ANNUAL AGOSERIS

Agoseris heterophylla (Nutt.) Greene
Asteraceae – Aster family

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ORGANIZATION

NOMENCLATURE

Annual agoseris (*Agoseris heterophylla* [Nutt.] Greene) belongs to the Asteraceae family, Cichorieae tribe, and Microseridinae subtribe (Feuer and Tomb 1977).

NRCS Plant Code. AGHE2 (USDA NRCS 2021).

Subtaxa. The Flora of North America recognizes a single annual agoseris species composed of three varieties: *A. h.* var. *heterophylla* (Nutt.) Greene, *A. h.* var. *cryptopleura* Greene, and *A. h.* var. *quentinii* G.I. Baird (Baird 2006).

Synonyms. *Macrorhynchus heterophyllus* Nutt., *Troximon heterophyllum* (Nutt.) Greene.

Agoseris species are widespread with high levels of morphological and regional variability. This variability makes identification difficult and many inaccurate descriptions exist in the literature. Hybridization and intermediate forms are also common within the genus. Many synonyms for *Agoseris* species have resulted from the naming of variant populations (Baird 2006).

Variety *heterophylla*: *A. heterophylla* var. *glabra* (Nutt.) Howell, *A. h.* subsp. *cryptopleura* Jeps., *A. h.* subsp. *glabrata* (Suksdorf) Piper, *A. h.* var. *kymapleura* Greene, *A. h.* subsp. *normalis* Piper, and *Troximon heterophyllum* (Nutt.) Greene var. *cryptopleuroides* Suksdorf.

Variety *cryptopleura*: *A. californica* (Nutt.) Hoover, *A. h.* subsp. *californica* (Nutt.) Piper, *A. h.* var. *californica* (Nutt.) Davidson & Moxley, *A. h.* var. *crenulata* Jeps., *A. h.* var. *turgida* (H.M. Hall) Jeps., *A. major* Jeps. ex. Greene, and *Cryptopleura californica* Nutt.

Variety *quentinii*: none.

Common Names. Annual agoseris, Arizona agoseris, California agoseris, and mountain dandelion (Rosiere and Vaughn 1986; Baird 2006).

Chromosome Number. Chromosome numbers for variety *heterophylla* are: 2n = 18, 36, and the

chromosome number for variety *cryptopleura* is 2n = 18 (Baird 2006).

Hybridization. Hybridization is not common but intermediates with woolly goat chicory (*A. apargioides*) and Coast Range agoseris (*A. hirsuta*) are known (Baird 2006).

DISTRIBUTION

Annual agoseris grows from British Columbia to Baja California and in all US states west of western Montana and western New Mexico except for Wyoming and Colorado (Baird 2006; Jensen 2007). Variety *heterophylla* is found throughout the range described for the species (Fig. 1; Baird 2004, 2006). Variety *cryptopleura* occurs in the foothills and Coast Mountain ranges surrounding California's Great Central Valley. Variety *quentinii* grows in Arizona and New Mexico (Baird 2006).

Habitat and Plant Associations. Annual agoseris grows in dry to wet grassland (Fig. 1), chaparral, desert shrub, shrub steppe (Fig. 2), oak (*Quercus* spp.) woodland, and conifer forest communities (Baird 2006). In California, it grows in open grassy sites in a variety of plant communities (Munz and Keck 1973). In the Great Basin, it grows in dry prairies, grasslands, and foothill woodlands (Lambert 2005). In Utah, it is considered rare but occurs in dry, open lowland and foothill sites in sagebrush (*Artemisia* spp.)/grass and mountain brush communities up to 2,300-foot (700 m) elevation (Jensen 2007; Welsh et al. 2016).

Figure 1. Grassland habitat supporting annual agoseris in the seed collecting stage in Oregon. Photo: USDI, BLM SOS OR931.

In the available literature, details about annual agoseris habitats and plant associations were largely limited to Washington, Oregon, and California. In Washington, annual agoseris occurs in bunchgrass prairies dominated by bluebunch wheatgrass (*Pseudoroegneria spicata*) and Sandberg bluegrass (*Poa secunda*) (Piper 1906). In southeastern Washington and adjacent Idaho, it is reported growing on southern aspects but was absent from northern aspects of moist prairie hillsides with bluebunch wheatgrass, Idaho fescue (*Festuca idahoensis*), and arrowleaf balsamroot (*Balsamorhiza sagittata*) (Weaver 1914). In the same area, it occurred in 11 of 15 climax bluebunch wheatgrass-Sandberg bluegrass communities surveyed by Daubenmire (1942). In recently burned Wyoming big sagebrush (*A. tridentata* subsp. *wyomingensis*)/Sandberg bluegrass vegetation at the Hanford Nuclear Site in south-central Washington, annual agoseris cover averaged 0.1% in cheatgrass (*Bromus tectorum*)-dominated plots and 0.8% in Sandberg bluegrass-dominated plots (Durham et al. 2001).

Annual agoseris grows in several shrubland communities in Oregon. It is a representative species in chaparral vegetation in the southwestern part of the state. In the Rogue Valley it grows with buckbrush (*Ceanothus cuneatus*) at sites with low annual and summer rainfall and mild winter temperatures (Detling 1961). In central and south-central Oregon, it occurs in little sagebrush (*A. arbuscula*)/Idaho fescue communities (Franklin and Dyrness 1973). In the pumice region of central Oregon, *Agoseris* species are considered diagnostic of ponderosa pine (*Pinus ponderosa*)/ antelope bitterbrush (*Purshia tridentata*)/Idaho fescue communities. These communities occupy sandy loam soils and gentle slopes at elevations below 2,500 feet (760 m) (Dyrness and Youngberg 1966).

Figure 2. Annual agoseris seed collection site along a roadside in Idaho. Photo: BLM SOS ID931.

In California, annual agoseris occurs in grassland, shrubland, and oak savannah vegetation. It grows in grasslands on serpentine and non-serpentine soils and with various grazing use and fire histories. Annual agoseris is often found in both native and nonnative species-dominated grasslands in California but is often more abundant in those grasslands dominated by native species (Harrison et al. 2003). In California's Coast Range, annual agoseris and butte desertparsley (*Lomatium marginatum*) made up 40% of the cover in the shrub interspaces in a serpentine shrubland dominated by leather oak (*Quercus durata*), toyon (*Heteromeles arbutifolia*), and Jepson ceanothus (*C. jepsonii*) (DeGrood et al. 2005).

Annual agoseris was an indicator species ($P < 0.05$) of open grassland sites dominated by oats (*Avena* spp.), bromes (*Bromus* spp.), and annual fescue (*Vulpia myuros*) in oak savannas in Santa Ynez, California (Stahlheber et al. 2015). Large populations of annual agoseris were reported in moist sites at about 5,000 feet (1,500 m) elevation on Mount Shasta in the California's Cascade Range (Cooke 1940). In an annual grassland on Jasper Ridge, Stanford, California, annual agoseris was present in all serpentine outcrop study plots in all 20 years of monitoring. Jasper Ridge experiences a Mediterranean climate where annual rainfall averages 26 inches (658 mm), and May through September are virtually rainfree (Hobbs et al. 2007).

Elevation. Annual agoseris occupies an elevation range from 0 to 7,550 feet (2,300 m) (Munz and Keck 1973; Baird 2006). Variety *heterophylla* occupies the elevation range reported for the species, variety *cryptopleura* occurs at elevations of 500 to 6,900 feet (150-2,100 m), and variety *quentinii* occurs at elevations of 4,000 to 6,600 feet (1,200-2,000 m) (Baird 2006).

Soils. Annual agoseris occurs in soils of various textures (Fig. 3), depths, and nutrient and metal contents are tolerated by annual agoseris. Annual agoseris is recorded from logged and burned Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) forests in the HJ Andrews Experimental Forest east of Eugene, Oregon. At these sites, soils were poorly developed, moderately stony loams with high porosity and water storage capacity (Halpern 1989). Annual agoseris grew in oak savanna grasslands on a mesa in the Sedgwick Reserve, Santa Ynez, California, where soils were fine sands (Stahlheber et al. 2015). In recently burned buckbrush chaparral in southwestern Oregon, annual agoseris occurred on south-facing slopes in clayey soils with slow to moderate permeability (Sikes and Muir 2009). Annual agoseris was associated with California's annual vegetation type in the central North Coast Range. This vegetation type occupies deep, moderately well-drained soils (Heady 1956).

In central California, annual agoseris was often reported in serpentine soils containing heavy metals (chromium, nickel, cobalt, and manganese) but with low levels of nitrogen, phosphorus, potassium, calcium, and sodium (Gram et al. 2004; DeGrood et al. 2005; Hobbs et al. 2007). Serpentine soils often have a mottled green-gray color and waxy feel (St. John and Tilley 2012). On the Jasper Ridge Experimental Area, Stanford, California, annual agoseris occurred on serpentine but not sandstone soils. The magnesium content was six times greater in serpentine than sandstone soils (McNaughton 1968). In a study on Jasper Ridge, annual agoseris was present in all study plots on serpentine outcrops in all 20 years of monitoring. Serpentine outcrops characteristically have shallow soils (16 in [<40 cm]) overlying ultramafic serpentine (Hobbs et al. 2007).

Figure 3. Rocky soil site in Idaho where annual agoseris seed was collected. Photo: BLM SOS ID931.

DESCRIPTION

Annual agoseris is an upright, slender, taprooted annual with several flowering scapes typically 16 inches (40 cm) or shorter but ranging from 1 to 24 inches (2.5-60 cm) tall (Fig. 4) (Munz and Keck 1973; Hitchcock and Cronquist 2018; Luna et al. 2018). Herbage is subglabrate to densely hairy and exudes a milky juice when damaged (Baird 2006; St. John and Tilley 2012). Leaves are petiolate and mostly erect from a basal cluster. Leaf blades are oblong to spatulate or linear and up to 10 inches (25 cm) long. Leaf margins are entire or lobed with two or three pairs (Munz and Keck 1973; Baird 2006).

Figure 4. Annual agoseris plant growing in California. Photo: Genevieve Walden, Cal Photos.

Plants often produce five or more flower heads, which occur singly on scapes (Hickman 1993). Flower heads are comprised of 5 to 300 yellow ligulate florets (2–15 mm × 1–3 mm) that often close in the afternoon (Hermann 1966; Baird 2006; Luna et al. 2018). Anthers are sagittate at the base with rounded tips. Style branches are linear and pubescent (Hitchcock and Cronquist 2018). The involucre, which encloses the flower head, is 0.3 to 1 inch (0.8-2.5 cm) tall in fruit and typically hairy to tomentose (Hickman 1993; St. John and Tilley 2012). Involucre bracts occur in a 2 to 3 series. Outer bracts are sometimes purple or black spotted or red tinged and are shorter and wider than inner bracts (Hickman 1993; Baird 2006; Hitchcock and Cronquist 2018; Luna et al. 2018). Mature fruits (cypselae) of annual agoseris are 2 to 6 mm long with or without slender beaks that are two to three times as long as the body (Keeley and Keeley 1987; Hickman 1993; Welsh et al. 2016). Cypselae are linear or wavy ribbed with 4 to 9 mm long pappus bristles (Fig. 10) (St. John and Tilley 2012).

Figure 5. Annual agoseris flower heads (left is variety *heterophylla*, right is variety *cryptopleura*). Photos: ©2015 Richard Spellenberg, Cal Photos (left); ©2012 Barry Rice, Cal Photos (right).

Variety *heterophylla* and variety *cryptopleura* exhibit almost complete morphologic overlap and are largely differentiated by their corollas. Variety *cryptopleura* produces showier ligules that greatly exceed the involucral bracts compared to the ligules of variety *heterophylla* that just surpass the involucre bracts. Variety *cryptopleura* also has larger anthers (2-4 mm long) than variety *heterophylla* (about 1 mm long). Variety *quentinii* is quite morphologically distinct from the other varieties. It has a prostrate growth form with shorter flowering scapes and fewer ligulate florets (Baird 1996, 2006).

Variety *heterophylla* produces glabrous to densely and uniformly hairy, erect to spreading leaves. Leaf blades typically measure 1 to 6 inches (3–15 cm) long and 2 to 10 mm wide with margins mostly with two or three teeth on each edge. Flowering scapes in flower or fruit are 0.5 to 4.5 times longer than the leaves. Flower heads are 2 to 12 mm wide and comprised of 5 to 100 ligulate florets. Ligules are 2 to 6 mm long and 1 to 2 mm wide, and anthers are 1 to 1.5 mm long. Involucre bracts are usually hairy but occasionally glabrous. Bracts are green or medially rosy purple or spotted. Cypselae can be highly variable in color, shape, ornamentation, and pubescence among plants and within the same flower (Baird 2006).

Variety *cryptopleura* leaves are densely hairy, rarely glabrous and erect to spreading. Leaf blades measure 0.8 to 9 inches (2–24 cm) long and 2 to 16 mm wide with margins mostly with two or three teeth on each edge. Flowering scapes in flower or fruit are 1.5 to 5 times longer than the leaves. Flower heads are 7 to 18 mm wide and comprised of 20 to 300 ligulate florets. Ligules are 10–15 mm long and 2 to 3 mm wide, and anthers are 2 to 4 mm long. Involucre bracts are usually hairy but occasionally glabrous or villous. Bracts are green or medially rosy purple or spotted. Cypselae can be highly variable in color, shape, ornamentation, and pubescence among plants and within the same flower (Baird 2006).

Variety *quentinii* in some habitats may grow as a winter annual. It produces spreading to prostrate

leaves that are pubescent above and glabrous below. Leaf blades measure 0.8 to 4.7 inches (2–12 cm) long and 0.1 to 0.5 inch (0.3–1.2 cm) wide with margins mostly lobed in 2 to 3 pairs. Flowering scapes are 0 to 10 inches (26 cm) tall and mostly less than 0.5 times the length of leaves when in flower and 0.5 to 3 times the length of leaves in fruit. Flower heads are comprised of 15 to 30 ligulate florets. Ligules are 2 to 3 mm long and 0.8 to 1.5 mm wide, and anthers are about 1 mm long. Cypselae lack the morphological variation and heterogeneity typical of the other varieties (Baird 2004, 2006).

Reproduction. Chambers (1963) reported that the more broadly distributed, small-flowered forms of annual agoseris (varieties *heterophylla* and *quentinii)* are largely self-pollinating, whereas the large-flowered forms restricted to central California (variety *cryptopleura*) are self-incompatible (Fig. 5) (Chambers 1963; Baird 1996). Varieties *heterophylla* and *quentinii* produce flower heads with small styles and anthers, which are typically self-fertilized before the flower heads close for the day (Chambers 1963). Variety *cryptopleura* is adapted for out crossing with exerted anthers and styles and heads that remain open for most of the day.

Plants can produce an abundance of seed (Fig. 6). In climax bluebunch wheatgrass-Sandberg bluegrass stands in southeastern Washington and adjacent Idaho, annual agoseris vigor was rated high. Plants generally set an abundance of seed in each year of observations (Daubenmire 1942).

Phenology. Annual agoseris flowers appear from March to September depending on the location, weather, and variety. Variety *quentinii* flowers are generally present from March to June (Baird 2006). In annual grasslands in central California, annual agoseris flowered from early March to late May during 3 years of monitoring (1983-85) (Mooney et al. 1986). In a big sagebrush (*Artemisia tridentata*)/bluebunch wheatgrass community in southern British Columbia, annual agoseris development was much more rapid in the drier of two years of monitoring (Pitt and Wikeem 1990). In 1978, total precipitation was 12.8 inches (326 mm) and in 1979, it was 10.9 inches (278 mm). April precipitation levels in April 1978 were six times those of 1979. In the dry year (1979), annual agoseris initiated growth and flowered in April, and set and shattered seed in May. In the wetter year (1978), plants initiated growth in April, flowered in May, and set and shattered seed in July (Pitt and Wikeem 1990).

Figure 6. Annual agoseris plants with open and closed seed heads. Photo: BLM SOS OR931.

Pollination. Several polylectic mining bees (*Andrena candida*, *A. cressonii*, *A. nigroclypeata*, *A. orthocarpi*) have been collected from annual agoseris flowers (LaBerge 1977, 1985, 1989).

ECOLOGY

Annual agoseris is an ephemeral annual (Price and Baranova 1976) that establishes from wind-dispersed seed (Keeley 1991). It grows best in full sun (Stahlheber et al. 2015) and occurs in early seral (Titus et al. 1998) and disturbed communities (Hobbs et al. 2007; Potts and Stephens 2009).

Annual agoseris was an indicator species for open sites ($P < 0.05$) when canopy, canopy edges and open grasslands were compared in oak savannahs in Santa Ynez, California. Open grasslands were sites more than 16 feet (5 m) from tree canopy drip lines (Stahlheber et al. 2015). Annual agoseris occurred infrequently in early seral habitats created by the eruption of Mount St. Helens in Washington. It was one of the primarily wind-dispersed species on pumice plains and wetlands in the 13 to 14 years following the eruption. Pumice from the eruption was 30 to 650 feet (10-200 m) deep, and sites had high surface soil temperatures and frequent summer droughts (Titus et al. 1998).

Seed and Seedling Ecology. Annual agoseris seed morphology impacts germination. Keeley and Keeley (1987) found that annual agoseris produces beaked and non-beaked seeds. Germination of non-beaked seeds was significantly improved by heating (250 °F [120 °C] for 5 minutes) ($P < 0.001$) and by exposure to charred chamise wood (*Adenostoma fasciculatum*) ($P < 0.001$). Germination of heated or smoke-

exposed beaked seeds was not significantly different from controls (Keeley and Keeley 1987).

Seed production was estimated at 60 seeds/ft2 (630/m^2) in serpentine soils at Jasper Ridge Biological Preserve in San Mateo County, California, where annual agoseris cover averaged 0.7%, frequency averaged 50%, and maximum inflorescence height averaged 6.5 inches (16.6 cm) (Hobbs and Mooney 1985). Seed was dispersed in May and more than 90% of seeds were dispersed within and the rest dispersed beyond the 20-inch (50 cm) diameter area where all seeds were marked. Researchers coated the ends of the pappus with red ink before seed heads had fully opened in the marked area. Seven percent of total annual agoseris seed rain germinated in the field. In the laboratory, germination was 35% for 6-month-old seed treated with 0.01% gibberellic acid (Hobbs and Mooney 1985).

Seed predation. Seed-feeding ants (*Veromessor andrei*) took seeds from annual agoseris plants growing on serpentine outcrops of Jasper Ridge Biological Preserve (Hobbs 1985). Of the seeds found at a single ant nest, 5% were annual agoseris seeds brought by ants and almost 1% were annual agoseris seeds brought by wind. In cafeteria trials, between 9 and 10% of offered seeds were taken in late May and mid-July. Cafeteria trials were conducted for 24 hours and included six dishes each with seeds of eight test species. Seed-feeding ants played a role in limiting establishment of annual agoseris seedings, which were restricted to sites where ants were excluded. There were 16 annual agoseris seedlings/ft^2 (176/m^2) inside exclosures and none outside the exclosures that were created using plastic collars 6 inches (15 cm) in diameter and 5 inches (13 cm) tall (Hobbs 1985). In a later study at the same site, density of annual agoseris was significantly greater ($P \leq 0.10$) off ant mounds than on ant mounds. Density was 3.3 plants/ft2 (35.7/m^2) on nest mounds and 9.6 plants ft2 (103.6/m^2) 5 feet (1.5 m) away from nest mounds. Nest soils had higher levels of phosphorus and nitrogen and higher temperatures than surrounding serpentine grassland (Peters et al. 2005).

Seedling growth. In controlled experiments, annual agoseris root growth was slower than that of native and nonnative perennial and nonnative annual grasses (Roundy et al. 2014). Seedlings required about 500 degree days to develop a root reaching 6 inches (15 cm) deep when growing at temperatures of 39 to 54 °F (4-12 °C). Root growth was better in gravelly loams than sand (Roundy et al. 2014). All seeds were planted 0.2 inch (0.5 cm) deep in clear plastic root tubes. Seedling growth was evaluated at a range of constant growth chamber temperatures from 40 to 90 °F (5-30 °C) (20 tubes/temperature). Annual agoseris seedlings emerged from 13 to 18 of 20 tubes kept at temperatures between 40 to 80 °F (5-25 °C). Just one seedling emerged from the 20 tubes kept at 90 °F (30 °C). Optimal root growth temperature for annual agoseris was 70 °F (20 °C). A little less than 20 days were required for roots to grow 6 inches (15 cm) at 70 °F (20 °C), while it took almost 40 days at 90 °F (30 °C) and 100 days at 40 °F (5 °C) (Roundy and Young 2010).

Disturbance Ecology. Annual agoseris is often more abundant on disturbed than undisturbed sites and tolerates severe and repeated disturbances. At the Jasper Ridge Biological Preserve in northern California, cover of annual agoseris was not significantly different on protected and three-times disturbed plots by Botta's pocket gopher (*Thomomys bottae*) plots in the serpentine annual grassland (Hobbs and Mooney 1991). In an extension of disturbance studies in the same area, annual agoseris was sensitive to increasing levels of gopher disturbance but was present inside and outside of small mammal exclosures in all 20 years of monitoring. Plant numbers were negatively correlated with an increase in number of years disturbed, and cover increased as length of time since last disturbance increased (Hobbs et al. 2007).

Annual agoseris occurred on burned, masticated, logged and burned, and repeatedly burned sites. It occurred in prescribed burned plots and masticated plots in chamise chaparral in California's northern Coast Range (Potts and Stephens 2009). Prescribed fires burned in fall, winter, or spring and mastication occurred in fall or spring. Treatments were replicated four times and surveyed for 3 years following treatments. Researchers considered annual agoseris a 'fire following' species (Potts and Stephens 2009).

Sikes and Muir (2009) considered annual agoseris an indicator of 2-year-old burned scars following fuel treatments in buckbrush shrublands in southwestern Oregon ($P < 0.05$). Shrubs were removed and pile burned to create 25-foot (7.6 m) gaps between shrub clumps. In the HJ Andrews Experiment Forest east of Eugene, Oregon, annual agoseris abundance was greatest 3 to 5 years after logging and broadcast burning in Douglas-fir and western hemlock forests (Halpern 1989). Annual agoseris occurred in 3 of 4 post-fire monitoring years (1996-99) after three consecutive July burns to control yellow starthistle (*Centaurea solstitialis*) in a blue oak (*Quercus douglasii*) woodland in northern

California's Sugarloaf Ridge State Park (Kyser and DiTomaso 2002).

Annual agoseris persisted with sheep and cattle grazing at sites in Washington and California. Frequency of annual agoseris averaged 9% in heavily utilized bluebunch wheatgrass prairies and 16% in relatively undisturbed grasslands in southeastern Washington. Grazed portions of the prairies were utilized by cattle for many years then changed over to sheep (Daubenmire 1940). In California live oak (*Q. agrifolia*) savannahs on Sedgwick Reserve mesa, annual agoseris was significantly more abundant on cattle grazed than ungrazed ($P < 0.05$) plots. Grazed sites supported about 45 head of cows/10 to 30 acres (4-12 ha), which were rotated between plots from January to late May (Stahlheber et al. 2017).

Wildlife and Livestock Use. Annual agoseris is an important food source for Mazama pocket gophers (*Thomomys mazama*) (Burton and Black 1978), greater sage-grouse (*Centrocercus urophasianus*) (Pyle 1993), and seed-feeding ants (Hobbs 1985). It is palatable to domestic sheep and less palatable to cattle but rarely an important diet component to either class of livestock (Hermann 1966). In a literature review, *Agoseris* species received light use by mule deer (*Odocoileus hemionus*) in spring and summer (Kufeld 1973).

In Klamath County, Oregon, annual agoseris made up a high of 3.7% of Mazama pocket gopher diets (Burton and Black 1978). The study took place in a burned ponderosa pine forest dominated by grasses and forbs where the cover of annual agoseris was 0.2% in 1973 and 0.9% in 1974. Stomach contents were analyzed for 110 gophers. Annual agoseris made up a trace of diets in 1973, and in 1974 made up 0.2% of diets in March, 3.7% in May, and 1.6 % in July (Burton and Black 1978).

Agoseris species are one of the more important forbs for juvenile and adult greater sage-grouse (Martin et al. 1951; Pennington et al. 2016; Luna et al. 2018). In big sagebrush communities on Hart Mountain National Antelope Refuge in Lake County, Oregon, frequency of annual agoseris was 11% and it made up a high of 4.7% of greater sage-grouse chick diets (Pyle 1993).

Ethnobotany. Use of annual agoseris by Indigenous people was not reported in the available literature. *Agoseris* species were used as a chewing substance and medicine by Thompson Indians of British Columbia (Turner 1988).

Horticulture. Annual agoseris was recommended for low maintenance landscaping on the Palouse Prairie of Idaho and Washington. It is easy to grow from seed, grows well in dry open sites, and spreads by wind-borne seed (Skinner et al. 2005). Its disturbance tolerance suggests it could be used along roadsides, at campgrounds, and other public use areas.

REVEGETATION USE

Annual agoseris has many traits that suggest it may do well in the restoration of native habitats below 7,500 feet (2,300 m) in elevation. It is a colonizer of early successional and disturbed habitats (see Ecology section). It tolerates a variety of soils, dry conditions, and is an important food source for greater sage-grouse (see Soils and Wildlife and Livestock Use sections). Annual agoseris germinates best at cool temperatures suggesting it may provide some competition for invasive species like cheatgrass that germinate and establish in cool conditions (Kildisheva et al. 2019).

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 annual agoseris, 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 7, Omernik Level III Ecoregions (Omernik 1987) overlay the provisional seeds zones to identify climatically similar but ecologically different areas. For site-specific disturbance regimes and

restoration objectives, seed collection locations within a seed zone and ecoregion may be further limited by elevation, soil type, or other factors.

The Western Wildland Environmental Threat Assessment Center's (USFS WWETAC 2017) Threat and Resource Mapping (TRM) Seed Zone application provides links to interactive mapping features useful for seed collection and deployment planning. The Climate Smart Restoration Tool (Richardson et al. 2020) can also guide revegetation planning, seed collection, and seed deployment, particularly when addressing climate change considerations.

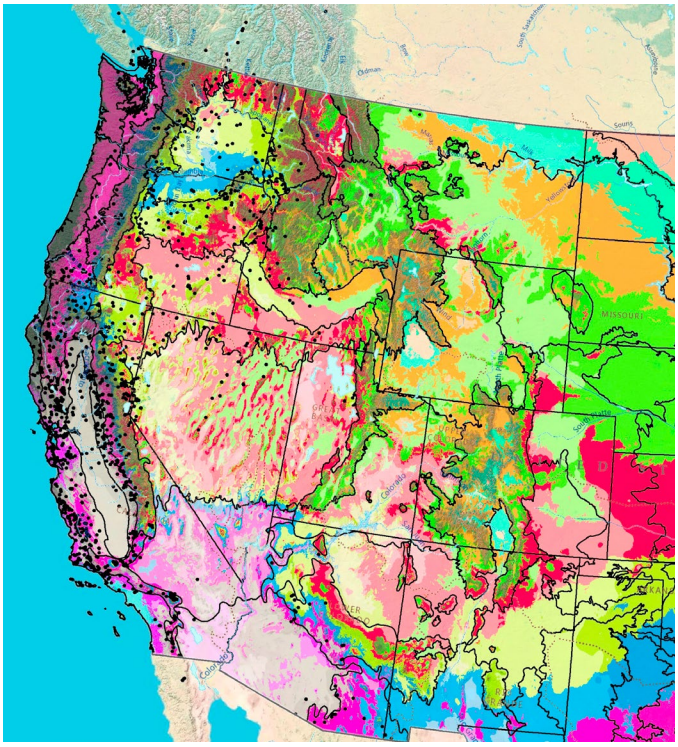

Figure 7. Distribution of annual agoseris (black circles) based on geo-referenced herbarium specimens and observational data from 1864-2018 (CPNWH 2017; SEINet 2017; USDI USGS 2017). Generalized provisional seed zones (colored regions) (Bower et al. 2014) are overlain by Omernik Level III Ecoregions (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 2021, there were no annual agoseris germplasm releases.

Wildland Seed Collection. Annual agoseris plants are often found at low densities, so wildland seed is typically collected by hand and multiple collections are necessary to maximize seed yields and insure the genetic diversity of the collection Fig. 8 (Jensen 2007).

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

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

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

Figure 8. Open annual agoseris seed head with off-white colored mature seeds. Photo: BLM SOS OR931.

Collection timing. Seed is wind-dispersed, making the timing of collections critical. Seeds

are mature when the pappus begins to spread open (Jensen 2007) and should be collected at this time (Skinner 2006; Jensen 2007). Seed maturity is indeterminant, and daily collections are required to maximize harvests (Skinner 2006). Mature seed can be found for a long period of time over a large area. Seed head size and the color of mature seeds are considerably variable, and thus, not good indicators of seed maturity (Camp and Sanderson 2007).

The Bureau of Land Management's Seeds of Success collection crews made 8 collections in 5 years (2002-2015) in Washington, Oregon, Nevada, and Idaho (Fig. 9). The earliest collection was made on May 29, 2015 in Harney County, Oregon at an elevation of 5,412 feet (1,650 m). The latest collection was made on July 20, 2010 in Douglas County, Washington at an elevation of 3,440 feet (1,049 m) (USDI BLM SOS 2017). In Washington, Camp and Sanderson (2007) collected annual agoseris seed from late May to mid-June at an elevation of 1,830 feet (560 m) in Burton Draw, Douglas County and at 2,260 feet (690 m) from Monument Hill in Grant County. Seed began maturing and was harvested in June near Pullman, Washington (Skinner 2006). Jensen (2007) collected seed from mid-June to July 1 at 5,430 feet (1,655 m) elevation in the foothills of the Santa Rosa Mountains in Humboldt County, Nevada.

Figure 9. Hand-stripped annual agoseris seeds. Note the tan to brown seed bodies and compare with Fig. 8. Photo: BLM SOS OR931.

Collection methods. Because densities of annual agoseris are typically low, wildland seed is hand collected. While seeds can be hand plucked from heads (Camp and Sanderson 2007), stripping the seed by clasping the base of the seed head between two fingers and pulling upward while keeping the hand closed reduces the loss of mature seed. These collection methods minimize the amount of inert material collected and make for easy cleaning (Jensen 2007).

Several collection guidelines and methods should be followed to maximize the genetic diversity of wildland collections: collect seed from a minimum of 50 randomly selected plants; collect from widely separated individuals throughout a population without favoring the most robust or avoiding small stature plants; and collect from all microsites including habitat edges (Basey et al. 2015). General collecting recommendations and guidelines are provided in online manuals (e.g. ENSCONET 2009; USDI BLM SOS 2016). As is the case with wildland collection of many forbs, care must be taken to avoid inadvertent collection of weedy species, particularly those that produce seeds similar in shape and size to those of annual agoseris, like dandelion (*Taraxacum* spp.) and hawksbeard (*Crepis* spp.) (Fig. 10) (St. John and Tilley 2012).

Figure 10. Annual agoseris seeds (< 5 mm long) and pappi (about 8 mm long and 1 cm wide). Photo: © 2012 Jean Pawek, Cal Photos.

Collection rates. Camp and Sanderson (2007) report it is moderately time consuming to collect annual agoseris in quantitiy (Camp and Sanderson 2007). Likely wildland seed cannot be collected at the scale needed for restoration.

Post-collection management. Seed should be stored in breathable bags in a dry, cool or room temperature location free of rodents (Skinner 2006; Camp and Sanderson 2007; Jensen 2007).

Seed Cleaning. For small seed collections, larger chaff can be removed by hand and the seed rubbed to free the seed from the pappus. Collections can then be finished using air columns or air screen equipment (Skinner 2006; Jensen

2007). Larger seed harvests could be threshed with a hammermill, then air screened (Skinner 2006).

Seed Storage. Cleaned seed can be stored at 40 °F (4 °C) and 35 to 40% relative humidity (Skinner 2006; Camp and Sanderson 2007). Annual agoseris seed is orthodox. Dry seed remained 100% viable after 2 months of storage at 70 °F (20 °C) and 15% relative humidity (RBG Kew 2020).

Seed Testing. There is no Association of Official Seed Analysts (AOSA) rule for testing germination or AOSA protocol for examining the viability of annual agoseris seed (AOSA 2010, 2016). Tetrazolium chloride testing (TZ) should follow that suggested for other Asteraceae species, which includes cutting seeds longitudinally leaving the distal end intact and soaking for 6 to 12 hours in 0.1% TZ concentration at (86- 95 °F [30-35 °C]). The embryos of viable seed will be entirely stained (AOSA 2010).

Germination. Annual agoseris produces non-dormant seed that germinates best at cool temperatures or with cold stratification prior to exposure to warm temperatures. Yet, Methow Natives (Winthrop, WA) reported 78% germination for seeds without any pretreatment when they were planted 0.13-inch (0.3 cm) deep and kept at room temperature (Camp and Sanderson 2007).

Annual agoseris germinated much better at cool than warm temperatures in laboratory studies conducted by Kildisheva et al. (2019). Germination was nearly 100% for seed incubated at 40 to 50 °F (5-10 °C) and less than 50% at incubation temperatures of 60 to 77 °F (15-25 °C) ($P <$ 0.05). Seeds were germinated on water agar substrates at 12 hour light-dark cycles. Seed was wild collected near the Steens Mountains in southeastern Oregon in June 2015 at an elevation of 5,335 feet (1,626 m). It was dried for 3 to 4 weeks at 60 °F (15 °C) and 15% relative humidity then stored in hermetically sealed bags and kept at the same conditions for 3 months before testing. Seed fill was 97%. The addition of gibberellic acid (1 mM) increased the rate of germination by 4.4 days ($P < 0.05$) and increased final germination by about 25% after 28 days (Kildisheva et al. 2019).

Germination of seed that was cold stratified or incubated at cool or cold temperatures ranged from 40 to 100% in other studies. Ninety percent of plugs produced a seedling when Jensen (2007) cold stratified 2.5-year-old seed for 3 weeks before being moved them into the greenhouse. Ninety percent of plugs produced plants when 1.5-year-old seed was sown in soil-filled cells without stratification. Seed was collected from the foothills of the Santa Rosa Mountains in Humboldt County, Nevada (Jensen 2007). For seed collected near Pullman, Washington, germination was 12% without stratification, 50% with 30 days of stratification, and 40% with 90 days of stratification. After learning this, seed was sown outdoors in late November or early December to germinate annual agoseris seed at the Pullman Plant Materials Center (Skinner 2006). Laboratory studies from the Royal Botanical Gardens, Kew, reported between 80 and 100% germination for seeds incubated on 1% agar in 8 hours of light and 16 hours of dark at constant temperatures of 40, 50, 60, or 70 °F (5, 10, 15, or 20 °C). Germination took 21 days at 40 °F (5 °C) and 50 °F (10 °C), 7 to 70 days at 60 °F (15 °C), and 49 days at 70 °F (20 °C) (RBG Kew 2020).

In outdoor experiments, most annual agoseris germinated in the fall, and germination was inhibited by 0.5-inch (1.2 cm) deep burial (Table 1; Gulmon 1992). The experiment was designed to evaluate the effects of burial and dates of watering on germination. Seed was spring or summer collected from a serpentine grassland at Jasper Ridge Biological Preserve, San Mateo County, California. Experiments were initiated in the fall. Seed was placed on top of 1.2 inches (3 cm) of sifted, serpentine topsoil in flats that were kept outside and protected from birds. Moisture treatments began on 9/17, 10/12, 11/16, or 12/15 and were delivered as a fine spray twice daily for 2 weeks, after which the flats received natural rainfall. Burial depth experiments included adding 0.3 inch (0.8 cm) or 0.5 inch (1.2 cm) of topsoil and leached or fresh litter equivalent to 1.5 to 3 times the average depth of litter in the serpentine grasslands (Gulmon 1992).

Table 1. Germination of annual agoseris seed with burial and various timing of 2-week watering treatments.

Treatment	**Litter**		**Topsoil**		**Unwatered**	**Watered**			
Type, amount, start date	leached	fresh	1.2 cm	0.6 cm	rain only	9/17	10/12	11/16	12/15
Cumulative fraction of seeds germinating	0.87	0.76	0.59	0.80	0.81	0.70	0.82	0.97	.87

Seed morphology also affected germination of annual agoseris seed (Table 2; Keeley and Keeley 1987). Germination of non-beaked cypselae was improved by high temperature exposure 250 °F (120 °C) for 5 minutes or by adding charred chamise wood to the germination media (P <0.001). For beaked cypselae, germination did not change with high temperature or charred wood exposure. Seed was collected in southern California and stored in paper bags at room temp for 14 to 18 months prior to the experiments. Seed was sown in petri dishes filled with potting soil (Keeley and Keeley 1987).

Table 2. Germination of beaked and non-beaked annual agoseris seeds with heating and exposure to charred wood.

Seed morphology	Control	250 °F/5 min	Charred wood
Beaked seeds	79	86	88
Non-beaked seeds	62	78	92

Wildland Seed Yield and Quality. Post-cleaning seed yield and quality of seed lots collected in the Intermountain region are provided in Table 3 (USFS BSE 2017). The results indicate that annual agoseris seed can generally be cleaned to high levels of purity and seed fill and that viability of fresh seed is generally high. Most of the seeds/lb estimates from other sources fell within that reported in Table 3 (276,691-722,000 seeds/lb [609,989-1,591,711/kg]) (Swingle 1939; Keeley 1991; USFS GBNPP 2014; RBG Kew 2020), but some were higher than those reported in Table 3 (1,157,700-1,295,977 seeds/lb 2,552,249-2,857,092/kg]) (Gulmon 1992; Camp and Sanderson 2007).

Table 3. Seed yield and quality of annual agoseris 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)	0.83	0.05-4.5	6
Clean weight (lbs)	0.33	0.012-1.9	6
Clean-out ratio	0.28	0.09-0.4	6
Purity (%)	97	88-99	6
Fill (%)[1]	97	95-99	6
Viability (%)[2]	95	92-98	6
Seeds/lb	557,273	308,564-731,600	6
Pure live seeds/lb	336,716	206,581-530,100	6

[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.

AGRICULTURAL SEED PRODUCTION

Indeterminate seed production and easily wind-dispersed seed will likely make field production of annual agoseris seed challenging (Jensen et al. 2011; St. John and Tilley 2012). Yet, greenhouse production shows that annual agoseris grows well under cultivation producing an abundance of flowering stems and seeds in response to irrigation and fertilizer (Jensen et al. 2011). Extrapolated data from greenhouse production indicates that annual agoseris can yield as much as 900 lbs/acre (1,000 kg/ha). Although operational scale production and harvesting challenges would reduce actual yields, annual production of several hundred pounds per acre should be feasible. Hand-held or backpack vacuums would be practical for harvesting small field plots. Larger tractors with mounted brush machines or vacuum harvesters could be used to harvest larger plots (Jensen et al. 2010).

As of 2021, there were no published reports detailing how to produce annual agoseris seed in an agricultural field setting. When the U.S. Forest Service Shrub Laboratory (FSSL) in Provo, Utah, provided annual agoseris seed to private growers, both field seed production attempts failed. One attempt reported good germination after a rainstorm in December but was then frost killed. The other reported poor establishment because of residual herbicide at the site (Jensen et al. 2010).

The FSSL increased a single annual agoseris source in a greenhouse for three generations yielding 2, 9, and 4 lbs pure live seed (PLS) (Figure 11; S. Jensen, USFS, personal communication, April 2021) in subsequent years. Plants were grown on benches filled with a 4-inch (10 cm) depth of horse manure, irrigated through drip tape placed on the soil surface, and seed was harvested with a shop vac. Seed production varied annually.

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.

Figure 11. Annual agoseris growing in the USFS Shrub Laboratory in Provo, Utah. Greenhouse growth yielded 9 lbs. pure live seed in 2008. Photo: USFS.

NURSERY PRACTICE

Studies indicate that annual agoseris plugs and seed can be produced in a nursery setting (Skinner 2006; Jensen 2007). The following protocol was used by the Pullman Plant Materials Center (PMC) to produce annual agoseris plugs (Skinner 2006). Seed was sown in late November or early December in 10 in^3 (164 cm^3) cone-tainers filled with Sunshine mix #4. Seed was covered lightly with soil followed by a thin layer of pea gravel to prevent seeds from floating. Cone-tainers were watered deeply and kept outside until they were moved into a greenhouse in early January. Alternately, seed can be stratified in a refrigerator for 30 days before sowing in the greenhouse. Germination began in 3 days and was complete in 6 days. Seedlings were watered deeply every other day and fertilized once/week using a complete water-soluble fertilizer with micronutrients. Some plants flowered while still in the greenhouse, but they did not produce viable seed. The active growth phase was reported as 2 to 3 months. Plants were moved from the greenhouse to a cold frame in late March or early April and watered every other day during cool conditions and every day during hot, dry weather. Plants were considered hardened after 2 to 4 weeks. No insect or disease problems were encountered at the Pullman PMC (Skinner 2006).

The FSSL used the following procedure to produce annual agoseris seed in the greenhouse. Seed was wild collected from Humboldt County, Nevada, in June 2003 and stored for 1.5 to 2.5 years before being sown in root trainers (3 seeds/cell). The oldest seed was cold stratified for 3 weeks. The younger seed did not receive a cold treatment. Both seed lots resulted in 90% of cells producing a seedling. The soil in the root trainers was a mix of 2 parts sieved peat, 2 parts vermiculite, 1 part Turface (montmorillonite clay), 1 part #20 quartz silica sand, 1 part native soil plus fertilizer and micronutrients. Soil was steam aerated at 140 °F (60 °C) for 30 minutes. Seeds were lightly covered with soil and received frequent, light, soft-spray watering. Seedlings were considered established after 2 weeks, and plants remained in the 5.5 in3 (90 cm3) root trainers for seed production. Flowering began in mid-May and continued into July when water was applied only when plants were wilting. Plants averaged four stems, each with a single flower. Flowering and seed ripening continued for 2 months and was likely extended with watering. Seed was collected prior to watering so seeds were not disturbed. Plants produced 0.04 lb (18 g) of seed per 30 ft^2 (3 m^2) of greenhouse bench (Jensen 2007).

The following fungi have been collected from annual agoseris: *Bremia lactucae*, *Puccinia hieracii*, *P. troximontis*, *Ramularia agoseridis*, *R. compacta*, *Sphaerotheca humuli*, *S. macularis*, and *Uromyces psoraleae* (Garrett 1910, 1914; Farr and Rossman 2017). There were no reports of fungi impacting field or nursery growth of annual agoseris.

WILDLAND SEEDING AND PLANTING

Use of annual agoseris in wildland restoration was not reported in the published literature. Yet, its colonization of early successional and disturbed

habitats (see Ecology section), and its tolerance of a variety of soils and dry conditions suggests it may be useful in arid-land restoration. Its ability to germinate at cool temperatures suggests it may provide some competition for invasive winter annuals like cheatgrass (Kildisheva et al. 2019). St. John and Tilley (2012) suggest that annual agoseris could be used as a minor component of a restoration seed mix and that management strategies would be based on the key species in the seed mix and should include grazing deferment for at least two growing seasons.

N-sulate fabric improved initial germination of *Agoseris* spp. in small-plot experiments designed to evaluate the effects of the fabric on field germination and establishment of forb species at three sites in the Great Basin and one site in the Colorado Plateau (Gunnell and Summers 2016). Sites average 12 to 14 inches [305-356 mm] of annual precipitation. The fabric lets light through, increases temperatures, and improves moisture retention during the germination period. Forbs were seeded on 4.9 × 24.9-foot (1.5 × 7.6 m) plots, where standing plant material was removed with a Dixie harrow before seeding. The seeding rate for annual agoseris was 2.8 PLS ft^2 (29.6 PLS/m^2) and bigflower agoseris (*Agoseris grandiflora*) was 3 PLS/ft^2 (31.8 PLS/m^2). Seed mixes were sown with rice hulls using a hand-operated broadcaster. Plots were then compacted using a Brillion packer wheel (Brillion, WI) to improve seed-soil contact. Initial emergence of *Agoseris* spp. was close to 0.8 seedling/ft^2 (9 seedlings/m^2) on covered and about 0.2 seedling/ft^2 (2 seedlings/m^2) on uncovered plots in first post-seeding year. In the second post-seeding year, there were about 0.2 seedling/ft^2 (2 seedlings/m^2) *Agoseris* spp. on covered and about 0.1 seedling/ft^2 (1.5 seedlings/m^2) on uncovered plots. By the fifth post-seeding year, there were fewer than 0.02 plant ft^2 (0.2 plant/m^2) on either covered or uncovered plots (Gunnell and Summers 2016).

Other studies found that annual agoseris grows well with competition but is sensitive to herbicides. Annual agoseris grew well but biomass was reduced by 28% when grown with annual ryegrass (*Festuca perennis*). Seeds were grown in field-collected serpentine soils (San Mateo Co, CA) in 0.5-quart (0.5 L) pots grown in the greenhouse in October 2011. Plants were transferred to larger pots and moved outdoors in December 2011 (Funk and Wolf 2016). In a bluebunch wheatgrass/needle and thread (*Hesperostipa comata*) community, annual agoseris was reduced for the first 2 years following an imazapic treatment in Morrow County, Oregon. Imazapic (70 g ai/ha) was used in an attempt to reduce cheatgrass abundance and increase abundance of native vegetation. Annual agoseris frequency was significantly lower ($P < 0.1$) from pretreatment levels for the first two post-treatment years, but not in post-treatment years three and four (Elseroad and Rudd 2011).

In a study evaluating the effect of sowing depth and row cover fabric in the central Great Basin, average emergence for annual agoseris was 0.36%. It ranked 14th among 20 species where only four species exceeded 1% establishment. Depth effects were undetected in four site/year combinations, positive in one combination and negative in another. The odds of emergence were 80 to 95% lower in control plots compared to row cover plots (S. Jensen, USFS, personal communication, April 2021).

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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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