008	1.4	3.2	6.7	1087
2009	4.1	6.7	8.9	1207
2010	4.3	8.4	11.7	971
2011	4.8	9.3	14.5	856
2012	2.6	6.1	8.4	1228
2013	0.9	2.4	5.3	1319
2014	1.7	5.1	8.1	1333
2015	3.2	5.9	10.4	1610
2016	2.2	5.0	10.1	1458
2017	4.0	9.7	12.7	1196
Mean	2.9	6.3	9.8	1207

Pollinator Management

Sweat bees (*Halictus* and *Lasioglossum* spp.) and honeybees (*Apis* spp.) were found in cultivated stands of fernleaf biscuitroot (Tilley et al. 2010; Shock et al. 2012). Mining bees migrating from nearby populations of spring-blooming floral hosts (Salicaceae, Rosaceae, Brassicaceae) may also pollinate fernleaf biscuitroot. Mining bees nest underground and are univoltine (one annual generation) and nest in the spring (Cane et al. 2020).

At OSU MES hived honeybees from a neighboring farm were abundant on the flowers of cultivated fernleaf biscuitroot, and seed production was substantial despite a lack of native bees. Honeybees did not commonly visit fernleaf biscuitroot flowers at sites not near towns or apiaries (Cane et al. 2020). For more on the importance of pollinators for fernleaf biscuitroot seed production, see Pollination section.

Table 8. Seed yields (lbs/ac) for fernleaf biscuitroot ecotypes growing with and without supplemental irrigation at Oregon State University's Malheur Experiment Station near Ontario, OR. Fernleaf biscuitroot was seeded in fall 2005. (Shock et al. 2018).

Ecotype	Year*	0 inch	4 inches	8 inches
		Seed yield (lbs/ac)		
Riggins**	2014	276.8a	497.7b	398.4ab
	2016	299.1a	679.5b	592.4b
	2017	315.1a	405.1b	440.0b
	Ave	297.0a	527.4b	476.9b
Washington Co, ID #38	2014	281.9a	356.4a	227.1a
	2015	865.1a	820.9a	774.6a
	2016	474.8a	634.5b	620.0b
	2017	398.8a	575.0a	553.2a
	Ave	508.4a	596.7a	523.7a
Washington Co, ID #41	2014	222.2a	262.4a	149.8a
	2015	152.2a	561.9b	407.4b
	2016	238.1a	297.7a	302.0a
	2017	214.9a	363.0b	377.5b
	Ave	206.9a	371.2b	309.2ab

*Values for an ecotype within a year that are followed by different letters are significantly different ($P \leq 0.1$).

**Seed inadvertently not collected in 2015 for the Riggins ecotype.

Pest Management

Fernleaf biscuitroot growth and survival can be impacted by a host of animal, insect, and fungal pests (see also Seed and Seedling Ecology section). Beetles (*Smicronyx* spp.), moths (*Depressaria multifidae* and *D. leptotaeniae*), midges (*Contarinia* spp.), leaf miner flies (*Phytomyza* spp.), aphids (*Aphis heraclella*), and rust (*Puccinia* spp.) were collected from wildland and cultivated stands of fernleaf biscuitroot (Hammon and Cane 2005). At OSU MES, several fernleaf biscuitroot seed production plots were infected by *Alternaria* spp. This fungal infection delayed plant development and seed production. Resistance to *Alternaria* varied by seed source (Shock et al. 2012). Other fungal pests collected from fernleaf biscuitroot include powdery mildew (*Comoclathris depressa*, *Crocicreas cyathoideum* var. *cacaliae*, *Euryachora* spp., *Leveillula taurica*, and *Phyllachora* spp.) (Sampangi et al. 2013; Farr and Rossman 2020).

Seed Harvesting

Fernleaf biscuitroot seed can be harvested in production fields using a vacuum type harvester or flail vac. At the Aberdeen PMC, field-harvested seed lots were cleaned to purities of nearly 100% (Ogle et al. 2012a).

Seed Yields And Stand Life

At OSU MES, fernleaf biscuitroot seed was harvested for 7 years (Fig. 18) (Shock et al. 2016). Seed yields averaged 475 lbs/ac (532 kg/ha) for non-irrigated stands, 923 lbs/ac (1,035 kg/ha) for stands receiving 4 in (100 mm) of irrigation, and 968.5 lbs/ac (1,085 kg/ha) for stands receiving 8 in (200 mm) of irrigation. Seed production was significantly increased with irrigation ($P < 0.05$), but seed yields were rarely significantly different between the 4- and 8-in (100 and 200 mm) irrigation treatments (Table 6). Seed yields showed a quadratic response to irrigation and were estimated to be highest with 13 to 17 in (335-425 mm) of total applied water plus fall, winter, and spring precipitation (Table 9; Shock et al. 2016).



Figure 18. Fernleaf biscuitroot seed production plots at Oregon State University's Malheur Experiment Station near Ontario, OR. Photo: USFS RMRS.

Table 9. Regression analysis for fernleaf biscuitroot seed yield (2009-2017) in response to irrigation plus spring precipitation using the equation $y = a + b \cdot x + c \cdot x^2$, where y = seed yield and x = irrigation plus spring precipitation. Studies conducted at Oregon State University's Malheur Experiment Station in Ontario, OR. Only those years where irrigation resulted in significantly greater seed yields are shown below (Shock et al. 2018).

Year	Highest yield (lbs/ac)	Irrigation + spring precipitation for maximum seed yield (in)	Spring precipitation (in)
2009	478	9.1	4.1
2010	514	10.8	4.3
2011	1,380	9.9	4.8
2013	1186	10.5	0.9
2014	1524	14.3	1.7
2015	1441	14.3	3.2
2016	1623	10.2	2.2
2017	730	8.5	4.0
Ave	999	9.5	2.9

Nursery Practice

Several growers have propagated fernleaf biscuitroot in a greenhouse or outdoor nursery setting. Most seed sown outdoors in Moscow, Idaho, in pots in late August and early September germinated the following spring. Seedlings grew slowly and took at least 2 years to reach transplant size and one or two more to flower (Skinner et al. 2005). Parkinson and DeBolt (2005) found that plants developed true leaves within 14 days of planting germinated seed in a 50:50 peat and vermiculite mix. Greenhouse temperature was a constant 81°F (27°C) and containers were watered when saturation reached 80%.

At the Pullman PMC, fernleaf biscuitroot seed was sown in 10 in 3 containers filled with Sunshine #4 potting mix and covered lightly with soil and a layer of pea gravel in late August. Containers were watered deeply and placed outdoors, where they were watered through the fall and during dry spells in the winter and spring. Germination began in March and continued for about 3 weeks. Seedlings were fertilized once a week with a complete, water-soluble fertilizer and considered established at 6 to 7 months. Plants went dormant in July or August and were overwintered in a lath house (Skinner 2004).

Wildland Seeding And Planting

Once established, fernleaf biscuitroot is long-lived and competitive against weeds (Tilley et al. 2010; Ogle et al. 2012a), but seedling growth is slow (Ogle et al. 2011) suggesting this species should be seeded so that it does not directly compete with rapid growing perennial grasses. Studies have reported establishment after seeding in grasslands and from seed rain on mine spoils (Smyth 1997; Skinner 2004).

Fernleaf biscuitroot can be broadcast or drill seeded on adapted sites. Fall seeding is necessary to relieve dormancy. The recommended seeding rate is 20 to 24 PLS lbs/ac (22-27 kg/ha) and seeding depth is 0.125-0.5 in (0.3-1.3 cm) (Tilley et al. 2010; Ogle et al. 2011, 2012a, 2019). In field experiments, germination of fernleaf biscuitroot was much higher in wet silt or sandy loams than in mid-precipitation silt loams or dry sand loams (James 2015). Field germination and short-term survival were evaluated across nine Great Basin sites that differed in soil texture and annual precipitation. Fernleaf biscuitroot was seeded at 56 PLS/ft²/plot (600 PLS/m²/plot) with and without crested wheatgrass seeded at the same rate. Fernleaf biscuitroot germination was highest (almost 80%) in wet silt or sandy loams and much lower ($\leq 20\%$) in dry sandy loam and silt loam sites with moderate levels of precipitation. Second-year emergence was less than 2% for germinated

seeds that survived through the first growing season regardless of the soil type. Seeding with crested wheatgrass did not impact germination (James 2015).

Fernleaf biscuitroot has been seeded on diverse sites in the Northwest. At the Pullman PMC, fernleaf biscuitroot emerged at low levels (<10%) over two growing seasons after being broadcast in an existing grassland in southeastern Washington (Skinner 2004). In Oregon white oak woodlands on Vancouver Island, British Columbia, fernleaf biscuitroot first-year emergence was better in plots where vegetation has been removed but second-year emergence was better in plots with intact vegetation (Marsico and Hellmann 2009).

Fernleaf biscuitroot emerged on restoration sites in the transition zone between alpine tundra and Engelmann spruce-subalpine fir in British Columbia (Smyth 1997). Various methods were used to revegetate a 3-year dormant mine spoil dump of primarily siltstone and carbonaceous shale. Fernleaf biscuitroot seed was not included in the mix used to reseed the spoils but did emerge on plots treated with 2 in (5 cm) of native soil, suggesting it was part of the native seed bank. The spoil was seeded and fertilized (NPK 171-17-17 lbs/ac [192:19:19 kg/ha]) in mid- to late May (Smyth 1997).

Studies evaluating the transplanting of fernleaf biscuitroot are not common in the literature. When researchers excavated 100 taproots from a large native population near Logan, Utah, to establish a research garden, 25 of the transplants survived and flowered (Cane et al. 2020). Most greenhouse-grown and acclimated fernleaf biscuitroot seedlings planted in a native garden at the Columbia River Gorge National Scenic Area between Hood River and The Dalles, Oregon did not survive. Seedlings were transplanted in early March, but no other details were available (Youtie 1992).

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