



NINELEAF BISCUITROOT

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

ORGANIZATION

Names, subtaxa, chromosome number(s), hybridization.

Range, habitat, plant associations, elevation, soils.

Life form, morphology, distinguishing characteristics, reproduction.

Growth rate, successional status, disturbance ecology, importance to animals/people.

Current or potential uses in restoration.

Seed sourcing, wildland seed collection, seed cleaning, storage, testing and marketing standards.

Recommendations/guidelines for producing seed.

Recommendations/guidelines for producing planting stock.

Recommendations/guidelines, wildland restoration successes/failures.

Primary funding sources, chapter reviewers.

Bibliography.

Select tools, papers, and manuals cited.

NOMENCLATURE

Nineleaf biscuitroot (*Lomatium triternatum* [Pursh] J.M. Coult. & Rose) belongs to the Apiaceae family, Apioideae subfamily, and Peucedaneae tribe (Harborne and Williams 1972; Albach et al. 2001).

NRCS Plant Code. LOTR2 (USDA NRCS 2019).

Subtaxa. As of 2020, the following nineleaf biscuitroot varieties were recognized: *Lomatium triternatum* var. *anomalum*, *L. t.* var. *brevifolium*, *L. t.* var. *macrocarpum*, *L. t.* var. *triternatum* (ITIS 2020; USDA NRCS 2019).

Synonyms. *L. t.* subsp. *platycarpum*, *L. t.* var. *alatum* (ITIS 2020).

Common Names. Nineleaf biscuitroot, broadnineleaf biscuitroot, narrowleaf biscuitroot, narrowleaf desert-parsley, nineleaf lomatium, and ternate lomatium.

Chromosome Number. $2n = 22$ (Munz and Keck 1973; Constance et al. 1976; Hickman 1993; Welsh et al. 2016). $2n = 22$ was reported for var. *anomalum* (Constance et al. 1976) and *brevifolium* (Rice et al. 2015). $2n = 22, 44$ were reported for varieties *macrocarpum* and *triternatum* (Munz and Keck 1973; Hickman 1993).

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

DISTRIBUTION

Nineleaf biscuitroot is most common in the northwestern US states of Washington, Oregon, and Idaho (USDA FS 1937; Soltis et al. 1997) and also occurs in the southern portions of British Columbia and Alberta, Canada. The species range covers both sides of the Cascade Range and Sierra Nevada Mountains, all but the northernmost and easternmost parts of Montana, all but the easternmost part of Wyoming, and northern

California, northern Nevada, eastern Utah, western Colorado, and northwestern New Mexico (BONAP 2017).

Habitat and Plant Associations. Nineleaf biscuitroot is adapted to intense sun exposure (Fig. 1). Plants have leaves with very narrow blades that resist water loss with excessive radiation. It is common in open terrain, rocky sites, meadows, and mountain sites with high sun exposure (Daubenmire 1975a). Nineleaf biscuitroot occurs in dry to moist plains, foothills, lower and mid-montane locations, and is occasional at high-elevation sites averaging 90 or more frost-free days (USDA FS 1937; Lambert 2005a; Tilley et al. 2010; Pavék et al. 2012). It occurs at sites receiving 8 to 20 inches (203–508 mm) of annual precipitation that are typically moist in spring but dry by early summer (Taylor 1992; Skinner 2007).



Figure 1. Nineleaf biscuitroot growing in a dry sagebrush community in Oregon. Photo: Bureau of Land Management (BLM) OR014, Seeds of Success (SOS).

Nineleaf biscuitroot commonly occurs in grassland, sagebrush (*Artemisia* spp.) steppe, mountain shrub, pinyon-juniper (*Pinus-Juniperus* spp.), ponderosa pine (*P. ponderosa*), and alpine communities (USDA FS 1937; Munz and Keck 1973; Stevens and Monsen 2004; Tilley et al. 2010). It is especially common in the antelope bitterbrush-bluebunch wheatgrass (*Purshia tridentata*-*Pseudoroegneria spicata*) rangeland cover type in the Pacific Northwest and in the basin big sagebrush (*Artemisia tridentata* subsp. *tridentata*), mountain big sagebrush (*A. t.* subsp. *vaseyana*), threetip sagebrush (*A. tripartita*), and little sagebrush (*A. arbuscula*) rangeland cover types in the Great Basin (Shiflet 1994).

Forests and woodlands. Nineleaf biscuitroot is an indicator of dry forest and woodland communities in the West (Fig. 2). In Oregon and California, it occurred in western juniper (*J. occidentalis*)

woodlands where soil moisture availability was limited by layers of hard clay and duripan (Driscoll 1964; Miller et al. 2000). On pumice soils in central Oregon, nineleaf biscuitroot was most common in the driest, lowest elevation ponderosa pine/antelope bitterbrush communities (Dyrness and Youngberg 1966). In western Montana, nineleaf biscuitroot was an indicator of xeric subalpine larch (*Larix lyallii*) stands based on the species composition of 127 stands found near timberline at cold, rocky sites (Arno and Habeck 1972).



Figure 2. Nineleaf biscuitroot growing in a montane forest opening in Oregon. Photo: BLM OR014, SOS.

Shrublands. Sagebrush shrublands are common habitat for nineleaf biscuitroot (Fig. 3). In Oregon and Idaho, nineleaf biscuitroot occurred in little sagebrush, mountain big sagebrush, threetip sagebrush, and antelope bitterbrush shrublands (Tisdale et al. 1965; Dealy and Geist 1978; Doescher et al. 1986; Huntly et al. 2011). On Silver Lake winter range in south-central Oregon, nineleaf biscuitroot was a prominent forb in little sagebrush at 5,200 feet (1,585 m) where annual precipitation averaged 15 inches (380 mm) (Dealy and Geist 1978). Nineleaf biscuitroot was a principal forb in threetip sagebrush/Idaho fescue (*Festuca idahoensis*) vegetation on north and east slopes and in threetip sagebrush/Idaho fescue/bluebunch wheatgrass vegetation on south and west slopes at Craters of the Moon National Monument, Idaho. The threetip sagebrush community occupied moister, cooler sites with relatively deep, fertile soils (Tisdale et al. 1965).

Grasslands. Although nineleaf biscuitroot is common in bluebunch wheatgrass grasslands (Fig. 4), but is more abundant in Idaho fescue grasslands (Tisdale 1979). In western Montana, nineleaf biscuitroot averaged 1.8% cover in Idaho fescue and 0.4% cover in bluebunch wheatgrass grasslands (Mitchell 1957). In Power County, Idaho, nineleaf biscuitroot frequency and production

was lower in grasslands on north- (0.9 lbs/acre [1 kg/ha]; 1% freq) than south-facing slopes (7 lbs/acre [8 kg/ha]; 32% freq) with extremely stony, silt loam soils (Shiflet 1975). Nineleaf biscuitroot was also associated with rough fescue (*F. campestris*)-bluebunch wheatgrass and rough fescue-Idaho fescue communities in western Montana (Mueggler and Stewart 1980). In the Bitterroot Mountains, nineleaf biscuitroot was common in high-elevation grassland balds (>6000 ft [1,830 m]). The balds are considered climax vegetation and occur on south-facing slopes within the spruce-fir (*Picea-Abies* spp.) zone where soils are coarsely fractured and excessive summer moisture deficiencies restrict tree establishment (Root and Habeck 1972).



Figure 3. Nineleaf biscuitroot growing in an upper elevation sagebrush community abutting a montane forest in Oregon. Photo: BLM OR014, SOS.



Figure 4. Nineleaf biscuitroot growing with bluebunch wheatgrass near Boise, ID. Photo: US Forest Service, Rocky Mountain Research Station (USFS, RMRS).

Elevation. Nineleaf biscuitroot is most common at low and mid-elevations but also occurs at elevations up to 10,000 feet (3,000 m) (USDA FS

1937). In California, nineleaf biscuitroot often occurs at elevations below 5,000 feet (1,500 m) (Munz and Keck 1973), but ranges from 660-6,600 feet (200-2,000 m) (Hickman 1993). In Utah, the elevation range is 4,300 to 9,500 feet (1,300-2,900 m) (Tilley et al. 2010). High elevation occurrences of 9,500 feet (2,900 m) were reported from Utah and 10,000 feet (3,000 m) from Wyoming (USDA FS 1937).

Soils. Nineleaf biscuitroot commonly grows in relatively neutral (6.5-8.8 pH), well-drained or dry, rocky soils (USDA FS 1937; Stevens and Monsen 2004; Tilley et al. 2010). Vegetation and habitat studies report nineleaf biscuitroot in sandy to clay loam soils 8 to 39 inches (20-100 cm) deep (Driscoll 1964; Dealy and Geist 1978; Doescher et al. 1986; Bryant et al. 2013). Although rare in clay-rich soils (Darrach et al. 2010), clay or hardpan layers beneath coarser soil layers are common (Driscoll 1964; Miller et al. 2000).

Several studies provide additional information about the soil characteristics in nineleaf biscuitroot habitats. In an evaluation of vegetation along a moisture gradient in the Siskiyou Mountains of Oregon and California, nineleaf biscuitroot abundance was greater at xeric, low-elevation sites with serpentine soils (Whittaker 1960). Near Craters of the Moon National Monument, Idaho, nineleaf biscuitroot was a principal forb in deep fertile soils dominated by threetip sagebrush/Idaho fescue vegetation (Tisdale et al. 1965). In western Montana, nineleaf biscuitroot abundance was significantly greater ($P < 0.05$) in low nitrogen than high nitrogen plots when control, thinned, burned, and thinned and burned ponderosa pine stands were compared (Gundale et al. 2006).

In Oregon and northeastern California, nineleaf biscuitroot was found in sandy loams, loams, and clayey soils. In the High Desert and Klamath Ecological Provinces of southeastern Oregon and northeastern California, nineleaf biscuitroot occurred in little sagebrush/Sandberg bluegrass (*Poa secunda*) communities on clayey soils 8 to 24 inches (20-60 cm) deep underlain by fractured basalt. It was also common in mountain big sagebrush/Thurber's needlegrass (*Achnatherum thurberianum*) vegetation on loam soils 14 to 26 inches (36-67 cm) deep underlain by hardpan (Miller et al. 2000). On a semi-isolated plateau between the Crooked and Deschutes river canyons in central Oregon, nineleaf biscuitroot occurred in western juniper woodlands in non-rocky, loess, and very fine sand soils with a dense clay or stony clay loam layer at 8 to 15 inches (20-38 cm) deep. Soils averaged 1.5% organic matter, 0.08% total nitrogen, and pH 6.5 to 8

(Driscoll 1964). In Silver Lake winter range, nineleaf biscuitroot grew with little sagebrush and antelope bitterbrush in soils with fines, gravels, and rocks up to 8 inches (20 cm) in size. Soils included basalt, andesite, pumice, ash, and obsidian (Dealy and Geist 1978).

Resource acquisition. In field experiments, nineleaf biscuitroot nitrogen uptake was monitored throughout the spring by nitrogen type in a sagebrush community in eastern Oregon. Nitrogen (NH_4^+ , NO_3^-) was injected into soil around nineleaf biscuitroot at various depths in the spring (25 April and 23 May at 0.8-2.8 in [2-7 cm] and 6.7-8.7 in [17-22 cm] deep). In April, nineleaf biscuitroot captured about 20% of NH_4^+ and 50% of NO_3^- provided and less than 20% of both nitrogen types in May. Plants captured about the same amount of each type of nitrogen type (a little less than 20%) at 0.8-2.8 in (2-7 cm) deep, but much more NO_3^- (50%) than NH_4^+ (10%) at 6.7 to 8.7 in (17-22 cm) deep (James 2009).

DESCRIPTION

Nineleaf biscuitroot is a long-lived perennial forb (Tilley et al. 2010). Plants are 8 to 32 inches (20-80 cm) tall with slender, hollow, unbranched stems and leaves that are primarily or entirely basal (Munz and Keck 1973; Patterson et al. 1985; LBJWC 2020). Plants grow from a long, thick, somewhat woody taproot ranging from slender to massive and reaching several feet deep (USDA FS 1937; Hickman 1993). Five-year old plants growing in seed production plots had 11-inch (28 cm) long taproots weighing 0.28 lb (125 g) (Tilley et al. 2010).

Stems and leaves are green to blue-green, nearly hairless or with fine, soft, appressed hairs, and smell like celery (Fig. 5; Welsh et al. 2016; Luna et al. 2018). Leaves are ternately to ternate-pinnately compound with 9 to 21 narrowly linear, well-separated leaflets or segments (USDA FS 1937; Tilley et al. 2010; Welsh et al. 2016; Luna et al. 2018). Leaf petioles are up to 8 inches (20 cm) long with dilated bases forming a sheath around the stem. Leaflets range from 0.4 to 5 inches (1-13 cm) long and 0.4 to 0.6 inch (1-1.5 cm) wide (Tilley et al. 2010; Welsh et al. 2016).

Inflorescences are compound umbels (Fig. 5; Pavek et al. 2012). The umbels have 4 to 20 unequal rays ranging up to 3.5 inches (9 cm) long, which make the umbel irregular or lop-sided (USDA FS 1937; Luna et al. 2018). Rays are topped with umbellets, which contain numerous tiny yellow flowers (Fig. 6; Tilley et al. 2010). Umbellets on the longer rays support most of the bisexual

flowers with some male flowers, while those on shorter rays support mainly male flowers (Welsh et al. 2016; Hitchcock and Cronquist 2018). Individual flowers have five bright yellow stamens and five yellow petals, which fade to white with age (Welsh et al. 2016). Flowers produce schizocarps, which are fruits with two seeds (mericarps). Schizocarps are dry, oblong to elliptical, and 0.2 to 0.6 inch (6-15 mm) long by 0.2 to 0.4 inch wide (4-11 mm) wide (Patterson et al. 1985). Mericarps separate along their midlines when mature. Mericarps are strongly flattened, unnotched at the base and apex with 5 equal ribs on the dorsal side and thin wings along the sides (USDA FS 1937; Luna et al. 2018).



Figure 5. Nineleaf biscuitroot plant with highly dissected leaves and umbellets with small yellow flowers in compound umbels. Photo: BLM OR014, SOS.



Figure 6. Nineleaf biscuitroot's compound umbel with the typical unequal ray lengths and umbellets in full bloom. Photo: BLM ID931, SOS.

Varieties. Nineleaf biscuitroot varieties in some locations are poorly defined (Hickman 1993) and in other locations are in taxonomic flux

(Lesica and Kittelson 2013; Sosa et al. 2015). In California, variety *macrocarpum* is a stout plant that produces 0.3 to 0.8-inch (8-20 mm) long fruits and occurs at 660 to 5,000 feet (200-1,500 m) elevation (Munz and Keck 1973; Hickman 1993).

Researchers found no intermediate forms when studying varieties *anomalum* and *triternatum* that co-occurred near Hot Springs, Montana, which suggested no interbreeding and that the varieties should be recognized as two species (Lesica and Kittelson 2013). The varieties grew within 16 to 98 feet (5-30 m) of each other. Variety *anomalum* leaflets (6-11 mm) were wider than those of variety *triternatum* (2-4 mm) with no overlap. Mericarps of variety *anomalum* were larger (8.6 mm long, 4.8 mm wide) than those of variety *triternatum* (7 mm long, 4.2 mm wide) with little overlap. Specific leaf area of variety *anomalum* was about half that of variety *triternatum*. Variety *anomalum* occurred in swales dominated by tall, leafy forbs, while variety *triternatum* was most common on more xeric ridgetops and slopes dominated by sparse bluebunch wheatgrass tussocks (Lesica and Kittelson 2013).

Reproduction. Nineleaf biscuitroot reproduces from seed (Fig. 7; USDA FS 1937). Plants produce male and bisexual flowers (Schlessman 1982). Bisexual flowers are commonly found on the longer outer rays of the umbels and male flowers on the shorter inner umbel rays (Welsh et al. 2016; Hitchcock and Cronquist 2018). The proportion of male flowers increases in later flowering umbels (Skinner 2007).

Fruit set for biscuitroot species depends on pollination. Fernleaf biscuitroot (*L. dissectum*) fruit set was 60 times greater for flowers freely visited by pollinators than those protected from pollinators (Cane et al. 2020). Production of flowers fluctuates greatly from year to year within and between populations (Gilmartin 1982). Bisexual flowers produce the schizocarps that later split into two flat mericarps. A single umbel can produce up to several hundred mericarps (Thompson 1985).

Phenology. Nineleaf biscuitroot begins growing in early spring (Tilley et al. 2010). Plants generally flower in April and May, and seeds are typically mature in June and July (Stevens and Monsen 2004; Lesica and Kittelson 2010; BLM SOS 2017). Nineleaf biscuitroot phenology was monitored for 2 years in big sagebrush/bluebunch wheatgrass in southern British Columbia on steep slopes at 1,800 to 2,460 feet (550-750 m) where annual precipitation averaged 7 inches (188 mm). Plant growth began in March, flowering in April, and plants were in full flower in May. Seed set and shatter occurred in May and June, and plants were cured in July (Pitt and Wikeem 1990).

Pollination. Native ground nesting bees are important nineleaf biscuitroot pollinators, especially mining bees (*Andrena* or *Micandrena* spp.) (Cane and Love 2016). In a survey of bees and their floral associations at nine sites in Idaho, Oregon, and Wyoming, an average of 10 bees/100 plants were collected from late April to June sweeps of 1,309 nineleaf biscuitroot plants. Bees represented eight genera, predominantly pollen specialists: 51% mini-mining bees (*Micrandrena* spp., an *Andrena* subgenus), 32% nonsocial, ground-nesting, mining bees, 0.7% small carpenter bees (*Ceratina* spp.), 4% sweat bees (*Halictus* spp.), 8% sweat bees (*Lasioglossum* spp.), 2% cuckoo bees (*Nomada* spp.), 2% confluent miner bees (*Panurginus* spp.), and 0.7% mason bees (*Osmia* spp.) (Cane and Love 2016). In another survey, 149 bees representing 20 species were collected from nineleaf biscuitroot flowers at 12 western US sites. Mining bees were most common (*A. microchlora*, *A. chlorogaster*, *A. gordonii* primarily) (Cane et al. 2020).

Nineleaf biscuitroot provides habitat for mining bee species in fire-prone areas (Cane et al. 2020). Fires typically occur when nineleaf biscuitroot is dormant and likely to survive burning. Mining bees nest underground for one season and are active in the spring but deep underground (7.5 in [19 cm]) by summer. Seasonality of nineleaf biscuitroot and its mining bee pollinators should, therefore, survive wildfires relatively unscathed and be ready to reproduce the following spring. Consequently, when present before a fire, this pollinator relationship should recover quickly. However, without good knowledge of pre-fire communities or fire conditions, restoration is sometimes initiated even though natural regeneration may occur. If restoration includes creation of deep furrows, the apical taproot meristems of nineleaf biscuitroot can be damaged, setting back natural or assisted regeneration (Cane et al. 2020).

ECOLOGY

Nineleaf biscuitroot is a long-lived (20+ yrs), mid- to late-seral perennial (Walker and Shaw 2005; Tilley et al. 2010). It produces a well-developed taproot, and its above-ground growth structure and phenology make it drought, grazing, and fire tolerant (Daubenmire 1975a; Stevens and Monsen 2004; Skinner et al. 2005).

Seed and Seedling Ecology. Seed predation is common for nineleaf biscuitroot (Thompson 1985). In a grassland in eastern Washington, seeds were taken by small mammals and beetles. When 54 mixed piles of fernleaf biscuitroot and nineleaf

biscuitroot (5 of each) were monitored, more fernleaf biscuitroot than nineleaf biscuitroot seeds were taken, and fernleaf biscuitroot seeds were taken significantly faster than nineleaf biscuitroot seeds ($P < 0.0001$). Preference may have been influenced by nineleaf biscuitroot seed size which was 10 to 20% larger than nineleaf biscuitroot (Thompson 1985).

Above-ground seedling growth is slow, and plants produce only a few leaves in their first year because energy is devoted to taproot development (Ogle et al. 2012).



Figure 7. A single nineleaf biscuitroot compound umbel with mature fruits (schizocarps). Photo: BLM ID931, SOS.

Disturbance Ecology. Nineleaf biscuitroot is somewhat disturbance tolerant and generally more common in mid- to late-seral communities that are in good ecological condition with a diversity of other forb species. In canyon grasslands south of Lewiston, Idaho, nineleaf biscuitroot cover increased with increasing seral stage. Cover averaged 0.2% in annual-dominated, early seral communities, 0.4% in mid-seral communities, and 0.5% in perennial-dominated, late-seral communities. Nineleaf biscuitroot was negatively associated ($P < 0.05$) with yellow starthistle (*Centaurea solstitialis*), the dominant species in early seral communities (Robins 2001). In Clarkston, Washington, nineleaf biscuitroot was absent from agricultural fields abandoned for 1 to 12 years, rare in older fields abandoned for 39 to 52 years but had a frequency of up to 62% in never cultivated steppe vegetation (Daubenmire 1975b). In Benton County, Washington, nineleaf biscuitroot occurred in a 52-year-old field where sampling was concentrated at field edges closest to native, undisturbed vegetation (Simmons and Rickard 2002).

Nineleaf biscuitroot populations produced seed in the ash fallout from the eruption of Mt. St. Helens

in Washington (May 1980). These plants showed no difference from those evaluated the year before the eruption in number of leaves produced, sex ratio, or proportion of flowering individuals (Gilmartin 1982).

Fire. Nineleaf biscuitroot typically survives fire and its abundance is often greater on burned than unburned sites (Daubenmire 1975b; Busse et al. 2000; Riegel et al. 2006). Cover of nineleaf biscuitroot was not significantly different on unburned, low-severity, or high-severity burned plots in the first 3 years following fire in ponderosa pine forests on the Coeur d'Alene Indian Reservation (Armour et al. 1984). Following an August fire in a sagebrush-grassland near Pocatello, Idaho, nineleaf biscuitroot cover was significantly greater on burned plots that were not seeded with a mixture of nonnative grasses and forbs. In the first postfire growing season (May), nineleaf biscuitroot cover was 1.0% in seeded and 1.8% in unseeded plots (Ratzlaff and Anderson 1995).

Following summer fires in Idaho and Washington, nineleaf biscuitroot abundance was greater on burned than unburned plots and increased with time since fire (Daubenmire 1975b; Gucker 2004). Frequency of nineleaf biscuitroot was greater on burned than unburned bluebunch wheatgrass-Sandberg bluegrass communities near Clarkston, Washington. Frequency was about 6 times greater on burned than unburned plots in the second postfire year, about four times in the fourth postfire year, and about equal by the eight postfire year (Daubenmire 1975b). Following a low-severity, summer fire in northern Idaho, nineleaf biscuitroot cover increases occurred on both burned and unburned plots but changes from pre-fire levels were greater on burned plots (Table 1; Gucker 2004).

Table 1. Nineleaf biscuitroot cover (%) after a low-severity fire in bluebunch wheatgrass-Sandberg bluegrass-arrowleaf balsamroot vegetation south of Lewiston, Idaho (Gucker 2004).

Post fire year	2 yrs before fire	1 yr before fire	2 yrs post-fire	3 yrs post-fire
	-----% cover-----			
Unburned	0.16	0.42	1.58	1.04
Burned	0.40	0.39	2.20	4.02

Although nineleaf biscuitroot abundance was often greater on burned than unburned plots, that was not the case following an intense August fire in Gambel oak (*Quercus gambelii*) and big sagebrush/bluebunch wheatgrass vegetation near Midway, Utah (Table 2). In the first postfire year, nineleaf biscuitroot cover and frequency were

much lower on burned than unburned plots in both vegetation types (Table 2; Poreda and Wullstein 1994).

Table 2. Frequency and cover (%) of nineleaf biscuitroot in the first postfire year following a severe summer fire near Midway, Utah (Poreda and Wullstein 1994).

Vegetation type	Unburned		Burned	
	Frequency	Cover	Frequency	Cover
-----%-----				
Big sagebrush/ bluebunch wheatgrass	27.3	0.91	4.9	0.02
Gambel oak	35.3	0.77	1.8	0.01

High levels of seedling establishment were reported for one combination of seeding rate and heat produced in a field experiment at Morgan Prairie, in Thurston County, Washington. Plots (10 ft² [1 m²]) were burned at low (547 °F [286 °C]), moderate (648 °F [342 °C]), and high surface temperatures (1,047 °F [564 °C]) and then seeded with a mix of 10 native species at rates of 0, 50, 100, and 200 seeds/m² (5, 9, and 19/ft²). Nineleaf biscuitroot recruitment was nearly 5 seedlings/ft² (50/m²) at moderately burned plots seeded at 200 seeds/m² (19/ft²), which was much greater than any other treatment combination. Recruitment of nineleaf biscuitroot was almost zero on unburned plots and less than 0.5 seedlings/ft² (5/m²) on low or high temperature burns (Reagan 2014).

Wildlife and Livestock Use. Nineleaf biscuitroot provides important spring forage to native ungulates, domestic grazers, bears, small mammals, greater sage-grouse, and insects (Gullion 1960; Mueggler and Stewart 1980; Knight and Blanchard 1983; Cox 1989; Pyle 1993; Landis and Savoie 2018). It is considered valuable forage because of its large stature and high-production levels (Tilley et al. 2010). Elk (*Cervis canadensis*), deer (*Odocoileus* spp.), pronghorn (*Antilocapra americana*), and bighorn sheep (*Ovis canadensis*) feed on nineleaf biscuitroot throughout its range (Gullion 1960). Forage is considered good for elk and deer, fair to good for sheep, and poor to fair for cattle (Mueggler and Stewart 1980).

Mammals. Amounts and seasons of use of nineleaf biscuitroot were reported for several mammals in the West. In south-central Oregon, mule deer (*Odocoileus hemionus*) fed on flower heads and flower stalks in meadows in a lodgepole pine forest (Stuth and Winward 1977). Mountain goats (*Oreamnos americanus*) fed on nineleaf biscuitroot in June in western Montana's Swan Mountains (Chadwick 1974). On the Desert Game Range, in Clark County, Nevada, bighorn sheep fed on nineleaf biscuitroot in July (Hall

cited in Gullion 1960). Domestic sheep readily consume its leaves, flowers, and green seeds (USDA FS 1937). On elk winter range in Cow Creek, Montana, nineleaf biscuitroot represented a trace of cattle diets in late July and 3% of diets in August (Gordon 1968). In Yellowstone National Park, nineleaf biscuitroot was 1% of grizzly bear (*Ursus arctos*) diets by volume from scat analysis (Knight and Blanchard 1983). Northern pocket gophers (*Thomomys talpoides*) feed on nineleaf biscuitroot and it is a highly preferred food source. At Lawrence Memorial Grassland Preserve, north-central Oregon, all 9 nineleaf biscuitroot roots in monitored tunnels were taken. At this site, many plants were rooted within large grass clumps, which may offer protection from predation (Cox 1989).

Birds. Nineleaf biscuitroot foliage and insect visitors are important to greater sage-grouse (*Centrocercus urophasianus*). Leaves are eaten in early spring, and the flowers support invertebrates, which are a critical food source for greater sage-grouse chicks (Rhodes et al. 2010; Tilley et al. 2010; Pennington et al. 2016; Luna et al. 2018). At the Hart Mountain National Antelope Refuge in Lake County, Oregon, nineleaf biscuitroot was recovered from the crops of greater sage-grouse chicks collected from brood-rearing habitat (Pyle 1993).

Insects. Early spring green-up and flowering make nineleaf biscuitroot important for spring pollinators, especially pollen-collecting mining bees (Tilley et al. 2010). Nineleaf biscuitroot is a host species for swallowtail butterflies (*Papilio zelicaon* and *P. indra*) (James and Nunnallee 2011; Landis and Savoie 2018) and a nectar source for Puget blue (*Icaricia icarioides blackmorei*) and other butterflies (LaBar and Schultz 2012).

Many mining bee species have been collected from nineleaf biscuitroot including *Andrena angustitarsata*, *A. auricoma*, *A. forbesii*, *A. fulvinigra*, *A. hippotes*, *A. merriami*, *A. oligolege*, *A. pallidifovea*, *A. salicifloris*, *A. scurra*, *A. striatifrons*, *A. quintiliformis*, and *A. wheeleri* (La Berge 1973; Ribble 1974; Laberge and Ribble 1975; LaBerge 1989).

Ethnobotany. Indigenous people living in the western US and Canada used nineleaf biscuitroot for food, medicine, ceremonies, and luck. Roots, leaves, and flowers were eaten but roots were the staple (Johnston 1970; Reveal et al. 1999). Roots, leaves, flowers, and fruits were used medicinally.

Nineleaf biscuitroot roots were eaten raw, roasted, or dried for later use by many Indigenous groups (Johnston 1970; Marshall 1977; Turner et al. 1980; Reveal et al. 1999; Moerman 2003). The

Atsugewi of northern California, cooked the roots in earth ovens (Moerman 2003). The Okanagan-Colville, Blackfeet, and other tribes in Montana baked biscuits and cakes from flour made from the roots (Patterson et al. 1985; Moerman 2003). The Blackfeet used nineleaf biscuitroot flowers to make pemmican (Moerman 2003). The Okanagan-Colville used dried flowers and upper leaves to add a celery-like flavor to meats, stews, and salads. Sanpoil and Nespelem tribes ate roots raw or pit-cooked and laid leaves and roots on top of cooking baskets to add flavor (Turner et al. 1980).

Medicinally, nineleaf biscuitroot was used by Indigenous people to treat respiratory illnesses. The Blackfeet considered nineleaf biscuitroot to be a cure-all (Moerman 2003). Chewed roots were made into a spray and believed to penetrate and heal the body at the point of pain. An infusion of roots was used to treat chest troubles, and fruits were chewed by long-distance runners to avoid side aches (Moerman 2003). The Okanagan-Colville used an infusion of flowers and upper leaves for colds and sore throats (Turner et al. 1980).

There were several other miscellaneous uses for nineleaf biscuitroot. It was carried by Indian men as a love charm (Van Allen Murphey 1990). Seeds were stuffed in a porcupine foot that was tied in the hair of young Blackfeet girls for good luck (Moerman 2003). Seeds were also used during the tanning of animal pelts to control the odor. The Paiute believed they could summon cold winds by breaking nineleaf biscuitroot stems or roots (Moerman 2003).

Horticulture. Nineleaf biscuitroot is an attractive, long-lived, drought-tolerant plant that would be useful in low-maintenance landscapes such as campgrounds, roadsides, or rest areas where native and adapted. Bright yellow flowers and interesting brown striped seeds grow on upright plants with unusual leaves. Its use has been encouraged for native landscaping in the Palouse region of Idaho and Washington where it thrives with little added water or fertilizer (Skinner et al. 2005).

REVEGETATION USE

Nineleaf biscuitroot is recommended for pollinator and wildlife habitat conservation plantings and provides fair soil stabilization where native and adapted (Shaw and Monsen 1983; Tilley et al. 2013; Dumroese et al. 2016). It grows well in

mountain big sagebrush, pinyon-juniper, aspen (*Populus tremuloides*), and subalpine zones receiving annual precipitation of 12 to 20 inches (305-508 mm) (Tilley et al. 2013; Ogle et al. 2019). Once established it is competitive with weeds and tolerant of drought, grazing, and fire (Daubenmire 1975a; Stevens and Monsen 2004; Skinner et al. 2005; Tilley et al. 2010).

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. Because empirical seed zones are not currently available for nineleaf 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 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.

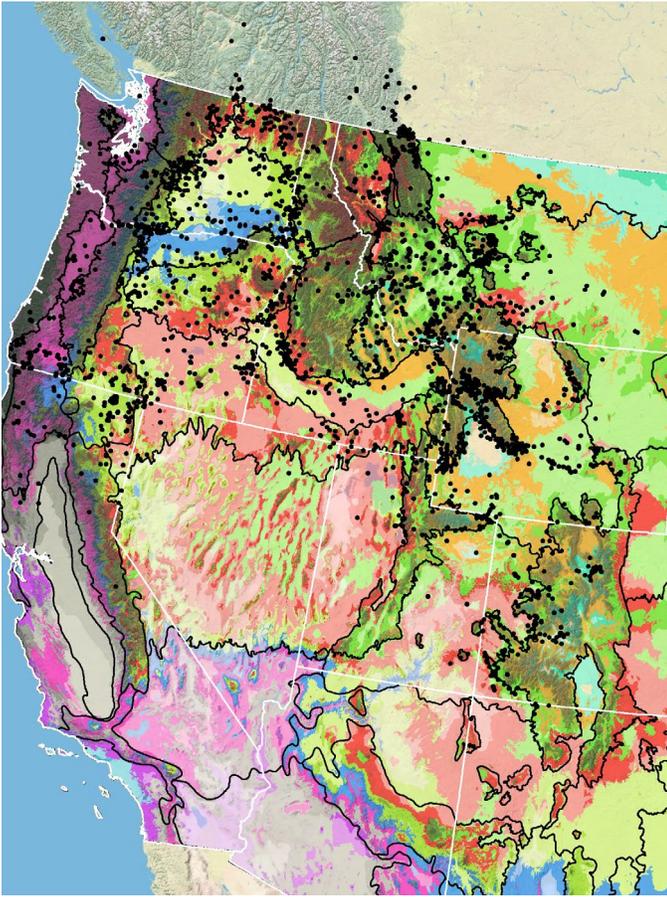


Figure 8. Distribution of nineleaf biscuitroot (black circles) based on geo-referenced herbarium specimens and observational data from 1881-2016 (CPNWH 2017; SEINet 2017; USDI USGS 2017). Generalized provisional seed zones (colored regions) (Bower et al. 2014) are overlain by Omernik Level III Ecoregions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

Wildland Seed Collection. Nineleaf biscuitroot seeds are typically ready for harvest when the inflorescence is dry and fruits are tan, which is generally in late June or July (Skinner 2007). Because many lomatium species have similar looking seeds, it is best to collect from plants that still have leaves to aid identification (Camp and Sanderson 2007).

Wildland seed certification. Wildland seed collected for 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. At maturity nineleaf biscuitroot seeds are dry, papery, tan to brown, and easily dislodged from the inflorescence (Fig. 9). This typically occurs 5 to 8 weeks after flowering in late June or July. (Parkinson and DeBolt 2005; Camp and Sanderson 2007; Skinner 2007; BLM SOS 2017). Seed ripens uniformly within individual umbels but ripening can vary among umbels on the same plant or on different plants (Skinner 2007).

The Bureau of Land Management's Seeds of Success crews made 48 collections of nineleaf biscuitroot over 9 years between 2000 to 2016 (USDI BLM SOS 2017). Harvests were made in Washington, Oregon, California, Nevada, Utah, Idaho, and Wyoming. Sixty seven percent of the collections were made in July, and 25% were made in June. The earliest collection was made on May 22, 2013, from 3,340 feet (1,020 m) elevation in Malheur County, Oregon. The latest harvest was made on September 2, 2013, from 5,700 feet (1,740 m) elevation in Lassen County, California. In the single year with the greatest number of collections (19 harvests in 2010), the earliest was June 21 from 2,968 feet (905 m) in Ada County, Idaho, and the latest was July 27 at 6,570 feet (2,000 m) in Uinta County, Wyoming (USDI BLM SOS 2017).



Figure 9. Nineleaf biscuitroot with mature seed dispersing. Photo: BLM CA350, SOS.

Collection methods. Wildland seed is easily hand collected by stripping or shaking umbels over a container or by clipping the inflorescences (Fig. 10; Jorgensen and Stevens 2004; Parkinson and DeBolt 2005; Skinner 2007). Seed detaches readily from the umbellets. Collections made by shaking ripe inflorescences over a container are very clean (Ogle et al. 2012).



Figure 10. Collecting wildland nineleaf biscuitroot seed in a sagebrush community. Photo: US Forest Service, Rocky Mountain Research Station (USFS RMRS).

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).

Collection rates. Hand-stripping is easy but can be moderately time consuming, depending on stand conditions (variability in seed ripening, plant distribution) if a large quantity of seed is required (Fig. 11; Camp and Sanderson 2007).

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 in a dry, cool location 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 harvest, the more ventilation and drying a seed lot may need (Gold n.d.; Parkinson and DeBolt 2005; Hay and Probert 2011). Camp and Sanderson (2007) recommend drying nineleaf biscuitroot at room temperature for 2 to 4 weeks before cleaning.

Seed Cleaning. Seed can be cleaned to high purity with minimal air screening (Ogle et al. 2012). Seeds must be handled carefully as they are fragile and brittle. Small collections can be carefully hand-rubbed to free seeds from the inflorescence then cleaned using an air column separator. Large collections require cleaning with air screen equipment (Skinner 2007).



Figure 11. Nineleaf biscuitroot fruits (winged schizocarps with ribs) and a mericarp (center) with the commissure visible. Photo: USFS RMRS.

A small seed lot collected from the Columbia Basin was cleaned by hand rubbing inflorescences, then using an air column separator, and finally shaking seed through a standard soil testing sieve (3.5

meshes/inch). Some chaff remained following this process (Camp and Sanderson 2007).

A larger, hand-collected seed lot (2.5 lbs [1.1 kg]) was cleaned at the USFS Bend Seed Extractory. Seed was processed using a Westrup Model LA-H laboratory brush machine (Corvallis, OR), with a #20 mantel and medium speed. Seed was then air-screened using an office Clipper (Bluffton, IN) with a 1/12 round top and 7 x 3/4 cross slot bottom screen. Seed was rescreened using a 1/12 top round screen, 18 bottom round screen, medium speed, and medium air (Barner 2007).

Seed Storage. Nineleaf biscuitroot seed retains its viability after 3 to 4 years of storage (Stevens and Monsen 2004). Recommended storage conditions range from 33 to 40 °F (0.6-4 °C) and 35 to 44% relative humidity (Barner 2007; Camp and Sanderson 2007; Skinner 2007). Nineleaf biscuitroot seed viability was 92% after 18 months of storage at room temperature in a glass container (Parkinson and DeBolt 2005). Viability of multiple collections ranged from 44 to 95% after dry seed was stored 5 months at 68 °F (20 °C) at the Royal Botanical Gardens Kew. Pre-storage viability was not reported (RGB Kew 2017).

Seed Testing. Seed fill can be evaluated by viewing mericarps over a light table (Parkinson and DeBolt 2005). There is no Association of Official Seed Analysts (AOSA) rule for testing germination of nineleaf biscuitroot. Vankus (2006) recommends testing germination at temperatures of 59 to 77 °F (15-25 °C). First seed count is made after 7 days and the final count at 28 days. Fresh seed requires 28 to 63 days of cold stratification at 37 to 41 °F (3-5 °C). Older seed may germinate during stratification (Vankus 2006).

Viability testing. The following tetrazolium chloride (TZ) testing procedure can be used to evaluate viability of nineleaf biscuitroot seed. Barely cover seed with water and soak it overnight at room temperature, then cut the seed longitudinally to remove about one quarter of the mericarp. Discard the quarter sections and soak the rest of the mericarp for 6 hours or overnight in a 1% TZ solution. Staining is evaluated by making a longitudinal cut at the center of the seed through the embryo. Normal live embryos stain pink or reddish. Dead embryos are unstained, partially stained, or very darkly stained (Hurd n.d.).

Germination. Nineleaf biscuitroot produces seed with immature embryos that require a long period (9+ weeks) of cold stratification to develop and germinate (Shaw and DeBolt 2005; Skinner

2007; RBG Kew 2017). Germination occurs at low temperatures, light is not required, and gibberellic acid fails as a cold (< 50 °F [10 °C]) stratification substitute (Shaw and DeBolt 2005). In trials conducted at the NRCS Pullman Plant Materials Center, nineleaf biscuitroot failed to germinate after 30 days of cold stratification, but seed sown outdoors in November emerged in late March (Skinner 2007).

Several studies report on the necessity of cold stratification for germination. Jorgensen and Wilson (2004) reported 50% germination after 100 days in the dark at 34 to 38 °F (1-3 °C) and a little less than 70% after 250 days (Jorgensen and Wilson 2004). Parkinson and DeBolt (2005) achieved 93% germination when imbibed seeds were chilled at 39 °F (4 °C) in the dark for 60 days. Germination began after 36 days of stratification, and most seeds germinated within 49 days. Seeds were soaked for 24 hours before the cold stratification treatment (Parkinson and DeBolt 2005). The Royal Botanical Gardens Kew obtained 100% germination for 19 seeds placed on 1% agar, treated to 8 hours of light and 16 hours of dark at 41 °F (5 °C) for 258 days (RBG Kew 2017).

Drake et al. (1998) and Drake and Ewing (n.d.) reported no germination (0%) with 6 weeks stratification and 6.7% germination following 12 weeks of cold stratification at 36 to 43 °F (2-6 °C). Germination results were the same for seed germinated outdoors (48-65 °F [9-18 °C]) or in a greenhouse (65-85 °F [18-29 °C]) following the stratification treatments. Seed was 63% viable based on TZ testing.

Wildland Seed Yield and Quality. Post-cleaning seed yield and quality of nineleaf biscuitroot seed lots collected in the Intermountain region are provided in Table 3 (USFS BSE 2017). Results indicate that fresh nineleaf biscuitroot seed purity, fill, and viability can be highly variable. Most other estimates of seeds/lb reported elsewhere in the literature fall within those reported in Table 3 (37,130-63,812 seeds/lb [81,856-140,679/kg]) (Lambert 2005a; Skinner 2007; USFS GBNPP 2014; RBG Kew 2017), but some reports exceeded those values (90,500 seeds/lb [199,515/kg]) (Wiese et al. 2012) and 113,500 seeds/lb [250,220/kg]) (Camp and Sanderson 2007).

Table 3. Seed yield and quality of nineleaf 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)	1.5	0.11-5.6	26
Clean weight (lbs)	0.7	0.05-3.0	26
Clean-out ratio	0.5	0.10-0.8	26
Purity (%)	92	66-99	26
Fill (%) ¹	87	50-98	26
Viability (%) ²	88	59-98	25
Seeds/lb	50,464	32,000-87,000	26
Pure live seeds/lb	38,740	14,807-73,602	25

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. The following marketing standards were suggested for nineleaf biscuitroot seed: acceptable purity 75%, viability 70%, and germination 70% (Walker and Shaw 2005).

AGRICULTURAL SEED PRODUCTION

Trials for growing nineleaf biscuitroot for seed production were conducted at Oregon State University's Malheur Experimental Station (OSU MES) (Shock et al. 2016) and the NRCS Aberdeen Plant Materials Center (Ogle et al. 2012). At OSU MES, production plots were planted with seed collected near Lakeview, Oregon. Plants began flowering and produced some seed in their second year, but seed yields were low until year three (Shock et al. 2018). Seed was harvested for 11 years at OSU MES, where they found that seed production increased with irrigation in most years (see [Irrigation](#) section) (Shock et al. 2016, 2018). Seed production plots at the Aberdeen PMC did not flower or produce seed until year four (Ogle et al. 2012).

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. Seeding is best in firm, weed-free seedbeds. Seed production plots that were used to test preemergence herbicides at OSU MES were seeded at a rate of 30 pure live seed (PLS)/foot 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/foot [0.6 g/m] of row) and row cover until April 7, 2010 (Shock et al. 2011).

Weed Management. Weed control is necessary for good seed yields (Tilley et al. 2010). Weed control can be achieved using weed barrier fabric, cultivation, and hand roguing (Ogle et al. 2012; Shock et al. 2016). Because nineleaf biscuitroot goes dormant early in the growing season, plots can be treated later in the growing season without compromising seed production (St. John and Ogle 2011).

Trials at OSU MES evaluated emergence of nineleaf biscuitroot following preemergent herbicide treatments (Shock et al. 2011). Most herbicide treatments had minimal effect on emergence, which was only about 25% regardless of treatment (Table 4). Preemergent herbicides were applied in late November using a CO₂ sprayer at 30 PSI (Shock et al. 2011).

Table 4. Emergence of nineleaf 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).

Herbicide applied Nov 30, 2009	Application rate (lb ai/acre)	Emergence (%)
Untreated	NA	26.0
Bensulide	5.0	26.5
Pronamide	1.0	17.2
Trifluralin	0.375	24.2
Pendimethalin	0.75	24.3
Benefin	1.2	26.3
Dimethenamid	0.656	21.2
Linuron	0.5	24.0

*Providing charcoal protection to the seed with treatments of pendimethalin had a significantly detrimental effect on nineleaf biscuitroot emergence.

Yields of nineleaf biscuitroot seed were not significantly different with most annual post-emergent herbicide treatments (Table 5), except the first year's treatment of bromoxynil, which significantly reduced seed yields compared to untreated plants. Herbicides were applied in the spring for 4 consecutive years. Seed production was very low in 2009, the reason for this was not reported. Seed yields represent small, one-row plots without borders and may not be representative (Shock et al. 2011).

Table 5. Seed yield of nineleaf biscuitroot following the second, third, and fourth years of post-emergent herbicide treatments in experimental plots seeded in November 2005 at Oregon State University's Malheur Experiment Station, Ontario, OR (Shock et al. 2011).

Herbicide	Application rate (lb ia/acre)	Year 2	Year 3	Year 4
		3/12/2008	3/20/2009	4/7/2010
Seed yields (lbs/acre)				
Control	NA	981.5a	32.6a	475.3a
Bromoxynil	0.125	187.9b	20.8a	462.8a
Oxyfluorfen	0.125	820.8a	28.2a	421.6a
Clethodim	0.094	1,062.1a	38.2a	449.1a
Pendimethalin	1.0	922.7a	28.6a	488.7a
Prometryn	0.8	1,069.8a	27.8a	449.1a
Dimethenamid	0.656	987.0a	26.6a	413.4a
Linuron	0.5	888.1a	31.2a	533.3a

At the Aberdeen PMC, nineleaf biscuitroot was direct seeded in November 2005 in weed barrier fabric. Weeds were controlled with wick applications of glyphosate and hand weeding while nineleaf biscuitroot was establishing and actively growing. In June 2007, survival was 71%, but no plants flowered. By early July, plants were dormant, and plots were sprayed with glyphosate.

In 2008 and 2009, plants produced seed in July. Seed production was nearly twice as much in 2009 as in 2008. Plots were glyphosate treated in November in 2008 and 2009. Better seed production in 2009 than in 2008 was due to plant age and not related to weed treatments (St. John and Ogle 2011).

Seeding. Nineleaf biscuitroot was seeded in late October 2005 at rates of 20 to 30 PLS/linear foot (66-98 PLS/m) in seed production plots at OSU MES. It was seeded in silt loams using a custom, small-plot, grain drill with disk openers. Seed was planted 0.5 inch (1.3 cm) deep (Shock et al. 2016, 2018). Seeds were placed on the soil surface, then buried with a thin layer of sawdust. A long period of cold stratification is needed for seed to germinate, and in spring 2006, stands were considered excellent (Shock et al. 2016, 2018). Seedlings failed to emerge when seed was cold stratified for 1 month prior to early spring seeding on March 3 (Shock et al. 2018).

At the Aberdeen PMC, nineleaf biscuitroot was fall seeded in rows at a rate of 25 PLS/foot (82 PLS/m) of row or into weed barrier fabric at 18 to 24-inch (40-60 cm) spacings (Ogle et al. 2012). In the establishment of a common garden near Boise State University, nineleaf biscuitroot was seeded 0.4 to 0.8 inch (1-2 cm) deep in holes burned into weed barrier cloth in fall 2004. Emergence began in late February 2005 when a high percentage of holes had seedlings (Shaw and DeBolt 2005).

Establishment and Growth. In its first year of growth, nineleaf biscuitroot produces few leaves and devotes energy to taproot development (Ogle et al. 2012). In the early seedling stage, nineleaf biscuitroot can be mistaken for a grass due to its linear cotyledons (Fig. 12; Pavék et al. 2012). Plants are considered established after a year and flower after 2 to 4 years of growth (Ogle et al. 2012; Shock et al. 2016). Once established, nineleaf biscuitroot is a strong perennial when protected from rodents (Shock et al. 2018). Plants green up, flower, and set seed early in the growing season (Table 6).



Figure 12. Nineleaf biscuitroot seedlings emerging from a southern Idaho planting. Photo: USFS RMRS.

Table 6. Timing of flowering and seed harvest dates for nineleaf biscuitroot seed production fields over a period of 9 years at Oregon State University's Malheur Experiment Station, Ontario, OR (Shock et al. 2016). Seed yields are provided in Table 7 (Shock et al. 2016, 2018).

Year	Flower start	Flower peak	Flower end	Harvest
	----- Date -----			
2007	25 Apr		1 Jun	29 Jun, 16 Jul
2008	25 Apr		5 Jun	3 Jul
2009	10 Apr	7 May	1 Jun	26 Jun
2010	25 Apr		15 Jun	22 Jul
2011	30 Apr	23 May	15 Jun	26 Jul
2012	12 Apr	17 May	6 Jun	21 Jun
2013	18 Apr		10 May	4 Jun
2014	7 Apr	29 Apr	2 May	4 Jun
2015	10 Apr	28 Apr	20 May	7 or 15 Jun
2016	11 Apr	28 Apr	20 May	15 Jun
2017	24 Apr	15 May	30 May	27 Jun

Irrigation. Trials conducted at OSU MES (Fig. 13) found that plant size and seed yield of nineleaf biscuitroot were significantly greater with irrigation (Table 7) (Shock et al. 2018). Irrigation trials delivered 0, 4, or 8 inches (101 or 203 mm) of water in March 2006 to plots that were seeded in late October 2005. Irrigation treatments were delivered four times at about 2-week intervals beginning at the time of bud formation and flowering. Irrigation was delivered through drip tape buried 12 inches (30 cm) deep, so as not to affect flowering and to limit germination of weed seed (Shock et al. 2016). In most years, nineleaf biscuitroot seed yields increased significantly with irrigation ($P < 0.05$). Seed yield was maximized by 4 inches (101 mm) or more of water in cool, wet years and by 8 inches (203 mm) of water in warm, dry years (Shock et al. 2016). Seed yields exhibited a quadratic response to irrigation from 2008 to 2012 and a linear response to irrigation in 2007, 2013, 2014, and 2015 (Shock et al. 2016, 2018). Accumulated growing degree hours were higher than average in 2006, 2007, and 2013 to 2016. High accumulated growing degree hours in 2015 were probably the reason for early harvest dates (Shock et al. 2018).

Pollinator Management. Nineleaf biscuitroot flowers attract and are primarily pollinated by mining bees that nest underground and live for one year. Seed production plots may attract mining bees from nearby populations of spring-blooming floral hosts (Salicaceae, Rosaceae, Brassicaceae). When grown near towns or apiaries, nineleaf biscuitroot flowers are visited by honeybees suggesting field pollination could be improved by providing hives (Cane et al. 2020).

Table 7. Nineleaf biscuitroot seed yields (lbs/acre) with and without irrigation for 11 years of varied precipitation and growing conditions at Oregon State University's Malheur Experiment Station, Ontario, OR (Shock et al. 2016, 2018).

Year	Precip levels	Growing degree hrs (50-86 °F) +/- the 25-yr mean	Added irrigation		
			0 in	4 in	8 in
Yield (lbs/acre)					
2007	Below normal	+66	2.3a	17.5ab	26.7b
2008	Below normal	+199	195a	1,061b	1,387b
2009	Above normal	-120	182a	780b	676b
2010	Above normal	0	1,637a	2,830b	3,195c
2011	Above normal	-236	1,983a	2,625b	2,028a
2012	Normal	-351	239a	603b	733b
2013	Below normal	+21	154a	734b	1,051b
2014	Below normal	+112	241a	897b	1,497c
2015	Normal	+403	403a	441a	955b
2016	Normal	+251	395a	476ab	639b
2017	Above normal	-11	933a	949a	1,266b
11-yr ave	9.8 in (fall + winter + spring)	1,207 hrs	579a	1,038b	1,211c

Pest Management. Insects and mammals can affect nineleaf biscuitroot growth and reproduction (see [Seed and Seedling Ecology](#) and [Wildlife and Livestock Uses](#) sections). Nineleaf biscuitroot is also host to various fungi: *Asperisporium peucedani*, *Cercospora herpotrichoides*, *Fusicladium peucedani*, *Leptosphaeria conoidea*, *Nodulosphaeria modesta*, *Phoma lomatiae*, and *Puccinia jonesii* (Farr and Rossman 2017). Effects or impacts of fungi on nineleaf biscuitroot growth or survival were not reported.

Seed Harvesting. At OSU MES, nineleaf biscuitroot was harvested by hand and cleaned using an Office Clipper (Bluffton, IN) (Shock et al. 2015). At the Aberdeen PMC harvested nineleaf biscuitroot seed was harvested using vacuum type or flail vac harvesters. These harvests were easily air screened to nearly 100% purity (Ogle et al. 2012). Nineleaf biscuitroot seed harvested using the Jet Harvester developed by the Aberdeen PMC was much more efficient than

hand harvesting, and the seed required little post-harvest cleaning (Tilley and Bair 2011).



Figure 13. Nineleaf biscuitroot irrigation trial at OSU MES. Photo: USFS RMRS.

Seed Yields and Stand Life. Nineleaf biscuitroot was harvested for 11 years at OSU MES (Shock et al. 2018). Averaged over the years, seed yield was maximized at 1,213 lb/acre (1,360 kg/ha) with 12.4 inches of water (irrigation + spring precipitation) (Shock et al. 2018).

Regression analyses estimated that seed yields were greatest with 4 to 8 inches (102-210 mm) of irrigation, depending on the year (Table 8; Shock et al. 2016). Seed yields showed a quadratic response to irrigation plus spring precipitation from 2008 through 2013. In 2007, and 2014 to 2016, seed yield showed a positive linear response to irrigation plus spring precipitation. In 2017, seed yields were not responsive to irrigation, likely because of heavy winter and spring precipitation (Shock et al. 2018).

Table 8. Regression analysis for fernleaf biscuitroot seed yield (y, lbs/acre) (in response to irrigation plus spring precipitation (x, mm/season) using equation $y=a + b \cdot x + c \cdot x^2$) in 2007-2017 and the 11-year average. Study 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	Max yield (lb/acre)	Water applied plus spring ppt for max yield (in/season)	Spring ppt (in)
2007	28	9.9	1.9
2008	1,390	9.8	1.4
2009	824	9.5	4.1
2010	3,196	12.1	4.3
2011	2,623	8.8	4.8
2012	734	10.8	2.6
2013	1,115	11.6	0.9
2014	1,509	9.7	1.7
2015	875	11.2	3.2
2016	624	10.2	2.2
Ave	1,213	12.4	2.9

*2017 seed yield was not responsive to irrigation, probably because of heavy winter and spring precipitation (Table 7).

NURSERY PRACTICE

Nineleaf biscuitroot plants were grown successfully outdoors and in greenhouses (Parkinson and DeBolt 2005; Camp and Sanderson 2007), but plants started outdoors that were moved to a greenhouse died at the Aberdeen PMC. Causes of mortality were thought to be due to temperature changes or root pathogens (Skinner 2007).

Parkinson and DeBolt (2005) planted germinating seed 0.4 inch (1 cm) deep in Styrofoam containers filled with equal parts peat and vermiculite. Containers were kept at a constant 81 °F (27 °C) in the greenhouse and watered when saturation levels fell below 80%. Small amounts of seedling fertilizer were added periodically. True leaves appeared after 14 days. Seedling survival was 53% after 77 days in the greenhouse (Parkinson and DeBolt 2005).

Camp and Sanderson (2007) planted nineleaf biscuitroot in a soil mix of 50% peat, 35% perlite, and 15% sand in early November. Seeds were lightly covered with sand and kept outdoors. Germination was good and began in late February. Seedlings developed 3 to 4 leaves in the spring. Planting beds were top dressed with 14:14:14 fertilizer. Good stands re-emerged the following spring and about 5% of the plants bloomed.

Outdoor beds were not watered or fertilized in the second year (Camp and Sanderson 2007).

Nineleaf biscuitroot plants were grown successfully outdoors at the Pullman PMC. Seed was collected from the Paradise Creek Drainage near Pullman, Washington. Seed was sown in Ray Leach Super cell containers (10 cu in) filled with Sunshine #4 soil mix. Seeds were covered lightly with soil and a thin layer of coarse grit to prevent seeds from floating when watered. Containers were watered deeply and placed outside. Additional watering occurred only during dry spells. Seedling emergence began in March with warm daytime temperatures and occurred over a period of 3 to 4 weeks. Seedlings were watered as needed and fertilized once a week with a complete, water-soluble fertilizer. Seedlings were moved to a lath house in early June, where they were only watered to prevent complete drying. Plants overwintered in a lath house, where they were protected from rodents and covered with mulch or foam sheets in extremely cold temperatures. A few plants flowered in the year following outplanting but most required 2 years in the field to produce flowers and seed (Skinner 2007).

WILDLAND SEEDING AND PLANTING

Nineleaf biscuitroot is recommended for restoration or revegetation in sagebrush, pinyon-juniper, and aspen zones where precipitation averages 8 to 25 inches (203-635 mm)/year (Shaw and Monsen 1983; Walker and Shaw 2005; Ogle et al. 2011). Nineleaf biscuitroot provides good pollinator habitat and fair soil stabilization (Shaw and Monsen 1983; Ogle et al. 2011; Eldredge et al. 2013). Although nineleaf biscuitroot has a slow initial growth rate, it is competitive with weeds once established and persists as a mid- to late-seral species (Walker and Shaw 2005; Tilley et al. 2010).

Fall seeding is necessary for seed stratification and germination. Seed can be broadcast or drill seeded 0.1 to 0.2 inch (0.3-0.6 cm) deep as a mix or separately (Shaw and Monsen 1983; Stevens and Monsen 2004; Tilley et al. 2010). The pure seeding rate is 20 to 24 PLS lbs/acre (22-27 kg/ha) (Ogle et al. 2011). In wildland restoration efforts, nineleaf biscuitroot was seeded in mixes at a rate of 0.2-1.5 lbs/acre (0.2-1.7 kg/ha) (Cosgriff et al. 2004; Lambert 2005b; Applestein et al. 2018). Newly seeded sites should be protected from grazing for at least 2 years (Stevens and Monsen 2004).

Transplants and root material were established successfully in field evaluations at the Aberdeen PMC. Transplants grown for a full season and overwintered before planting were very hardy and established at almost 100% when weeds were controlled (Tilley et al. 2010). At Canaday Farm in Spring Creek, Nevada, root pieces 2 to 8 inches (5-20 cm) long had good emergence when field planted in the spring of 2010. By April 13, 2011, multiple leaflets and flowering stems had emerged from most roots. The orientation and size of the roots in the planting hole did not impact emergence. Plants generally produced aboveground growth proportional to the size of the transplanted rootstock. Height of the plants, which included flowering stems, was typically less than 8 inches (20 cm). Survival through the first spring was good and some plants produced limited amounts of seed (Jensen and Stettler 2012).

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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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COLLABORATORS

