WESTERN FORBS: BIOLOGY, ECOLOGY, AND USE IN RESTORATION

HOARY TANSYASTER

Dieteria (Machaeranthera) canescens (Pursh) Nutt.

Asteraceae – Aster family

Corey L. Gucker & Nancy L. Shaw | 2018

ORGANIZATION

NOMENCLATURE

Dieteria canescens (Pursh) Nutt. until recently (2010) was known as *Machaeranthera canescens* (Pursh) A. Gray (ITIS 2017; USDA NRCS 2017). This species belongs to the Astereae tribe of the Asteraceae family (Morgan 2006) and will hereafter be referred to by its common name, hoary tansyaster.

NRCS Plant Code. MACA2 (USDA NRCS 2017).

Subtaxa. The Flora of North America (Morgan 2006) recognizes ten varieties of hoary tansyaster: *Dieteria canescens* var. *canescens*, *ambigua*, *aristata*, *glabra*, *incana*, *leucanthemifolia*, *nebraskana*, *sessiliflora*, *shastensis*, and *ziegleri*.

Synonyms (Morgan 2006).

Dieteria canescens: *Machaeranthera canescens* (Pursh) A. Gray; *Aster canescens* Pursh
D. c.* var. *ambigua: *M. canescens* (Pursh) A. Gray var. *ambigua* B.L. Turner
D. c.* var. *aristatus: *A. canescens* Pursh var. *aristatus* Eastwood; *M. canescens* (Pursh) A. Gray var. *aristata* (Eastwood) B.L. Turner; *M. rigida* Greene
D. c.* var. *canescens: *M. divaricata* (Nuttall) Greene; *M. laetevirens* Greene; *M. latifolia* A. Nelson; *M. pulverulenta* (Nuttall) Greene; *M. viscosa* (Nuttall) Greene
D. c.* var. *glabra: *M. canescens* (Pursh) A. Gray var. *glabra* A. Gray; *A. canescens* Pursh var. *viridis* A. Gray; *M. linearis* Greene
D. c.* var. *incana: *Diplopappus incanus* Lindley; *Dieteria incana* (Lindley) Torrey & A. Gray; *M. canescens* (Pursh) A. Gray var. *incana* (Lindley) A. Gray; *M. incana* (Lindley) Greene
D. c.* var. *leucanthemifolia: *A. leucanthemifolius* Greene; *M. canescens* (Pursh) A. Gray var. *leucanthemifolia* (Greene) S.L. Welsh; *M. leucanthemifolia* (Greene) Greene
D. c.* var. *nebraskana: *M. canescens* (Pursh) A. Gray var. *nebraskana* B.L. Turner

D. c.* var. *sessiliflora: *D. sessiliflora* Nuttall; *M. canescens* (Pursh) A. Gray var. *sessiliflora* (Nuttall) B. L. Turner; *M. sessiliflora* (Nuttall) Greene
D. c.* var. *shastensis: *M. shastensis* A. Gray; *A. shastensis* (A. Gray) A. Gray; *M. canescens* (Pursh) A. Gray var. *shastensis* (A. Gray) B. L. Turner
D. c.* var. *ziegleri: *M. canescens* (Pursh) A. Gray subsp. *ziegleri* Munz; *M. canescens* var. *ziegleri* (Munz) B. L. Turner (Morgan 2006).

Common Names. Hoary tansyaster, hoary-aster, hoary goldenweed, hoary machaeranthera, Nebraska tansyaster, purple aster, Shasta tansyaster, whiteflower tansyaster, Ziegler's tansyaster (Welsh et al. 1987; Morgan 2006; Tilley et al. 2014).

Chromosome Number. Chromosome number is 2n = 8 (Strother 1972; Anderson et al. 1974; Keil et al. 1988; Morgan 2006).

Hybridization. Intergradation is common where the distributions of *Dieteria* species and infrataxa meet or overlap. Variety *canescens* is the most widespread of the varieties and therefore has the greatest potential for forming hybrids. It intergrades with: *D. bigelovii* in Colorado, Utah, and Wyoming; variety *ambigua* in Utah; *aristata* in Utah and Colorado; *glabra* in Colorado; *incana* in Idaho and Washington; *leucanthemifolia* in Utah and California; *nebraskana* in Nebraska and South Dakota; *sessiliflora* in Idaho; *shastensis* in California, Nevada, and Oregon; and *ziegleri* in California (Morgan 2006).

DISTRIBUTION

The species is common and broadly distributed throughout western North America, ranging from southern British Columbia south to Baja California and east to western North Dakota, western Texas, and Chihuahua, Mexico (Cronquist et al. 1994; Morgan 2006). Variety *canescens* is the most widespread of the varieties, most of which have much more limited distributions (Table 1) (Morgan 2006).

Habitat and Plant Associations. Hoary tansyaster grows in a wide variety of community types throughout the western US where annual precipitation ranges from 8 to 60 inches (200-1,520 mm) (Tilley et al. 2014). It is most common in open, dry, low-elevation habitats (Cronquist et al. 1994).

Plants are found in semi-arid grasslands, shrublands, woodlands, and pine forests and are common in gravelly or sandy soils along streams and in washes. Plant communities where hoary tansyaster is often found include: sagebrush (*Artemisia* spp.), blackbrush (*Coleogyne ramosissima*), cold desert and saltbush (*Atriplex* spp.) scrub, greasewood-shadscale saltbush (*Sarcobatus vermiculatus* – *A. confertifolia*), creosote bush (*Larrea tridentata*), chaparral, mountain mahogany (*Cercocarpus* spp.), pinyon-juniper (*Pinus*-*Juniperus* spp.), pine-oak (*Pinus*-*Quercus* spp.), quaking aspen (*Populus tremuloides*)-sagebrush, Douglas-fir (*Pseudotsuga menziesii*), lodgepole pine (*Pinus contorta*), and ponderosa pine (*P. ponderosa*) (Flowers 1934; Munz and Keck 1973; Brotherson et al. 1984; Welsh et al. 1987; Ehleringer 1988; Morgan 2006).

On the North Rim of Grand Canyon National Park, Arizona, hoary tansyaster was common in ponderosa pine and ponderosa pine-Gambel oak (*Q. gambelii*) forests. It was considered a montane zone indicator when montane and subalpine communities were compared (Laughlin et al. 2005). In the Wasatch Mountains of central Utah, it was a prominent understory species of Gambel oak and Utah serviceberry (*Amelanchier utahensis*) woodlands (Yake and Brotherson 1979).

Elevation. Hoary tansyaster occupies sites from about 1,000 to 11,000 feet (300-3,400 m) (Table 2) (Morgan 2006).

Soils. Hoary tansyaster grows well on medium- to coarse-textured soils with pH of 6 to 8.4 and rooting depths of at least 10 inches (25 cm) (Tilley et al. 2014). However, it also grows in less optimal soil conditions.

Plants were found throughout 40 years of vegetation surveys of the Pumice Desert in Crater Lake National Park, Oregon, where soils were described as gravelly, ashy, loamy, coarse sands with excessive drainage and little profile development (Horn 2009). In northern Arizona ponderosa pine forests, hoary tansyaster was characteristic of xeric, basalt sites with low nitrogen, loamy soils (Abella et al. 2012). In Bingham County, Utah, frequency of hoary tansyaster was 50% on sulfide-bearing waste sites created from copper pit mining. Waste site age averaged 30 years, pH levels were neutral (6-7.9), and salinity levels were low (0.06-0.5 dS/m). Hoary tansyaster was absent from waste areas with lower pH and higher salinity (Borden and Black 2005). In Carter County, Montana, plants occurred with low cover on old bentonite mine spoils where pH averaged 5.6, sodium and sulphur concentrations were high, and compaction was extreme (average penetrometer reading: 480 kg/cm^2) (Sieg et al. 1983).

Table 1. Distribution and elevational range for hoary tansyaster varieties (Morgan 2006).

D. canescens var.	States/Provinces	Elevation (ft)
ambigua	AZ, CO, NM	4,300-8,500
aristata	AZ, CO, NM, UT	3,300-8,900
canescens	AZ, CA, CO, ID, MT, ND, NE, NV, SD, UT, WY; Canada: AB, BC, SK	3,300-9,800
glabra	AZ, CO, KS, NM, TX, WY; Mexico: Chih.	3,300-7,500
incana	ID, OR, WA; Canada: BC	980-4,900
leucanthemifolia	CA, NV, UT	1,600-8,200
nebraskana	NE, SD	3,300-4,900
sessiliflora	ID (along the Snake River and its tributaries)	2,000-5,900
shastensis	CA, NV, OR (Cascade, Sierra Nevada, and adjacent mountains)	3,900-11,000
ziegleri	CA (Santa Rosa Mtns.)	4,600-8,200

DESCRIPTION

Hoary tansyaster is a highly variable species and grows as an annual, biennial, or short-lived perennial. The *artistata* and *glabra* varieties typically grow as annuals or biennials, variety *nebraskana* grows as a biennial or short-lived perennial, and variety *ziegleri* is a perennial subshrub (Cronquist et al. 1994; Morgan 2006).

Plants are taprooted, often with a simple to branched caudex producing one to many loosely spreading or erect stems (Fig. 1). Variety *nebraskana* is typically single stemmed. Plants are commonly 2.5 to 30 inches (6-80 cm) tall, but robust specimens of up to 40 inches (1 m) tall have been reported (Hitchcock et al. 1955; Welsh et al. 1987; Cronquist et al. 1994; Morgan 2006). Hoary tansyaster flower heads, stems, and leaves are covered with a sticky pungent resin (Pavek et al. 2012; Tilley et al. 2014). Leaves are alternate, fleshy and firm, sparsely to densely hairy, and linear to oblong. Leaf margins are entire to toothed. Basal leaves, which grow up to 4 inches (10 cm) long and 0.8 inch (2 cm) wide, are persistent, shriveled, or absent at the time of flowering and seed production. Stem leaves are slightly smaller and persistent (Welsh et al. 1987; Cronquist et al. 1994; Pavek et al. 2012). Flower heads are numerous and produced singularly or in simple flat- or round-topped inflorescences at branch ends (Fig. 2) (Welsh et al. 1987; Hickman 1993; Cronquist et al. 1994; Morgan 2006). Flower heads contain 10 to many yellow disk flowers, and 8 to 25 ray flowers, which are purple-blue to pink or white (Welsh et al. 1987; Hickman 1993; Cronquist et al. 1994; Morgan 2006). Ray flowers are pistillate and fertile, except for variety *shastensis*, which produces only sterile ray flowers (Hickman 1993; Morgan 2006). Fruits are very small cypselas or false achenes, 2.5 to 4 mm long with a dirty white, hair-like pappus (Fig. 3; Welsh et al. 1987; Cronquist et al. 1994; Tilley 2015a). Throughout this review, the term seed will refer to the fruit (cypsela) and the seed it contains.

Plants growing along roadsides in central New Mexico produced an average of 121 flower heads per plant (range: 29-260). Heads averaged 32 ray flowers (range: 26-38) and 66 disk flowers (range: 54-80) (Parker and Root 1981).

Figure 1. Hoary tansyaster growing in New Mexico. Photo: USDI BLM NM930N SOS.

Reproduction. Hoary tansyaster reproduces entirely from seed. Asexual reproduction does not occur.

Figure 2. Lower heads on hoary tansyaster plants contain 8 to 25 purple-blue to white ray flowers and 10 or more yellow disk flowers. Photo: S. Murray, USDI BLM AZ932 SOS.

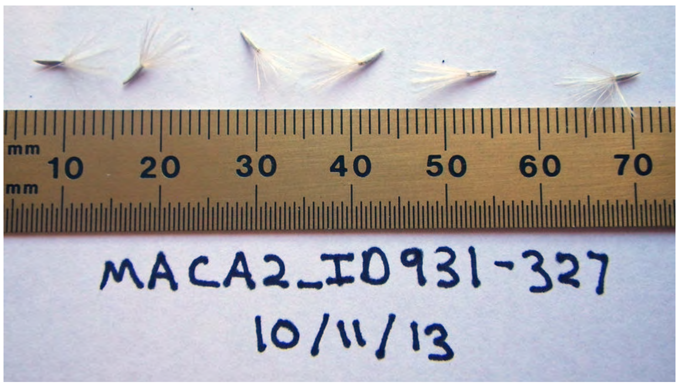

Figure 3. Hoary tansyaster seed collected from plants in Idaho. Photo: USDI BLM ID931 SOS.

Seed Production. Hoary tansyaster flowers in its first year. Flowering is indeterminate, and the first flowers appear in summer or fall depending on the variety and site conditions (Fig. 4) (Shaw et al. 2012; Tilley 2015b). There is a high degree of overlap in the timing of flowering among varieties. However, varieties *incana* and *leucanthemifolia* are generally earliest, producing flowers in June. Flowers are commonly found into September for all varieties, and many produce flowers into October. Variety *canescens* can be found flowering into November (Morgan 2006).

Seeds mature within 4 or 5 weeks of flowering (DeBolt and Parkinson 2005). The very small fruits (cypselas or false achenes) have a hair-like pappus (Welsh et al. 1987; Cronquist et al. 1994; Tilley 2015a) and are easily wind-dispersed (Drezner and Fall 2002).

Figure 4. Hoary tansyaster displaying indeterminate flowering in Idaho. Photo: USDI BLM ID931 SOS.

Pollination. Flowers attract a variety of pollinators and are considered a valuable late summer and early fall pollinator food source (Fig. 5) (Tilley et al. 2014). In some years, some flowers are still present in mid-November, depending on plant variety and weather conditions (Tilley 2015b). In seed production fields growing at the USDA NRCS Aberdeen Plant Materials Center in southern Idaho (IPMC), hoary tansyaster flowers were visited by various bees (*Halictus* spp., *Agapostemon* spp., and *Apis mellifera*), bee flies (Diptera: Bombyliidae), western white butterflies (*Pontia occidentalis*), and garden white butterflies (*Pieris* spp.) (Tilley et al. 2014, 2015b).

Figure 5. Cabbage white butterfly (*Pieris rapae*) on hoary tansyaster flowers at the USDA NRCS Aberdeen Plant Materials Center in southern Idaho. Photo: D. Tilley, USDA NRCS.

ECOLOGY

Hoary tansyaster is a fast-growing, early reproducing, disturbance-tolerant species.

Seed Ecology. Seed produced by hoary tansyaster is mostly non-dormant and does not require cool-moist stratification to germinate. In field establishment studies where fall, spring, and summer seeding were evaluated, pre-chilling was not required for germination of seed collected from Idaho and Utah (Tilley et al. 2014). Germination of seed collected in the spring and summer from central New Mexico began within days of imbibition with or without stratification. Germination was 99 to 100% for untreated, cool-moist (41°F [5 °C]), and warm-moist (86 °F [30 °C]) stratified seed (Pendleton and Pendleton 2014).

Successional Status. Hoary tansyaster is an early colonizer in both primary and secondary succession (Brandt and Rickard 1994; Peinado et al. 2005; Pavek et al. 2012; Shaw et al. 2012; Stephens et al. 2016). It establishes readily from shattered seed (Tilley 2015b). It is common on disturbed sites (Goodrich 1997; Loeser et al. 2007), and its abundance and persistence may benefit from periodic disturbance (Koniak and Everett 1982; Poreda and Wullstein 1994).

Hoary tansyaster was a pioneer species on marble outcrops in the Sierra Nevada Mountains (Peinado et al. 2005) and on sandhills in Montana (Lesica and Cooper 1999) and Nebraska (Tolstead 1942). In sandhill vegetation in southwestern Montana, cover of hoary tansyaster was greatest (4.4%) in the earliest successional stage and decreased with advancing succession. Seral stages were primarily based on topography and sand movements with the earliest seral stage on lower slopes with active sand erosion, slightly later seral stages on upper slopes with active sand deposition, and late seral stages where sand was stabilized and shrub cover was greatest (Lesica and Cooper 1999).

Fire response. In several studies, hoary tansyaster appears soon after fire. Although not seeded, it occurred in the first, second, and third post-fire years following a summer fire and restoration treatments in sagebrush steppe in west-central Utah (Ott et al. 2003). Frequency of hoary tansy aster was 4% in the first and second and 2% in the third post-fire years on sites that were chained following seeding. Frequency was slightly higher, 7% in the first, 8% in the second, and 6% in the third post-fire years on plots that were not chained following seeding (Ott et al. 2003). In the central Wasatch Mountains near Midway, Utah, frequency was 9.8% on 1-year old burns, but plants were absent from unburned big sagebrush sites (Poreda and Wullstein 1994). Hoary tansyaster occurred with 0.5% cover on 4-year-old burned mountain big sagebrush sites but was not found on adjacent unburned sites in Wasatch County, Utah (Goodrich 2006).

On the North Rim of Grand Canyon National Park, Arizona, hoary tansyaster occurred in frequently burned old-growth ponderosa pine forests and in forests that had burned recently, but for the first time in 76 years. Hoary tansyaster was a significant indicator ($P = 0.002$) of frequently burned forests, where its relative abundance and frequency were high (Laughlin et al. 2004). In the Sweetwater Mountains of eastern California, hoary tansyaster was restricted to early seral sites when singleleaf pinyon (*Pinus monophylla*) woodlands ranging from recently burned and grass-forb dominated to late-seral, tree-dominated sites were compared. Hoary tansyaster was not found on shrub- or tree-dominated sites (Koniak and Everett 1982).

Wildlife and Livestock Use. Use of hoary tansyaster plants or seeds has been noted for elk (*Cervus canadensis*) (McCorquodale 1993), pronghorn (*Antilocapra americana*) (Beale and Smith 1970), Ord's kangaroo rats (*Dipodomys ordii*) (Henderson 1990), packrats (*Neotoma* spp.) (Fisher et al. 2009), and greater sage-grouse (*Centrocercus urophasianus*) (Pyle 1993).

Large mammals. Heavy use by elk and pronghorn has been reported. In big sagebrush-bluebunch wheatgrass (*Pseudoroegneria spicata*) communities in south-central Washington, the frequency of hoary tansyaster in elk diets as determined from fecal analyses was: 19.7% in October, 26% in November, 11.9% in December, 37.5% in January, 1.2% in February, and 0.3% in March (McCorquodale 1993). In the Greater Yellowstone area, mostly in Wyoming, elk feeding on stems and flowers was noted for July and November (Skinner 1928). In Bandelier National Monument, New Mexico, hoary tansyaster made up 0 to 2.9% of elk diets during periodic sampling from September 1991 to July 1993 (Wolters 1994).

Hoary tansyaster was moderately to highly preferred by pronghorn on the Desert Experimental Range in west-central Utah, even though its production reached a high of just 0.2 lb/acre (0.5 kg/ha). Plants were consumed more in wet than dry years based on pronghorn rumen samples collected between late August and early September (Beale and Smith 1970).

Small mammals. Seeds are eaten by Ord's kangaroo rats (Henderson 1990) and vegetative material or seeds of hoary tansyaster were recovered from packrat middens (Thompson and Anderson 2000; Fisher et al. 2009). In the Mojave Desert, hoary tansyaster was identified as a microhabitat variable significantly associated with the relative abundance of desert kangaroo rats (*D. deserti*), but actual use of the species was not determined (Stevens and Tello 2009).

Birds. Hoary tansyaster attracts a variety of native insects that are important to certain life stages of greater sage-grouse and other birds (Tilley 2015b). At the Hart Mountain National Antelope Refuge in southeastern Oregon, frequency of hoary tansyaster was 2% in the diet of greater sage-grouse chicks (Pyle 1993).

Livestock. Cattle did not appear to graze hoary tansyaster in a high-elevation, semi-arid grassland near Flagstaff, Arizona. Loeser et al. (2007) found no difference in the cover of hoary tansyaster in ungrazed, moderately grazed, and highly grazed pastures maintained for 8 years.

Ethnobotany. Several western tribes report medicinal and ceremonial uses of hoary tansyaster (Moerman 2003). The Navajo dried the plant and used it as a snuff to treat nose and throat troubles. The Paiute also used it to treat throat problems, but they applied a poultice of leaves to swollen jaws or neck glands. Shoshoni Indians took a decoction of fresh or dried leaves for headaches and used extracts of the whole plant as a blood tonic. An infusion of root material was used as an eyewash by the Shoshoni. Both the Shoshoni and Zuni used infusions to induce vomiting and purge their systems. Hopi Indians gave hoary tansyaster to women in labor and created a strong stimulant from a plant extract. The Okanagan-Colville used hoary tansyaster in ceremonies (Moerman 2003).

REVEGETATION USE

Many characteristics make hoary tansyaster a useful species for restoration, such as tolerance of early seral conditions; rapid establishment, growth, and reproduction; and food production for pollinators. However, reports on its successful use in wildland restoration and rehabilitation are limited.

Although not planted on reclaimed or abandoned mine sites, hoary tansyaster occurred on bentonite mine spoils in Montana (Sieg et al. 1983) and copper mine waste sites in Utah (Borden and Black 2005). In Carter County, Montana, cover averaged 0.1% on old bentonite mine spoils, 0.2% on reclaimed spoils, and less than 0.1% in undisturbed big sagebrush-grassland communities (Sieg et al. 1983). In Bingham County, Utah, hoary tansyaster occurred at 50% frequency and up to 3% cover on sulfide-bearing waste created from copper pit mining. Waste sites averaged 30 years old and had neutral pH (6-7.9) and low salinity levels (0.06-0.5 dS/m). Hoary tansyaster was absent from waste sites with lower pH and higher salinity levels (Borden and Black 2005).

DEVELOPING A SEED SUPPLY

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

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

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

The Western Wildland Environmental Threat Assessment Center's (USFS WWETAC 2017) Threat and Resource Mapping (TRM) Seed Zone application provides links to interactive mapping features useful for seed collection and deployment planning. The Seedlot Selection

Tool (Howe et al. 2017) can also guide restoration planning, seed collection, and seed deployment, particularly when addressing climate change considerations.

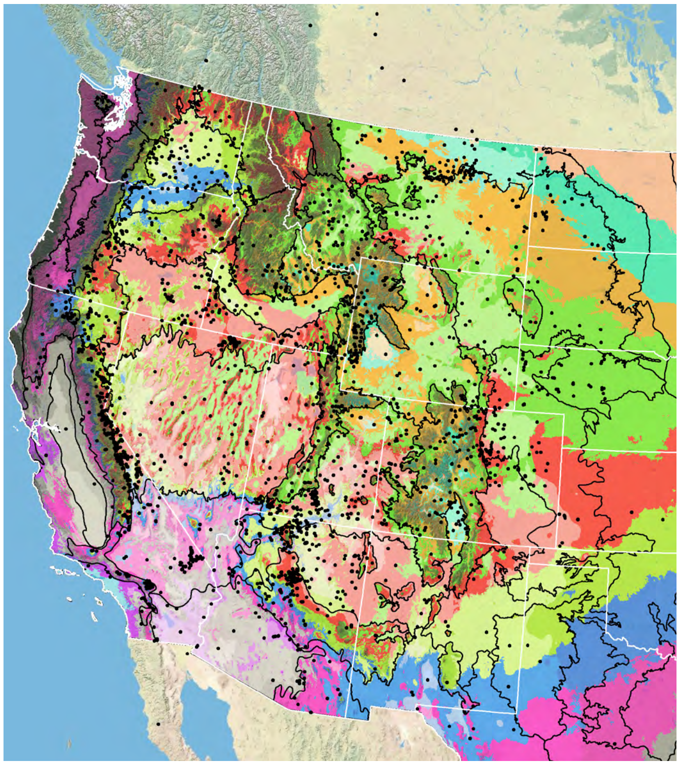

Figure 6. Distribution of hoary tansyaster (black circles) based on geo-referenced herbarium specimens and observational data from 1849-2016 (CPNWH 2017; SEINet 2017; USGS 2017). Generalized provisional seed zones (colored regions) (Bower et al. 2014) are overlain by Omernik Level III Ecoregions (black outlines) (Omernik 1987; USDI EPA 2018). Interactive maps, legends, and a mobile app are available (USFS WWETAC 2017; www.fs.fed.us/wwetac/threat-map/TRMSeedZoneMapper2.php?). Map prepared by M. Fisk, USGS.

Releases. Amethyst Germplasm hoary tansyaster, a selected class natural track germplasm, was released for use in restoration. The release exhibited exceptional establishment, growth, and seed production in a common garden setting among populations collected from northern Utah and southern Idaho (Tilley 2015a). Amethyst came from seed collected at a site near the St. Anthony Sand Dunes in Freemont County, Idaho. At this source location, the elevation was 5,000 feet (1,500 m), soils were loamy fine sands, average annual precipitation was 12 inches (300 mm), and dominant vegetation was antelope bitterbrush (*Purshia tridentata*), Indian ricegrass (*Achnatherum hymenoides*), and rubber rabbitbrush (*Ericameria nauseosa*) (Tilley 2014, 2015a).

Wildland Seed Collection. Although phenology can vary with variety and growing site and weather conditions (e.g., elevation, aspect, moisture), it is typical to see mature hoary tansyaster seeds within 4 to 5 weeks of flowering (DeBolt and Parkinson 2005; Tilley 2015b). Because seed readily disarticulates when ripe and is wind dispersed, proper planning and timing of wildland seed harvests is critical to collecting large quantities of seed. Because flowering is indeterminate, several collections can be made over the ripening period (Fig. 7) (Tilley 2011, 2015b).

Wildland seed certification. Wildland seed collected for direct sale or for establishment of agricultural seed production fields should be Source Identified through the Association of Official Seed Certifying Agencies (AOSCA) Pre-Variety Germplasm program that verifies and tracks seed origin (Young et al. 2003; UCIA 2015). For seed that will be sold directly, collectors must apply for certification prior to making collections. Applications and site inspections are handled by the state where collections will be made. For seed that will be used for agricultural seed fields, nursery propagation or research, the same procedure must be followed. Seed collected by some public and private agencies following established protocols may enter the certification process directly, if the protocol includes collection of all data required for Source Identified certification (see Agricultural Seed Certification section). Wildland seed collectors should become acquainted with state certification agency procedures, regulations, and deadlines in the states where they collect. Permits or permission from public or private land owners is required for all collections.

Figure 7. Indeterminate flowering of hoary tansyaster in Oregon. Photo: USDI BLM OR931 SOS.

Collection timing. Based on 10 years of seed collection records made by the BLM Seeds of Success (SOS) field crews, wildland seed was collected at an earliest date of June 17, 2011 from a 3,098-foot (944 m) elevation, recently burned shrubland site in Mohave County, Arizona. The latest collection date of November 7, 2012 was made in a wet meadow of unknown elevation in Boulder County, Colorado. The most common collection dates were in September and October (USDI BLM SOS 2017). On the western side of the Cascades, seed can be collected as early as the end of August and in Ontario, Oregon, collections can still be made in mid-October. These populations are thought to represent different hoary tansyaster varieties. The collection window lasts about 4 weeks. There are typically 2 to 6 ripe seed heads/plant near the beginning of the collection season, and this number increases a little as the collection season continues (B. Youtie, Eastern Oregon Stewardship Services [EOSS], personal communication, September 2017).

Collection methods. Wildland seed can be collected by hand stripping or shaking branches over collection bags (Tilley 2011). Field crews for the USFS Great Basin Native Plant Project collected wildland seed by shaking seed from the stems or seed heads into paper bags. Because plants are sticky, gloves are recommended when handling stems and flower heads (A. Malcomb, USFS, personal communication, June 2017). Some prefer to hand-collect the puffs when seed heads have dry, brown flower petals and nearly mature seed (Fig. 8). The pappus generally emerges from flower material within two days of drying (B. Youtie, EOSS, personal communication, September 2017).

Several collection guidelines and methods should be followed to maximize the genetic diversity of wildland collections: collect seed from a minimum of 50 randomly selected plants; collect from widely separated individuals throughout a population without favoring the most robust or avoiding small stature plants; and collect from all microsites including habitat edges (Basey et al. 2015). General collecting recommendations and guidelines are also presented in available manuals (e.g., USDI BLM SOS 2016; ENSCONET 2018).

Figure 8. Collected hoary tansyaster seed heads. Photo: D. Wilson, Chicago Botanic Garden.

Post-collection management. Seeds collected late in the growing season or when conditions are cool and moist must be carefully dried before storing or cleaning.

Seed Cleaning. Seed cleaning procedures depend on the harvest method and are more labor and time intensive for seed collections containing an abundance of plant material.

The following cleaning process was used by the USFS Bend Seed Extractory for a small lot of hand-collected seed (Barner 2009):

1. Process seeds using a Westrup Model LA-H brush machine, a number 30 mantel, and a medium rotation speed.

2. Air-screen the seed using an office Clipper, a 1/18 round-top screen, a blank bottom screen, and medium speed and air.

For seed collections containing flower heads and plant stems, the following seed cleaning guidelines were developed by the IPMC (Tilley et al. 2014):

1. Process flowers and seeds through a laboratory brush machine using a number 7 mantle and rotation speed of 3 with the gate closed. This breaks up the flower heads, disconnects seeds from their pappi, and allows seeds to fall into the catch pan.

2. Process brushed seed through a multi-deck, air screen cleaner using 6 x 30 and 6 x 32 screens and a low (1-2) air setting. This removes dust, any retained pappi, and unfilled seed. The air screening process may need to be repeated 6 to 10 times to adequately clean the seed.

3. Process screened seed through an indent cleaner if needed to remove weed seeds.

Cleaning procedures above can yield seed with 60 to 90% purity and viability (Tilley et al. 2014).

For field-grown seed collected using a vacuum (particularly the "jet harvester"; Tilley and Bair 2011), the IPMC developed the following cleaning guidelines (Tilley 2011):

1. Process seed through a Westrup brush machine with a number 7 mantle and a rotation speed of 2 with the gate closed to catch brushed seed. Seed lots may need to be brushed 2 to 3 times to remove seeds from the flower heads and to disconnect as many pappi as possible.

2. Clean brushed seeds with a Westrup LA-LS multi-deck air cleaner using a 2.3 top screen, blank middle screen, solid bottom screen, and a very low air setting (0.5) to remove remaining pappi and inert material.

Cleaning methods above for vacuum-collected seed, resulted in low seed purity (40-50%), but seed was clean enough to move through drill seeding equipment (Tilley 2011).

After more experimentation, researchers at the IPMC further reduced the vegetative material collected from seed fields (see Seed Harvesting section). This allowed development of simpler cleaning guidelines for seed lots containing primarily seeds, pappus fluff, and bracts (Simonson and Tilley 2016):

1. Process seed through a Westrup Laboratory Brush Machine using a number 7 mantle, keeping brushes 3 to 4 mm from the surface, setting the speed to 2, and leaving the gate open about 0.4 inch (1 cm). Brushing the seed twice using these methods successfully removes the pappus from the seed.

2. Using the harvest and cleaning methods above, a single harvest on September 14 yielded 149 lbs (68 kg) of unclean and 27 lbs (12 kg) of clean seed (Simonson and Tilley 2016).

Seed Storage. Hoary tansyaster seeds are orthodox and survive drying to low moisture contents (RBG Kew 2017). Seed was dried sufficiently in open collection sacks after 1 to 2 months at 50 °F (10 °C) and relative humidity of 20 to 30% (Tilley 2011, 2015a). Conditions for the best long-term seed storage were not described in the literature.

Seed Testing. There is no AOSA germination protocol available for hoary tansyaster. Guidelines for tetrazolium testing are available (Moore 1985).

Germination. Hoary tansyaster seed is mostly non-dormant and in many cases, does not require cold stratification to germinate; however, Kramer and Foxx (2016) found improved germination with exposure to cold temperatures.

In field establishment studies, pre-chilling, although not always necessary, was sometimes used to germinate seed collected from Idaho and Utah regardless of the timing of seeding (Tilley et al. 2014). For seed collected in the spring and summer from central New Mexico, germination began within days of imbibition and was 99 to 100% for untreated seeds and cool-moist (41°F [5 °C]) or warm-moist (86 °F [30 °C]) stratified seeds (Pendleton and Pendleton 2014). However, hoary tansyaster seed collected from San Juan County, New Mexico, germinated poorly when not exposed to cool-moist conditions (Kramer and Foxx 2016). Germination was 100% for seeds exposed to 12-hour light and 12-hour dark cycles for: 12 weeks at 34 °F (1 °C) and 4 weeks at alternating temperatures of 52 and 34 °F (11/1 °C), 59/41 (15/5 °C), or 68/50 °F (20/10 °C). Without initial pre-chilling, germination was 80% when seeds were incubated for 4 weeks at 52/ 35 °F (11/2 °C) and less than 25% when seeds were incubated for 4 weeks at 59/41 °F (15/5 °C) or for 4 weeks at 68/50 °F (20/10 °C) (Kramer and Foxx 2016).

Seed collected from the southern Idaho Snake River Plain, germinated within 10 to 14 days in a growth chamber after a single day of cool, moist stratification at 40 °F (4.4 °C) (Parkinson 2008). Seeds collected from Elmore County, Idaho, treated to cool-moist stratification for 35 days at 39 °F (4 °C) in the dark began germinating within 5 days in a germinator with 12-hr light/dark cycles at 70 °F (21 °C). After 8 days of incubation, germination was 76%, and total germination was 77% (DeBolt and Parkinson 2005). There were no reports of testing the germination of unchilled seed from either of the above studies.

Wildland Seed Yield and Quality. Post-cleaning seed yield and quality of seed lots collected in the Intermountain region are provided in Table 2 (USFS BSE 2017). The results indicate that hoary tansyaster seed can be cleaned to high levels of purity but that purity, seed fill, and viability of fresh seed are highly variable. Shock et al. (2014a, 2017a) reported viability of harvested seed from cultivated research plots ranged from 70 to 84%.

Hoary tansyaster seeds are tiny, averaging more than 1,100,000 seeds/lb (2,400,000/kg) (USFS BSE 2017). Other sources report a similar range of 521,000 to 2,160,000 seeds/lb (1,200,000-4,800,000/kg) (Ogle et al. 2011; Tilley 2011; Shock et al. 2014a, 2017a; RBG Kew 2017; USFS GBNPP 2017). Seed lots with the pappus attached weighed about 3 lbs/bushel, and without the pappus weighed between 20 and 24 lbs/bushel (Tilley et al. 2014).

Table 2. Seed yield and quality of hoary tansyaster 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).

Characteristic	Mean	Range	Samples (#)
Bulk weight (lbs)	1.2	0.04-13.35	50
Clean weight (lbs)	0.1	0.001-0.9	50
Clean-out ratio	0.15	0-0.5	50
Purity (%)	90	30-99	50
Fill (%)[1]	89	70-99	50
Viability (%)[2]	88	49-98	42
Seeds/lb	1,182,055	252,000-2,548,314	50
Pure live seeds/lb	843,570	405,784-1,866,240	42

[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 like that used in nurseries, while some rangeland seeding equipment handles less clean seed quite well.

AGRICULTURAL SEED PRODUCTION

Hoary tansyaster was grown over several years for seed production at two experimental sites, IPMC (Fig. 9) and Oregon State University's Malheur Experiment Station (OSU MES). The IPMC farm is on the Snake River Plains at 4,300 feet (1,310 m) in Major Land Resource Area B11. Soils are Declo silt loams with a pH of 7.4 to 8.4. Annual precipitation averages 9.4 inches (240 mm). Growing season length averages 110 days with the last spring frost in early June, and the first fall frost in mid-September. Temperatures range from highs of 98 °F (37 °C) to lows of -15 °F (-26 °C) (Tilley 2015b). At OSU MES, soils are Nyssa silt loams (Shock et al. 2017b), and annual precipitation averages 10 inches (260 mm). Growing season averages 161 days with the last spring frost occurring between late March and May and the last fall frost in mid-September or late October. High and low temperatures can reach 102 °F (39 °C) and -9 °F (-23 °C) (Feibert and Shock 2017).

Hoary tansyaster grows rapidly (Ogle et al. 2011), produces harvestable seed crops after the first full growing season (Tilley 2011; Shaw et al. 2012), and for some ecotypes, two to three additional years of seed harvests are possible (Tilley 2011). Timing of planting impacts seed production. When planted in spring or early summer, hoary tansyaster does not produce a harvestable crop until the following growing season, and plants die after second-season flowering and seed set (Tilley et al. 2014). Fields planted in late summer or fall will produce seed crops in the next two growing seasons (Tilley et al. 2014, 2015b). "Cropping time" was 4 months for production of seed (Tilley 2011).

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

Figure 9. Hoary tansyaster seed production at the USDA NRCS Aberdeen Plant Materials Center in southern Idaho. Photo: L. St. John, USDA NRCS.

Site Preparation. Two field systems were used successfully for hoary tansyaster seed production by the IPMC: planting in weed-barrier fabric and open drill-seeded fields. For both methods, fields were plowed, disked, and packed with a roller cultipacker before seeding (Tilley 2015b).

Seed Pretreatments. At OSU MES, pre-treating hoary tansyaster seeds with a liquid mix of fungicides did not improve stand or seed production (Shock et al. 2017a).

Weed Management. Hoary tansyaster establishes well even with moderate weed pressure. Seeding in late summer (August) when annual weed competition is low was optimal for seed production at the IPMC (Tilley 2015b). The use of weed barrier fabric can also limit competition from weeds in seed production fields (Tilley et al. 2014). Where weed barrier fabric is used, the establishment of low-growing perennial grasses at the fabric edges allows for the use of mowing for weed management. Mowing to control weeds means less cultivation and herbicide use, thus minimizing disturbances to ground-nesting pollinators (Tilley 2015b).

In trials conducted at OSU MES, hoary tansyaster showed some sensitivity to both pre- and post-emergence herbicides. However, stands were slightly better than untreated stands for 4 of 11 pre-emergent herbicides. Conversely, stand development was reduced in 6 of 7 post-emergence herbicides tested. Application of a thiocarbamate pre-emergent herbicide resulted in the best stand development (Shock et al. 2014b).

Several weed species (e.g. sowthistle [*Sonchus* spp.] and prickly lettuce [*Lactuca serriola*]) produce seeds that are comparable in size, weight, and shape to those of hoary tansyaster and are difficult to remove in the seed cleaning process. These weeds should be controlled in the field through hand pulling or targeted chemical control (Tilley et al. 2014).

Seeding. Successful seed production crops of hoary tansyaster have been grown using 30- or 36-inch (76-91 cm) row spacings in open fields (Tilley et al. 2014, 2017b) or 9- to 18-inch (23-46 cm) plant spacings in single or double rows down the center of weed barrier fabric (Tilley et al. 2014; Tilley 2015b). Seeding rates of 0.35 to 1 lb PLS/acre (0.4-1.1 kg/ha) are recommended (Tilley et al. 2014; Simonson and Tilley 2016). The IPMC recommends using a drop tube manual seeder and a target of 5 to 20 seeds/hole for seeding in weed barrier fabric. The drop seeder used by the IPMC had a 3-inch (7.6 cm) diameter tube with a spur at the bottom (Tilley 2015b).

Drill-seeding open fields using 36-inch (91 cm) row spacings, a seeding rate of 0.35 lb/acre (0.4 kg/ha), and a seeding depth of up to 0.25 inch (0.6 cm), can provide for a target of 35 PLS/linear foot of row (Tilley 2015b). The rate for drill seeding and a target delivery of 45 to 50 PLS/ft^2 (480-540/m^2) is 2 lbs PLS/acre (2.3 kg/ha). A diluent like rice hulls is recommended to improve the flow of seeds through drill equipment (Tilley et al. 2014).

Covering seeds after planting can improve stand productivity. At OSU MSE, the use of row cover improved hoary tansyaster stand growth and seed production more than other seed coverings, which included sawdust and sand. The row cover protected against soil drying and bird predation. The use of hydromulch when seeding hoary tansyaster was no better for stand growth and productivity than direct seeding without providing any protection (Shock et al. 2017a).

Pest Considerations. Hoary tansyaster is a host and/or food source for a variety of insects. It is the only confirmed host for a fruit fly (*Neaspilota appendiculata*), which feeds on its flower heads. In a study conducted in southern California, larvae damaged an average of 94% (range: 44-100%) of soft achenes after eggs of this insect were inserted into hoary tansyaster flower heads (Goeden 2000). Hoary tansyaster is also host to European aphids (*Uroleucon erigeronense*) (Jensen et al. 2010), scales (*Acanthococcus cryptus*) (Miller and Miller 1982), and sagebrush checkerspot butterflies (*Chlosyne acastus*) (Scott 1986 cited in Wahlberg 2001). The sagebrush checkerspot butterfly feeds on young leaf tissue (Cates 1980) and of 78 observations of the butterfly in the West, all were on hoary tansyaster (Cates 1981). In seed production plots at the IPMC, moth caterpillars (*Cucillia* spp.) fed on hoary tansyaster flowers but had little impact on plot-level seed production (Tilley et al. 2014).

In central New Mexico, hoary tansyaster populations were damaged by heavy predation from purple-striped grasshoppers (*Hesperotettix viridis*) (Parker and Root 1981). Researchers observed hoary tansyaster along roadsides but not within the interior broom snakeweed (*Gutierrezia sarothrae*)-grassland community. When researchers transplanted hoary tansyaster into the interior habitats, only protected plants survived. One-third of unprotected plants were colonized by purple-striped grasshoppers within 12 hours, and all plants were colonized within 3 days. On average, unprotected plants were completely defoliated within 7.5 days. Of the protected hoary tansyaster plants, 77% produced flowers. Purple-striped grasshoppers were found on hoary tansyaster roadside populations, but factors limiting herbivore damage there were unknown (Parker and Root 1981).

In field plots at OSU MES, hoary tansyaster was a host for powdery mildew (*Leveillula picridis*) (Braun and Mohan 2013). In wild populations in Utah, rust (*Puccina asteris*) was found on hoary tansyaster leaves (Garrett 1910).

Establishment and Growth. Hoary tansyaster emerges in early spring (late April or early May) (Tilley 2011), grows and matures quickly, and produces seed in the late summer or fall. However, seed production depends on the timing of planting. If planted in the spring or early summer, little if any seed is produced, and plants die after producing a single seed crop the second year. If planted in late summer or fall, plants produce seed the following summer or fall and at least one more seed crop is produced (Tilley et al. 2014; Tilley 2015b). Hoary tansyaster goes dormant after flowering in late summer or fall and tolerates mowing at that time (Tilley 2011).

When nine hoary tansyaster populations from Idaho and Utah were grown together at the IPMC, establishment ranged from 41 to 87%. Seeding occurred in November to allow for natural stratification (Tilley et al. 2014, 2015a). Hoary tansyaster establishment was good even with moderate weed competition (Tilley 2015b).

In a greenhouse study, the total relative growth rate of hoary tansyaster growing alone for a period of 12 weeks averaged 0.4 mg/mg/week, relative growth rate of shoots averaged 0.4 mg/mg/week and roots averaged 0.5 mg/mg/week (Parkinson 2008). The total biomass of hoary tansyaster averaged 0.4 g at 6 weeks, 1.1 g at 9 weeks, and 3.4 g at 12 weeks, and root-mass ratios were 0.2 at 6 weeks, and 0.2 at 9 weeks, and 0.3 at 12 weeks (Parkinson et al. 2013).

Irrigation. Supplemental irrigation for seed production fields may not be necessary. In irrigation trials at OSU MES that spanned 3 years (2013-2015), average seed yield of hoary tansyaster was greater but not significantly so in plots receiving 4 or 8 inches (100-200 mm) of supplemental irrigation (Shock et al. 2017b). For seed crops at the IPMC where annual rainfall ranges from 8 to 12 inches (200-305 mm), plants growing in weed barrier fabric were not provided supplemental irrigation (Tilley et al. 2014), but drill-seeded fields received 4 inches (100 mm) of supplemental irrigation in late April and mid-May (Tilley 2015b). Seed yields from the two treatments were not compared.

Seed Harvesting. Seed can be harvested by hand, vacuuming, combining, or by swathing and windrowing plants (Fig. 10). The method used will depend on resources, desire for multiple harvests, and/or minimizing plant damage (Tilley et al. 2014).

Seed matures 4 to 5 weeks after flowering and is typically harvested in late summer or fall (DeBolt and Parkinson 2005; Tilley et al. 2014; Shock et al. 2017b) depending on variety and location. In seed fields at IPMC, plants began flowering in late summer and continued flowering for several weeks into the fall. Only hand harvesting and vacuum harvesters allowed for multiple non-destructive harvests (Tilley et al. 2014). In seed production fields at OSU MES, the earliest flowering date was August 13 and latest flowering date was October 10 in 4 years of observations (Shock et al. 2017b).

Figure 10. Hoary tansyaster harvested using a standard Flail-Vac and containing significant amounts of vegetative material. Photo: D. Tilley, USDA NRCS.

Because hoary tansyaster flowers indeterminately, seed can be harvested multiple times using non-destructive hand or vacuum harvesting methods (Tilley et al. 2014). When growing on weed barrier fabric, the IPMC harvested hoary tansyaster using a "Jet Harvester" (see Tilley and Bair 2011) with a fan speed of 1,900 rpm. This harvest method allowed for multiple harvests of only ripe seed and provided seed lots with limited trash and other inert material. Harvesting seed from both sides of a 500-foot (150 m) row took about 90 minutes. Typically, 3 to 5 harvests were made over the season. Collected seed was air dried with the help of fans and manual turning the seed twice a day (Tilley 2015b).

Researchers at the IPMC developed a unique non-destructive seed collection method for larger seed fields than those discussed above through modification of a flail-vacuum harvester (Simonson and Tilley 2016). The equipment modification added a system of loose chains to the flail-vacuum hood, which agitated plants and dislodged ripe seed from the flower heads. This produced limited plant damage, allowed for repeat harvests, and collected a minimal amount of vegetative material in the harvest. For a single harvest on September 14, this collection method yielded 149 lbs (68 kg) of bulk seed or 27 lbs (12 kg) of clean seed. Harvested material was primarily seed, pappus fluff, and bracts from the flower heads (Simonson and Tilley 2016). Seed cleaning of these harvests was much quicker and simpler than seed collected by destructive harvest methods (see Seed Cleaning section). This method could also be used for other species with indeterminate, lightweight seed produced throughout the plant rather than at the periphery of the canopy.

At OSU MES, hoary tansyaster seed was harvested from small research plots by cutting and windrowing plants. After plants dried for two days, they were manually beat against plastic tubs to separate the seed heads from the flower stalks. Seed yields for this single destructive harvest ranged from 200 to 400 lbs of seed/acre (225-450 kg/ha) (Shock et al. 2017b).

NURSERY PRACTICES

A single report described procedures for small-scale production of hoary tansyaster nursery stock (DeBolt and Barrash 2013). Plants were grown from seed collected southeast of Boise, Idaho. Three to five seeds with pappi were planted into 2.9 x 5.5-inch (7.3 x 14 cm) containers filled with a 2:1:5 mix of lava fines, perlite, and nursery soil mix. Seeds were planted on February 27, covered with a 0.13-inch (0.33 cm) layer of chicken grit, kept outdoors in full sun, and hand watered as necessary. No fertilizers were applied. First emergence occurred on March 16. By April 3, about 80% of the containers had at least one seedling. Container stock was outplanted in early October. Survival of outplanted stock was not reported (DeBolt and Barrash 2013).

Hoary tansyaster grows quickly (DeBolt and Parkinson 2005; Ogle et al. 2011). Seeds germinate within about 5 days of exposure to incubation conditions and produce secondary leaves within about 1 week of germination. If seeds are pregerminated prior to planting, use of soil in germination dishes is recommended because roots quickly penetrate germination blotters (DeBolt and Parkinson 2005). In the production of hoary tansyaster container stock, the time to establishment was about 2 months and the time to produce roots that filled the container was about 6 months (DeBolt and Barrash 2013).

Although hoary tansyaster is host to several potential pests (see Pest Considerations section), the degree to which these might be problematic in nursery or crop systems is unknown.

WILDLAND SEEDING AND PLANTING

Based on seed production trials conducted by the IPMC, broadcast- or drill-seeding in the late fall into a firm, weed-free seed bed at sites receiving 7 to 15 inches (180-380 mm) of precipitation is recommended (Ogle et al. 2011; Tilley et al. 2014, 2015b). Seeding depth should be 0 to 0.25 inch (0.6 cm) (Tilley 2015b), and the recommended seeding rate is 1 to 2 lbs of PLS/acre (1.1-2.3 kg PLS/ha) for pure stands (Ogle et al. 2011; Tilley et al. 2014) or a target delivery of 20 to 30 PLS/foot^2 (215-323 PLS/m^2). Broadcast seeding rates are generally double that of drill seeding rates, and broadcast seeding should be followed by some method that ensures good seed-soil contact. For drill seeding, a dilutent like rice hulls improves seed flow through the equipment (Tilley et al. 2014).

Often hoary tansyaster is just one component of a wildland seed mix and normally makes up less than 10% of the mixture (Ogle et al. 2012). Hoary tansyaster makes a good candidate for inclusion in pollinator and wildlife rangeland seed mixes.

Stand Management. A weed-free seedbed is recommended for wildland seeding. Greenhouse experiments suggest that hoary tansyaster growth is reduced when grown with cheatgrass (*Bromus tectorum*) but not when grown with native grasses (Parkinson et al. 2013) or with competition from saltlover (*Halogeton glomeratus*) (Prasser and Hild 2016).

In a greenhouse study, 12-week old hoary tansyaster plants weighed 3.4 g when grown alone, 5.3 g with Sanberg bluegrass (*Poa secunda*), and 5.5 g with bottlebrush squirreltail (*Elymus elymoides*), and 0.8 g with cheatgrass, the later was significantly less ($P < 0.001$) than when grown alone (Parkinson et al. 2013). In big sagebrush communities in north-central Oregon, hoary tansyaster abundance increased significantly 3 and 4 years following treatment with imazapic to control cheatgrass and increases occurred on 2 of 3 sites (Elseroad and Rudd 2011). In another greenhouse competition study, hoary tansyaster seedling growth (leaf number, plant height, root:shoot ratio, canopy area, and plant specific area) was not significantly different when grown as a monoculture or with saltlover. However, survival of saltlover was 40% in monoculture but slightly lower, 30%, when grown with hoary tansyaster (Prasser and Hild 2016).

ACKNOWLEDGEMENTS

Funding for *Western Forbs: Biology, Ecology, and Use in Restoration* was provided by the USDI BLM Great Basin Native Plant Materials Ecoregional Program through the Great Basin Fire Science Exchange. Great thanks to the chapter reviewers: Jim Cane, USDA ARS and Clint Shock, OSU MES.

LITERATURE CITED

Abella, S.R.; Engel, E.C.; Springer, J.D.; Covington, W.W. 2012. Relationships of exotic plant communities with native vegetation, environmental factors, disturbance, and landscape ecosystems of *Pinus ponderosa* forests, USA. Forest Ecology and Management. 271: 65-74.

Anderson, L.C.; Kyhos, D.W.; Mosquin, T.; Powell, A.M.; Raven, P.H. 1974. Chromosome numbers in Compositae. IX. *Haplopappus* and other Astereae. American Journal of Botany. 61(6): 665-671.

Association of Official Seed Certifying Agencies [AOSCA]. 2003. The AOSCA native plant connection. Moline, IL: Association of Official Seed Certifying Agencies. 8 p.

Barner, J. 2009. Propagation protocol for production of propagules (seeds, cuttings, poles, etc.) *Machaeranthera canescens* (Pursh) A. Gray seeds. Native Plant Network. U.S. Department of Agriculture, Forest Service, National Center for Reforestation, Nurseries, and Genetic Resources. http://npn.rngr.net/propagation/protocols [Accessed 2017 July 21].

Basey, A.C.; Fant, J.B.; Kramer, A.T. 2015. Producing native plant materials for restoration: 10 rules to collect and maintain genetic diversity. Native Plants Journal. 16(1): 37-53.

Beale, D.M.; Smith, A.D. 1970. Forage use, water consumption, and productivity of pronghorn antelope in western Utah. The Journal of Wildlife Management. 34(3): 570-582.

Borden, R.; Black, R. 2005. Volunteer revegetation of waste rock surfaces at the Bingham Canyon Mine, Utah. Journal of Environmental Quality. 34: 2234-2242.

Bower, A.D.; St. Clair, J.B.; Erickson, V. 2014. Generalized provisional seed zones for native plants. Ecological Applications. 24(5): 913-919.

Brandt, C.A.; Rickard, W.H. 1994. Alien taxa in the North American shrub-steppe four decades after cessation of livestock grazing and cultivation agriculture. Biological Conservation. 68(2): 95-105.

Braun, U.; Mohan, S.K. 2013. New records and new host plants of powdery mildews (*Erysiphales*) from Idaho and Oregon (USA). Schlechtendalia. 27: 7-10.

Brotherson, J.D.; Anderson, D.L.; Szyska, L.A. 1984. Habitat relations of *Cercocarpus montanus* (true mountain mahogany) in central Utah. Journal of Range Management. 37(4): 321-324.

Cates, R.G. 1980. Feeding patterns of monophagous, oligophagous, and polyphagous insect herbivores: The effect of resource abundance and plant chemistry. Oecologia. 46(1): 22-31.

Cates, R.G. 1981. Host plant predictability and the feeding patterns of monophagous, oligophagous, and polyphagous insect herbivores. Oecologia. 48(3): 319-326.

Consortium of Pacific Northwest Herbaria [CPNWH]. 2017. Seattle, WA: University of Washington Herbarium, Burke Museum of Natural History and Culture. http://www.pnwherbaria.org/index.php2017 [Accessed 2017 July 21].

Cronquist, A.; Holmgren, A.H.; Holmgren, N.H.; Reveal, J.L.; Holmgren, P.K. 1994. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. New York, NY: The New York Botanic Garden, New York. 496 p.

DeBolt, A.; Parkinson, H. 2005. Propagation protocol for production of container (plug) *Machaerathera canescens* (Pursh) A. Gray plants 2.875 inch x 5.5 inch plant band (container). Native Plant Network. U.S. Department of Agriculture, Forest Service, National Center for Reforestation, Nurseries, and Genetic Resources. http://NativePlantNetwork.org [Accessed 2017 July 21].

DeBolt, A.M.; Barrash, K. 2013. Propagation protocol for production of container (plug) *Machaerathera canescens* (Pursh) A. Gray plants 2.875 inch x 5.5 inch plant band (container). Native Plant Network. U.S. Department of Agriculture, Forest Service, National Center for Reforestation, Nurseries, and Genetic Resources. http://NativePlantNetwork.org [Accessed 2017 July 21].

Drezner, T.D.; Fall, P.L. 2002. Effects of inter-annual precipitation patterns on plant cover according to dispersal mechanisms along a riparian corridor in the Sonoran Desert, U.S.A. Journal of the Arizona-Nevada Academy of Science. 34(2): 70-80.

Ehleringer, J.R. 1988. Changes in leaf characteristics of species along elevational gradients in the Wasatch Front, Utah. American Journal of Botany. 75(5): 680-689.

Elseroad, A.C.; Rudd, N.T. 2011. Can imazapic increase native species abundance in cheatgrass (*Bromus tectorum*) invaded native plant communities? Rangeland Ecology and Management. 64(6): 641-648.

European Native Seed Conservation Network [ENSCONET]. 2009. ENSCONET seed collecting manual for wild species. Edition 1: 17 March 2009. 32 p.

Feibert, E.B.G.; Shock, C.C. 2017. 2016 weather report. In: Shock, C.C., ed. Malheur Experiment Station Annual Report 2016. OSU AES Ext/CrS157. Corvallis, OR: Oregon State University: 1-10.

Fisher, J.; Cole, K.L.; Anderson, R.S. 2009. Using packrat middens to assess grazing effects on vegetation change. Journal of Arid Environments. 73(10): 937-948.

Flowers, S. 1934. Vegetation of the Great Salt Lake region. Botanical Gazette. 95(3): 353-418.

Garrett, A.O. 1910. The smuts and rusts of Utah. Mycologia. 2(6): 265-304.

Goeden, R.D. 2000. Life history and description of immature stages of *Neaspilota appendiculata* Freidberg and Mathis (Diptera:Tephritidae) on *Machaeranthera canescens* (Pursh) A. Gray (Asteraceae) in southern California. Proceedings of the Entomological Society of Washington. 102(3): 519-532.

Goodrich, S. 1997. Multiple use management based on diversity of capabilities and values within pinyon-juniper woodlands. In: Monsen, S.B.; Stevens, R., eds. Ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem. Provo, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 164-171.

Goodrich, S. 2006. Trout Creek 1999 burn. In: Kitchen, S.G.; Pendleton, R.L.; Monaco T.A.; Vernon, J., eds. Shrublands under fire: Disturbance and recovery in a changing world. Cedar City, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 147-150.

Henderson, C.B. 1990. The influence of seed apparency, nutrient content and chemical defenses on dietary preference in *Dipodomys ordii*. Oecologia. 82(3): 333-341.

Hickman, J.C., ed. 1993. The Jepson manual: Higher plants of California. Berkeley, CA: University of California Press. 1400 p.

Hitchcock, C.L.; Cronquist, A.; Ownbey, M.; Thompson, J.W. 1955. Vascular plants of the Pacific Northwest, Part 5: Compositae. Seattle, WA: University of Washington Press. 510 p.

Horn, E.L. 2009. Forty years of vegetation changes on the Pumice Desert, Crater Lake National Park, Oregon. Northwest Science. 83(3): 200-210.

Howe, G.; St, Clair, B.; Bachelet, D. 2017. Seedlot Selection Tool. Corvallis, OR: Conservation Biology Institute. https://seedlotselectiontool.org/sst/ [Accessed 2017 July 21].

Integrated Taxonomic Information Database [ITIS]. 2017. The Integrated Taxonomic Information System on-line database, http://www.itis.gov [Accessed 2017 September].

Jensen, A.S.; Miller, G.L.; Carmichael, A. 2010. Host range and biology of *Uroleucon* (*Lambersius*) *erigeronense* (Thomas 1878), and its synonymy with *Uroleucon* (*Lambersius*) *escalantii* (Knowlton) 1928 (Hemiptera: Aphididae). Proceedings of the Entomological Society of Washington. 112(2): 239-245.

Keil, D.J.; Luckow, M.A.; Pinkava, D.J. 1988. Chromosome studies in Asteraceae from the United States, Mexico, the West Indies, and South America. American Journal of Botany. 75(5): 652-668.

Koniak, S.; Everett, R.L. 1982. Seed reserves in soils of successional stages of pinyon woodlands. The American Midland Naturalist. 108(2): 295-303.

Kramer, A.; Foxx, A. 2016. Propagation protocol for production of propagules (seeds, cuttings, poles, etc.) *Machaeranthera canescens* (Pursh) A. Gray seeds. Native Plant Network. U.S. Department of Agriculture, Forest Service, National Center for Reforestation, Nurseries, and Genetic Resources. http://NativePlantNetwork.org [Accessed 2017 July 21].

Laughlin, D.C.; Bakker, J.D.; Fulé; P.Z. 2005. Understorey plant community structure in lower montane and subalpine forests, Grand Canyon National Park, USA. Journal of Biogeography. 32(12): 2083-2102.

Laughlin, D.C.; Bakker, J.D.; Stoddard, M.T.; Daniels, M.L.; Springer, J.D.; Gildar, C.N.; Green, A.M.; Covington, W.W. 2004. Toward reference conditions: Wildfire effects on flora in an old-growth ponderosa pine forest. Forest Ecology and Management. 199(1): 137-152.

Lesica, P.; Cooper, S.V. 1999. Succession and disturbance in sandhills vegetation: Constructing models for managing biological diversity. Conservation Biology. 13(2): 293-302.

Loeser, M.R.; Sisk, T.D.; Crews, T.E. 2007. Impact of grazing intensity during drought in an Arizona grassland. Conservation Biology. 21(1): 87-97.

McCorquodale, S.M. 1993. Winter foraging behavior of elk in the shrub-steppe of Washington. The Journal of Wildlife Management. 57(4): 881-890.

Miller, D.R.; Miller, G.L. 1982. Systematic analysis of *Acanthococcus* (Homoptera: Coccoidea: Eriococcidae) in the western United States. Transactions of the American Entomological Society. 118(1): 1-106.

Moerman, D. 2003. Native American ethnobotany: A database of foods, drugs, dyes, and fibers of Native American peoples, derived from plants. Dearborn, MI: University of Michigan. http://naeb.brit.org/ [Accessed 2017 July 21].

Moore, R.P. 1985. Handbook on tetrazolium testing. Zurich, Switzerland: International Seed Testing Association. 99 p.

Morgan, D.R. 2006. 197. *Dieteria*. In: Flora of North America Editorial Committee, ed. Flora of North America North of Mexico. Volume 20 Magnoliophyta: Asteridae, part 7: Asteraceae, part 2 Asterales, part 2 (Aster order). New York, NY: Oxford University Press: 395-401.

Munz, P.A.; Keck, D.D. 1973. A California flora and supplement. Berkeley, CA: University of California Press. 1681 p.

Ogle, D.; St. John, L.; Stannard, M.; Hozworth, L. 2012. Conservation plant species for the Intermountain West. Plant Materials Technical Note 24. Boise, ID: U.S. Department of Agriculture, Natural Resources Conservation Service. 57 p.

Ogle, D.; Tilley, D.; Cane, J.; St. John, L.; Fullen, K.; Stannard, M.; Pavek, P. 2011. Plants for pollinators in the Intermountain West. Plant Materials Technical Note 2A. Boise, ID: U.S. Department of Agriculture, Natural Resources Conservation Service. 40 p.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,000). Annals of the Association of American Geographers. 77(1): 118-125.

Ott, J.; McArthur; E.D.; Roundy, B. 2003. Vegetation of chained and non-chained seedings after wildfire in Utah. Journal of Range Management. 56: 81-91.

Parker, M.A.; Root, R.B. 1981. Insect herbivores limit habitat distribution of a native composite, *Machaeranthera canescens*. Ecology. 62(5): 1390-1392.

Parkinson, H.; Zabinski, C.; Shaw, N. 2013. Impact of native grasses and cheatgrass (*Bromus tectorum*) on Great Basin forb seedling growth. Rangeland Ecology and Management. 66(2): 174-180.

Parkinson, H.A. 2008. Impacts of native grasses and cheatgrass on Great Basin forb development. Bozeman, MT: Montana State University. Thesis. 73 p.

Pavek, P.; Erhardt, B.; Heekin, T.; Old, R. 2012. Forb seedling identification guide for the Inland Northwest: Native, introduced, invasive, and noxious species. Pullman, WA: U.S. Department of Agriculture, Natural Resources Conservation Service. Pullman Plant Materials Center. 144 p.

Peinado, M.; Aguirre, J.L.; Delgadillo, J.; Martínez-Parras, J.M. 2005. A phytosociological survey of the chionophilous communities of western North America. Part I: Temperate and Mediterranean Associations. Plant Ecology. 180(2): 187-241.

Pendleton, R.L.; Pendleton, B.K. 2014. Germination patterns of a suite of semiarid grassland forbs from central New Mexico. Native Plants Journal. 15(1): 17-28.

Poreda, S.F.; Wullstein, L.H. 1994. Vegetation recovery following fire in an oakbrush vegetation mosaic. The Great Basin Naturalist. 54(4): 380-383.

Prasser, N.P.; Hild, A.L. 2016. Competitive interactions between an exotic annual, *Halogeton glomeratus*, and 10 North American native species. Native Plants Journal. 17(3): 244-255.

Pyle, W.H. 1993. Response of brood-rearing habitat of sage grouse to prescribed burning in Oregon. Corvallis, OR: Oregon State University. Thesis. 56 p.

Royal Botanic Gardens, Kew [RBG Kew]. 2018. Seed Information Database (SID). Version 7.1. http://data.kew.org/sid/ [Accessed 2017 July 21].

SEINet–Regional Networks of North American Herbaria Steering Committee [SEINet]. 2017. SEINet Regional Networks of North American Herbaria. Symbiota.org/docs/seinet [Accessed 2017 July 21].

Shaw, N.; Pellant, M.; Fisk, M.; Denney, E. 2012. A collaborative program to provide native plant materials for the Great Basin. Rangelands. 34(4): 11-16.

Shock, C.C.; Feibert, E.B.G.; Rivera, A.; Saunders, L.D.; Kilkenny, F.F.; Shaw, N.L. 2017a. Direct surface seeding systems for the establishment of native plants in 2016. In: Shock, C.C., ed. Malheur Experiment Station Annual Report 2016. OSU AES Ext/CrS157. Corvallis, OR: Oregon State University: 123-130.

Shock, C.C.; Feibert, E.B.G.; Rivera, A.; Saunders, L.D.; Kilkenny, F.F.; Shaw, N.L. 2017b. Irrigation requirements for seed production of several native wildflower species planted in the fall of 2012. In: Shock, C.C., ed. Malheur Experiment Station Annual Report 2016. OSU AES Ext/CrS157. Corvallis, OR: Oregon State University: 131-140.

Shock, C.C.; Feibert, E.B.G.; Saunders, L.D.; Shaw, N. 2014a. Direct surface seeding systems for successful establishment of native wildflowers. In: Shock, C.C., ed. Malheur Experiment Station Annual Report 2013. OSU AES Ext/CrS149. Corvallis, OR: Oregon State University: 159-165.

Shock, C.C.; Feibert, E.B.G.; Saunders, L.D.; Shaw, N. 2014b. Tolerance of native wildflower seedlings to preemergence and postemergence herbicides. In: Shock, C.C., ed. Malheur Experiment Station Annual Report 2013. OSU AES Ext/CrS149. Corvallis, OR: Oregon State University: 98-206.

Sieg, C.H.; Uresk, D.W.; Hansen, R.M. 1983. Plant-soil relationships on bentonite mine spoils and sagebrush-grassland in the northern High Plains. Journal of Range Management. 36(3): 289-294.

Simonson, D.B.; Tilley, D.J. 2016. A low-cost modification to a Flail-Vac Harvester for collecting lightweight, wind-dispersed seed. Native Plants Journal. 17(2): 103-108.

Skinner, M.P. 1928. The elk situation. Journal of Mammalogy. 9(4): 309-317.

Stephens, G.J.; Johnston, D.B.; Jonas, J.L.; Paschke, M.W. 2016. Understory responses to mechanical treatment of pinyon-juniper in northwestern Colorado. Rangeland Ecology and Management. 69(5): 351-359.

Stevens, R.D.; Tello, J.S. 2009. Micro- and macrohabitat associations in Mojave Desert rodent communities. Journal of Mammalogy. 90(2): 388-403.

Strother, J.L. 1972. Chromosome studies in western North American Compositae. American Journal of Botany. 59(3): 242-247.

Thompson, R.S.; Anderson, K.H. 2000. Biomes of western North America at 18,000, 6000 and 0 14C yr BP reconstructed from pollen and packrat midden data. Journal of Biogeography. 27(3): 555-584.

Tilley, D. 2011. Propagation protocol for production of propagules (seeds, cuttings, poles, etc.) *Machaeranthera canescens* (Pursh) A. Gray seeds. Native Plant Network. U.S. Department of Agriculture, Forest Service, National Center for Reforestation, Nurseries, and Genetic Resources. http://NativePlantNetwork.org [Accessed 2017 July 21].

Tilley, D. 2014. Release brochure for Amethyst Germplasm hoary tansyaster (*Machaeranthera canescens*). Aberdeen, ID: U.S. Department of Agriculture, Natural Resources Conservation Service, Aberdeen Plant Materials Center. 2 p.

Tilley, D.J. 2015a. Notice of release of Amethyst Germplasm hoary tansyaster: selected class of natural germplasm. Native Plants Journal. 16(1): 54-60.

Tilley, D.J. 2015b. Seed production and field establishment of hoary tansyaster (*Machaeranthera canescens*). Native Plants Journal. 16(1): 61-66.

Tilley, D.; Bair, C. 2011. The Jet Harvester: A shop tool for harvesting forb and shrub seeds. Native Plants Journal. 12(2): 123-127.

Tilley, D.; Ogle, D.; St. John, L. 2014. Plant guide for hoary tansyaster (*Machaeranthera canescens*). Aberdeen, ID: U.S. Department of Agriculture, Natural Resources Conservation Service, Idaho Plant Materials Center. 4 p.

Tolstead, W.L. 1942. Vegetation of the northern part of Cherry County, Nebraska. Ecological Monographs. 12(3): 255-292.

USDA Forest Service, Bend Seed Extractory [USFS BSE]. 2017. Nursery Management Information System Version 4.1.11. Local Source Report 34-Source Received. Bend, OR: U.S. Department of Agriculture, Forest Service, Bend Seed Extractory.

USDA Forest Service, Great Basin Native Plant Project [USFS GBNPP]. 2017. Seed weight table calculations made in-house. Report on file. Boise, ID: U.S. Department of Agriculture, Forest Service, Boise Aquatic Sciences Laboratory. Available: https://www.fs.fed.us/rm/boise/research/shrub/Links/Seedweights.pdf

USDA Forest Service, Western Wildland Environmental Threat Assessment Center [USFS WWETAC]. 2017. TRM Seed Zone Applications. Prineville, OR: U.S. Department of Agriculture, Forest Service, Western Wildland Environmental Threat Assessment Center. https://www.fs.fed.us/wwetac/threat-map/TRMSeedZoneMapper.php [Accessed 2017 July 21].

USDA Natural Resources Conservation Service [USDA NRCS]. 2017. The PLANTS Database. Greensboro, NC: U.S. Department of Agriculture, Natural Resources Conservation Service, National Plant Data Team. https://plants.usda.gov/java [Accessed 2017 July 21].

USDI Bureau of Land Management, Seeds of Success [USDI BLM SOS]. 2016. Bureau of Land Management technical protocol for the collection, study, and conservation of seeds from native plant species for Seeds of Success. Washington, DC: USDI Bureau of Land Management. 37 p.

USDI Bureau of Land Management, Seeds of Success [USDI BLM SOS]. 2017. Seeds of Success collection data. Washington, DC: U.S. Department of the Interior, Bureau of Land Management, Plant Conservation Program.

USDI Environmental Protection Agency [USDI EPA]. 2018. Ecoregions. Washington, DC: U.S. Environmental Protection Agency. https://www.epa.gov/eco-research/ecoregions [Accessed 23 January 2018].

USDI Geological Survey [USGS]. 2017. Biodiversity Information Serving Our Nation (BISON). U.S. Geological Survey. https://bison.usgs.gov/#home [Accessed 2017 July 21].

Utah Crop Improvement Association [UCIA]. 2015. How to be a seed connoisseur. Logan, UT: UCIA, Utah State University and Utah State Seed Laboratory, Utah Department of Agriculture and Food. 16 p.

Wahlberg, N. 2001. The phylogenetics and biochemistry of host-plant specialization in Melitaeine butterflies (Lepidoptera: Nymphalidae). Evolution. 55(3): 522-537.

Welsh, S.L.; Atwood, N.D.; Goodrich, S.; Higgins, L.C., eds. 1987. A Utah flora. The Great Basin Naturalist Memoir 9. Provo, UT: Brigham Young University. 894 p.

Wolters, G.L. 1994. Elk effects on Bandelier National Monument meadows and grasslands. In: Allen, C.D., ed. Fire effects in southwestern forests: Proceedings of the Second La Mesa Fire Symposium; 1994 March 29-31; Los Alamos, NM. Gen. Tech. Rep. RM-GTR-286. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station: 196-205.

Yake, S.; Brotherson, J.D. 1979. Differentiation of serviceberry habitats in the Wasatch Mountains of Utah. Journal of Range Management. 32(5): 379-383.

Young, S.A.; Schrumpf, B.; Amberson, E. 2003. The Association of Official Seed Certifying Agencies (AOSCA) native plant connection. Moline, IL: AOSCA. 9 p.

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.kew.org/sites/default/files/ENSCONET_Collecting_protocol_English.pdf

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

SEEDLOT SELECTION TOOL
https://seedlotselectiontool.org/sst/

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

COLLABORATORS