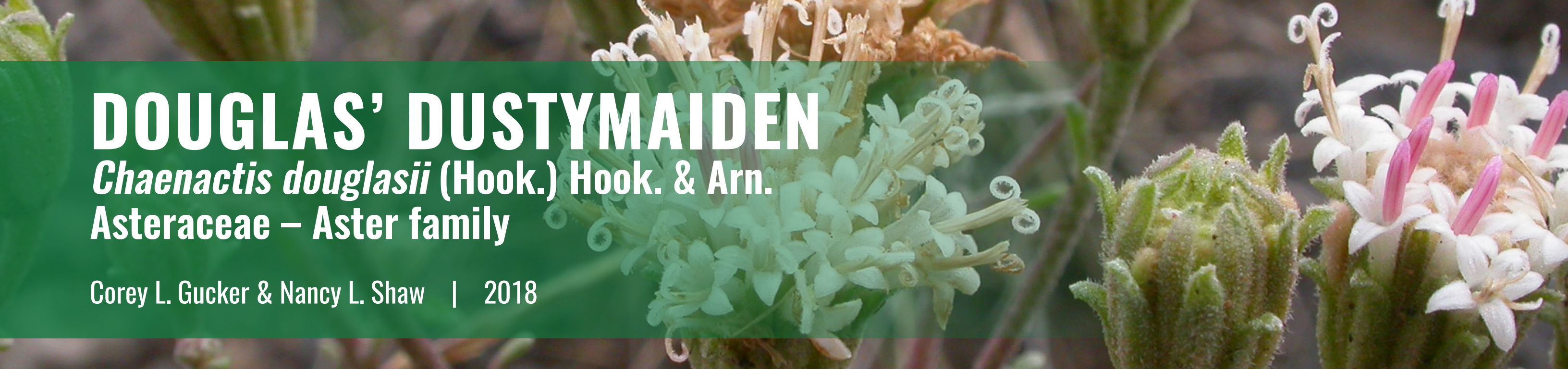

DOUGLAS' DUSTYMAIDEN

Chaenactis douglasii (Hook.) Hook. & Arn.

Asteraceae – Aster family

Corey L. Gucker & Nancy L. Shaw | 2018

NOMENCLATURE

Chaenactis douglasii (Hook.) Hook. & Arn., hereafter referred to as Douglas' dustymaiden, belongs to the Heliantheae tribe of the Asteraceae family (Hickman 1993; Pavek et al. 2012).

NRCS Plant Code. CHDO (USDA NRCS 2017).

Subtaxa. The Flora of North America (Morefield 2006) recognizes two varieties of Douglas' dustymaiden: *Chaenactis douglasii* var. *alpina* (A. Gray) and var. *douglasii*. The Intermountain Flora (Cronquist 1994) describes five varieties, but these are primarily ecogeographic variants and distinguishing characteristics are ill-defined.

Synonyms (Morefield 2006).

Chaenactis douglasii: *Hymenopappus douglasii* Hook., *Macrocarphus douglasii* (Hook.) Nutt.

C. d.* var. *douglasii: *Chaenactis angustifolia* Greene, *C. douglassii* var. *achilleifolia* (Hook. & Arnott) A. Gray, *C. d.* var. *montana* M.E. Jones, *C. d.* var. *rubricaulis* (Ryd.) Ferris, *C. pedicularia* Greene, *C. pumila* Greene, *C. ramosa* Stockwell.

C. d.* var. *alpina: *C. alpina* (A. Gray) M.E. Jones, *C. alpina* var. *leucopsis* (Greene) Stockwell, *C. alpina* var. *rubella* (Greene) Stockwell, *C. panamintensis* Stockwell (Morefield 2006).

Common Names. Douglas' dustymaiden, Douglas pincushion, dusty-maiden, duskymaiden, hoary pincushion, false yarrow (Anderson and Holmgren 1976; Lambert 2005; Morefield 2006; Tilley et al. 2010; USDA NRCS 2017). Alpine dustymaiden and pincushion are common names for *C. d.* var. *alpina* (Morefield 2006).

Chromosome Number. Douglas' dustymaiden chromosome numbers are highly variable: 2n = 6, 12, 13, 14, 15, 16, 17, 18, 24 or 36 (Mooring 1980; Cronquist 1994), but chromosome numbers of 2n = 12, 24, and 36 predominate (Morefield 2006). Plants with different ploidy levels can co-occur without any obvious distinction (Cronquist 1994). When 512 plants from 200 populations were analyzed, tetraploids were most frequent (47.2%), followed by diploids (35.8%), and hexaploids (7.4%). For each population, plants were almost exclusively diploid, tetraploid, or hexaploid (Mooring 1980). Tetraploids and hexaploids are typically winter annuals or biennials found in the Columbia Plateau and Great Basin provinces (Mooring 1992). Diploids are perennials and found in certain deep river canyons or gorges of the Intermountain Region. In this region, ploidy level is associated with geologic substrate age rather than climate, elevation, vegetation, or soil type. Diploids predominate on geologically older substrates of mesic montane and riparian sites. Polyploids predominate on younger volcanic and alluvial substrates of more arid environments (Mooring 1992).

Hybridization. Varieties *alpina* and *douglasii* intergrade where their distributions overlap (Hickman 1993).

DISTRIBUTION

Douglas' dustymaiden is native to North America and is widely distributed throughout the West, occurring from southern Alberta, British Columbia, and Saskatchewan to California, Nevada, northern Arizona, northern New Mexico, Colorado, and the Dakotas (See map in Seed Sourcing section; Cronquist 1994; Morefield 2006; LBJWC 2017). Variety *douglasii* is most widespread, occurring throughout the range reported for the species. Variety *alpina* occurs only in Montana, Idaho, Oregon, California, Utah, Colorado, and Wyoming (Morefield 2006).

Habitat and Plant Associations. Douglas' dustymaiden commonly occupies dry, open sites with sandy or gravelly soil (Fig. 1; Cronquist 1994; Lambert 2005) where annual precipitation averages 10 inches (250 mm) or more (Ogle et al. 2012). It occurs in a variety of plant communities from lowland valleys to timberline and above, including grasslands, shadscale (*Atriplex* *confertifolia*), desert saltbush (*A. polycarpa*), sagebrush (*Artemisia* spp.), pinyon and juniper (*Pinus-Juniperus* spp.), and conifer-dominated plant communities (Hatton and West 1987; Welsh et al. 1987; Pavek et al. 2012).

Douglas' dustymaiden is often an early colonizer of disturbed and harsh sites. It grows in cinder garden communities at Craters of the Moon National Monument in central Idaho where the parent material is young and growing conditions are extremely harsh (Day and Wright 1985).

Elevation. Douglas' dustymaiden's distribution ranges from near sea level to about 13,100 feet (4,000 m) (Mooring 1992; Morefield 2006). Variety *douglasii* occupies a broader elevation range and occurs at lower elevations than variety *alpina*, which is generally found between 8,800 and 13,100 feet (2,700-4,000 m) (Morefield 2006). In California, variety *douglasii* occurs at elevations between 3,200 and 11,500 feet (1,000-3,500 m), and variety *alpina* occurs at elevations of 9,800 to 11,500 feet (3,000-3,500 m) (Hickman 1993). In Utah, the species is found at elevations of 4,400 to 10,000 feet (1,340-3,050 m) (Welsh et al. 1987).

Soils. Gravelly clays, silts, or sands were common soils at Douglas' dustymaiden seed collection sites throughout the West (USDI BLM SOS 2017). In Yellowstone National Park it is often found on dry, coarse, exposed soils, especially obsidian sands (Link 1993). Reports suggest that Douglas' dustymaiden has low $CaCO_3$ tolerance and uses little water (LBJWC 2017), although it has grown well in common gardens with alkaline calcareous soils (J. Cane, USDA ARS, personal communication, August 2017).

Douglas' dustymaiden was common on silver mine dumps near Park City, Utah, visited about 45 years after the end of surface mining operations (Alvarez et al. 1974). It occurred on sites where average mid-July soil temperature averaged 62.2° F (16.8 °C) at 15 inches (38 cm) deep, phosphorous levels averaged 784 µg/300 cc of soil, and calcium levels averaged 376 mg/300 cc of soil. Density of the species increased significantly (P = 0.01) with increasing soil phosphorus (Alvarez et al. 1974). On sulfide-bearing waste areas left from copper pit mining operations at the Bingham Canyon Mine in Utah, Douglas' dustymaiden occurred on both saline (0.06-0.5 dS/m) and low to neutral pH (4.2-7.9) soils (Borden and Black 2005).

Figure 1. Douglas' dustymaiden in natural rangeland habitat. Photo: USFS.

DESCRIPTION

Douglas' dustymaiden may grow as a biennial or short-lived perennial and in rare cases as an annual (Hickman 1993; Cronquist 1994). Variety *douglasii* is typically a short-lived perennial (Cronquist 1994).

Plants are taprooted, typically without a caudex (Welsh et al. 1987), and range from 6 to 36 inches (7-91 cm) tall, but are often less than 24 inches (61 cm) tall (Lambert 2005; Ogle et al. 2011; Pavek et al. 2012). Variety *douglasii* is generally taller (ranging from 3-24 inches [8-61 cm]) and grows more erect than variety *alpina* (typically 2-4 inches [5-10 cm] tall), which has a caespitose to matted growth habit (Cronquist 1994; Morefield 2006). Stems of Douglas' dustymaiden are solitary to many (25 or more) and erect to spreading with sparse to dense cobwebby hairs that tend to fade upwards (Cronquist 1994).

Plants have alternate, finely dissected, gray-green leaves. Leaves are strictly basal for variety *alpina*, but basal and stem leaves are common for variety *douglasii* (Welsh et al. 1987). Leaves are woolly with small white hairs and are progressively smaller and less dissected up the stem. Leaves range from 0.8 to 5 inches (2-12 cm) long, and the largest leaves are pinnately lobed (Anderson and Holmgren 1976; Welsh et al. 1987; Hickman 1993; Cronquist 1994; Morefield 2006; Pavek et al. 2012).

Individual flowers are tiny, tubular, pinkish to white and number 10 to 50 in a leafy flat-topped inflorescence (a cyme) less than 1 inch

(2.5 cm) wide (Fig. 2; Anderson and Holmgren 1976; Hickman 1993; Pavek et al. 2012). Variety *douglasii* produces 1 to 25 or more flower heads per stem, but variety *alpina* produces only 1 or 2 (Welsh et al. 1987; Cronquist 1994; Morefield 2006). Individual flowers are radially symmetrical disk flowers near the center of the head with ray flowers around the edge, although all flowers in one head may be disk or ray flowers (LBJWC 2017). Involucres measure 8 to 12 mm high with 13 to 25 bracts (Welsh et al. 1987; Cronquist 1994; Morefield 2006). Fruits are stiffly hairy, club-shaped achenes (cypselas or false achenes) measuring 5 to 8 mm long (Hickman 1993) with an apical pappus and are readily wind dispersed at maturity (Fig. 3). Mature fruit color ranges from gold to black (Tilley et al. 2010).

Below-Ground Relationships. Douglas' dustymaiden can form mychrorrizal associations. Mychorrizal infections were found on plants growing on disturbed and undisturbed sites in a mid-elevation sagebrush community in western Colorado (Reeves et al. 1979).

Reproduction. Douglas' dustymaiden reproduces entirely from seed. Vegetative reproduction or regeneration do not occur following top-kill.

Flowering is indeterminate and occurs in the first year (Shock et al. 2014c). Flowers can be found anytime from April to September in the Intermountain West (Anderson and Holmgren 1976; Cronquist 1994; Parkinson and DeBolt 2005). Flowers in June and July are most typical (LBJWC 2017).

Figure 2. Douglas' dustymaiden flowers. Photo: J. Cane, USDA ARS.

Figure 3. Douglas' dustymaiden achene with pappus. Photo: J. Cane, USDA ARS.

Breeding system. Although Douglas' dustymaiden can produce seed through selfing, cross pollination by insects results in the greatest seed production (Cane et al. 2012).

Pollination. In experiments conducted at the U.S. Department of Agriculture's Pollinating Insect Research Unit in Logan, Utah, cross-pollinated flowers produced four times more filled achenes than self-pollinated flowers ($P < 0.05$) (Cane et al. 2012). Only bees were found visiting Douglas' dustymaiden flowers in wild and cultivated stands. Visitors were sparse, averaging 1 bee/plant, but the fauna from the limited collections was rich with 19 species represented. Bee collections suggested that nonsocial univoltine native bees were the primary pollinators. Most of the bees were floral generalists (Cane et al. 2012). The most practical, manageable bees to use to pollinate crops are the cavity-nesting Asteraceae specialist (*Osmia californica*) and the European honey bee (*Apis mellifera*) (Cane 2008; Cane et al. 2012).

ECOLOGY

Douglas' dustymaiden is a colonizer of early seral (Day and Wright 1985) and disturbed sites (Huffman et al. 2017), but it also occurs in late-seral communities (Koniak 1985). It may also play a role in advancing successional development. In Lassen Volcanic National Park, Douglas' dustymaiden grew as a mat and produced dense foliage that captured fine-moving debris and served to build up soil on the talus surface (Pérez 2012).

Seed and Seedling Ecology. Several seed and plant characteristics suggest that Douglas' dustymaiden opportunistically colonizes disturbed sites and openings in existing communities. These characteristics include reproduction during the first growth season; production of small, easily wind-dispersed, pappus-bearing fruits; and high establishment percentages of fall-planted seed (Parkinson and DeBolt 2005; Tilley 2011).

Disturbance Ecology. Several studies suggest that Douglas' dustymaiden is disturbance tolerant. Plant frequency was nearly the same at treated and untreated sites following lop and scatter woodland thinning in northwestern Arizona (Huffman et al. 2017). The species occurred in each of the first three post-treatment years following anchor chaining in pinyon-juniper near Ephraim, Utah, but their density and frequency decreased as time since disturbance increased (Davis and Harper 1990).

Douglas' dustymaiden is sometimes common in early post-fire vegetation. In studies following fall and spring prescribed fires in a mountain big sagebrush (*A. tridentata* subsp. *vaseyana*)/bunchgrass habitat at Lava Beds National Monument in northern California, seedlings germinated from soil collected immediately following and 1 year after a fall prescribed burn (Ellsworth and Kauffman 2013; Ellsworth, personal communication, Oregon State University, May 2017). Plants were present the first year following a fall prescribed fire in Wyoming big sagebrush (*A. t.* subsp. *wyomingensis*) in southeastern Oregon (Wrobleski 1999) and on 1-, 2-, and 3-yr old burned sites in sagebrush-pinyon-juniper vegetation in west-central Utah (Ott et al. 2003). When pinyon-juniper sites burned between 1 and 60 years earlier were evaluated in California and Nevada, Douglas' dustymaiden frequency was not significantly different in any of the seral stages (Koniak 1985).

Wildlife and Livestock Use. Livestock and wildlife use of Douglas' dustymaiden has not been documented.

Ethnobotany. Douglas' dustymaiden was important to Indians throughout western North America. The Gosiute of Utah, Shoshoni of Nevada, and Paiutes of Oregon used the plant to treat body soreness and aches (Moerman 2003). The Okanagon of British Columbia used a plant infusion to treat chapped hands, pimples, boils, tumors, swellings, and insect and snake bites. Tribes in Nevada and California used a Douglas' dustymaiden poultice to treat swellings and sprains. The Salishan people of northeastern Washington ingested a decoction of roots to purge or avoid illness (Moerman 2003). The Thompson Indians of British Columbia drank a strong tea to alleviate swelling, skin problems, and insect and snake bites. A milder tea was used to treat stomach problems (Shemluck 1982).

REVEGETATION USE

Seed production in the first growth season (Tilley 2011; Shock et al. 2017a), attractiveness to pollinators (Cane et al. 2012), and tolerance of disturbances and early seral conditions (Day and Wright 1985; Wrobleski 1999; Ott et al. 2003; Pérez 2012; Huffman et al. 2017) make Douglas' dustymaiden a good addition to restoration or revegetation seeding mixes. Its presence in early post-fire communities (Wrobleski 1999; Ott et al. 2003) also makes it desirable for revegetation of rangelands that have experienced increased fire frequencies in recent decades and require revegetation and management to improve resiliency (IRFMS Team 2016). Reliable early flowering suggests Douglas' dustymaiden may be useful in post-fire seed mixes to provide food for bees in the first post-fire year (Cane 2012).

Douglas' dustymaiden has colonized abandoned and reclaimed mine sites and has been used successfully to revegetate disturbed sites. It naturally colonized the ridgetops of a recontoured surface mine site in sagebrush steppe-salt desert shrub communities near Kemmerer, Wyoming. The last mining at this location occurred in the late 1970s, and rehabilitation began in 1982. Douglas' dustymaiden was not seeded, but occurred on the site by 1985 (Hatton and West 1987). Douglas' dustymaiden was one of the most common volunteer species on silver mine dumps near Park City, Utah, that were monitored about 45 years after surface mining operations ended (Alvarez et al. 1974). Similarly, it was one of the most successful volunteers on sulfide-bearing waste sites created during copper pit mining operations in Bingham Canyon, Utah (Borden and Black 2005). In Yellowstone National Park, Douglas' dustymaiden is hand collected for use in seeding and container stock revegetation of sites disturbed during road construction (Majerus 1991).

Seeds of Douglas' dusty maiden are not separated from the achene for use in restoration. Consequently, the term 'seed' as used by collectors, growers, and users refers to the fruits and that convention is applied in the following sections.

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 Douglas' dustymaiden, 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 4, 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.

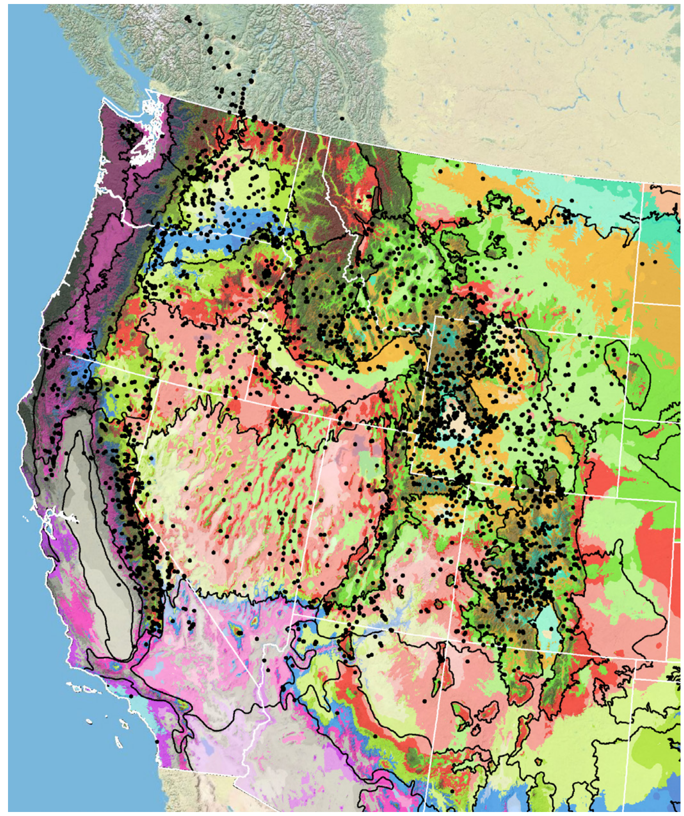

Figure 4. Distribution of Douglas' dustymaiden (black circles) based on geo-referenced herbarium specimens and observational data from 1881-2016 (CPNWH 2017; SEINet 2017; USGS 2017). Generalized provisional seed zones (colored regions; Bower et al. 2014) are overlain by Omernik Level iii Ecoregions (white 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. As of early 2018, there were no Douglas' dusty maiden germplasm releases.

Wildland Seed Collection. Douglas' dustymaiden seeds are ripe when seed heads have opened and formed a fluffy ball; seed heads shatter within about a week of ripening (S. Pinkus 2003 cited in Camp and Sanderson 2007). Seeds easily separate from the seed head when ripe (DeBolt and Barrash 2013; Tilley 2013). Once seed collection sites are selected, the wildland certification process needs to be started by completing the necessary paperwork.

Wildland seed certification. Wildland seed collected for direct sale or for establishment of agricultural seed production fields should be Source Identified through the certification process 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.

Collection timing. Timing of flowering and seed set is influenced by elevation, aspect, and seasonal weather patterns. Seed maturation generally occurs 4 to 5 weeks after flowering (Parkinson and DeBolt 2005) and varies widely among plants within a population and within individual plants (Fig. 5; B. Youtie, Eastern Oregon Stewardship Services [EOSS], personal communication, July 2017). Northern populations generally flower later than those from more southern latitudes. In the same year (2010), nearly half of plants in central and northern Utah were blooming on June 14 but only 2% of plants in southern and central Idaho were flowing on the same date (Tilley 2011). Similarly, at the USDA NRCS Aberdeen Plant Materials Center (IDPMC) in southeastern Idaho, flowering in a common garden began in early summer and lasted for several weeks (Tilley 2010). Plants from more northern collection sites flowered later than plants from more southern collection sites.

Estimates of seed maturation and fill to determine adequacy of sites for collection and collection timing can be made using a cut test or X-ray test. The 'pop test' described by Tilley et al. (2011) may be a useful predictor of seed fill (See Seed Testing section).

Figure 5. Uneven seed ripening is typical for Douglas' dustymaiden. Photo: M. Fisk, USGS.

Based on 2 years of observations during a time when moisture and temperatures were near the 30-year average in ponderosa pine (*Pinus ponderosa*)/big sagebrush communities near Penticton, British Columbia, Douglas' dustymaiden initiated growth in March and April, began flowering in April and May, reached full flower in May, produced and shattered seed in June, and was cured in July (Pitt and Wikeem 1990). Wildland seed collections made by Seeds of Success field crews ranged from an earliest date of June 9 in 2009 at 3,432 feet (1,046 m) in Owyhee County, Idaho to a latest date of October 7 in 2010 at 6,142 feet (1,903 m) in Jackson County, Oregon (USDI BLM SOS 2017). The most common harvest dates were late June to mid-late July. In Douglas County, Washington, seed collections were made at 1,830 feet (558 m) in late June (Camp and Sanderson 2007).

Collection methods. Wildland seed is collected by hand when the dandelion-like seed heads are white and spherical (Tilley 2010; B. Youtie, EOSS, personal communication, July 2017). The collection window is about 10 days. Harvest method differs with the stage of ripening as this varies widely within individual plants and populations. When collecting seed at the early to mid-ripening stage when not all seed heads have matured, seeds can be hand plucked from the mature flower heads. This process is slow, it generally precludes collection of large quantities of seed, and it will include only early ripening seed. Later in the ripening season when most seeds have matured and have begun to disperse, seeds can be stripped, shaken, or knocked into a container (Tilley 2010; B. Youtie, EOSS, personal communication, July 2017). If seed can only be collected on one date, collection at the time of mid-ripening would enable collection of more early, mid- and late-ripening seed, thus providing greater genetic diversity and yield. Seeds can also be harvested by clipping entire seed heads (Link 1993). However, considerably less inert material is collected when using the plucking and stripping/shaking methods, thus simplifying the cleaning process (St. George 2003 cited in Camp and Sanderson 2007; Tilley 2010). Pappus removal may still be required, depending upon intended seed use. Gloves should be worn when collecting as the seed heads are sticky (A. Malcomb, USFS RMRS, personal communication, June 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; 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; ESCONET 2018).

Collection rates. In Yellowstone National Park, rates for hand-collected seed averaged 0.33 lbs/hr (148 g/hr) (Majerus 1991).

Post-collection management. When collections are made in fall, Douglas' dustymaiden seed heads and stems can have a high moisture content. Properly and thoroughly drying this seed is critical for successful storage and cleaning. Harvested seed should be spread on racks in a protected area and thoroughly air dried in the field or following transport to the cleaning facility. Little drying will normally be required if fruits are collected in summer. Drying importance increases if inert material is included in the seed collection and if collection occurs during high humidity periods. Seed will dry in open collection sacks after 2 to 4 weeks (St. George 2003 cited in Camp and Sanderson 2007; Tilley 2010). Collected material can be transported in clean breathable bags or boxes and should be protected from overheating during transport. Insect infestations should be controlled by freezing collections for 48 hours (Parkinson and DeBolt 2005) or use of appropriate chemicals.

Seed Cleaning. Seeds collected by plucking them from seed heads or by knocking or shaking the plants will require less cleaning than seeds collected by clipping the seed heads. Selection of cleaning procedures also depends upon whether the pappus must be removed from the seed. Seeds with the pappus attached can be seeded through grain and no-till drills if they are mixed with a diluent such as rice hulls (Tilley 2010).

The Bridger Montana Plant Materials Center recommended that seed lots be threshed with a hammermill, then cleaned with an office model or larger model air screen cleaner. They noted that seed was difficult to clean to a flowable condition and that the seed lot remained bulky after cleaning (Link 1993).

The IDPMC found that seed can be removed from stems and seed heads using a hammermill with a 0.2-inch (0.6 cm) screen. The pappus can be removed using a debearder or brush machine. Seed is then fine cleaned with a multi-deck air screen cleaner followed by an indent cleaner (Tilley 2013).

The USFS Bend Seed Extractory, provided the following seed cleaning instructions based on one small seed lot (Barner 2009):

1. Process seed with a Westrup Model LA-H laboratory brush machine using a #40 mantel and speed of 3 to remove seed from the seed heads.

2. Finish seeds by air-screening to remove remaining nonviable seed and inert material using an office Clipper with top screen #12 triangle (2nd run, 3 x 5/16 cross slot) and bottom screen blank at medium speed with low to medium air.

Seed Storage. Cool dry storage is recommended for cleaned Douglas' dustymaiden seed. Dried seeds can be stored at 33 to 38 °F (1-4 °C) (Barner 2009) and can retain good viability for up to 5 years (Link 1993).

Seed Testing. There is no Association of Official Seed Analysts (AOSA) rule for testing germination or protocol for examining viability of Douglas' dustymaiden seed (AOSA 2016). Purity is evaluated using standard AOSA procedures.

Quick estimates of seed fill can be made using the 'pop test' described by Tilley et al. (2011), which uses a hot plate to heat seeds until the moisture contained in the seed is converted to gas and breaks the seed coat producing a pop. However, germination/viability tests and moisture content evaluations were not done on seeds that popped.

Germination. Cool moist stratification is required to break seed dormancy. Warm temperatures following stratification encourage germination. In laboratory tests, germination (27-30.5%) was greater after 60 or 90 days of cool moist stratification at 36 °F (2 °C) compared to 0 or 30 days (0.5-14%) (Tilley 2013). In other laboratory tests, cool afterripening resulted in earlier and greater total germination when warm temperatures followed cool moist seed stratification (Leger and Barga 2015). Douglas' dustymaiden seed for these tests came from three populations collected near Reno and Carson City, Nevada and exhibited population differences related to post-stratification incubation temperatures. For nursery stock production, the USFS Lucky Peak Nursery (LPN) uses a 24-hour cold water soak followed by a 30-day cold moist stratification to release dormancy (P. Winn, USFS LPN, personal communication, July 2017).

Fall, winter, or early spring field seeding of Douglas' dustymaiden has provided natural seed stratification and successful stand establishment. In a breeding biology study, stands established from seeds planted under snow in March 2009 (Cane et al. 2012). Cultivated Douglas' dustymaiden stands were established from fall seeding at the IDPMC (Tilley 2011).

Wildland Seed Yield and Quality. Post-cleaning seed yield and quality of seed lots collected in the Intermountain region are provided in Table 1 (USFS BSE 2017). The results indicate that Douglas' dustymaiden seed can generally be cleaned to high levels of purity and seed fill and that viability of fresh seed is generally high. Barner (2009) also reported high purity (97%), seed fill (92%), and viability (79%) for cleaned seed. Shock et al. (2014a) reported viability of harvested seed from cultivated research plots was typically about 70%.

Douglas' dustymaiden seeds are small, averaging more than 350,000 seeds/lb (770,000/kg) (Table 1). Other sources report similar values, which ranged from 300,000 to 450,000 seeds/lb (660,000-990,000/kg) (Majerus 1991; Lambert 2005; Parkinson and DeBolt 2005; Tilley 2013; Shock et al. 2014a; RGB Kew 2017).

Table 1. Seed yield and quality of Douglas' dustymaiden 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)	0.73	0.04-9	39
Clean weight (lbs)	0.08	0.002-0.48	39
Clean-out ratio	0.2	0.015-0.5	39
Purity (%)	95	79-99	38
Fill (%)[1]	92	70-99	39
Viability (%)[2]	91	79-98	31
Seeds/lb	381,483	229,000-620,000	39
Pure live seeds/lb	336,716	206,581-530,100	38

[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

In cultivated stands plants flower in their first year (Fig. 6; Cane et al. 2012; Shock et al. 2014c). At Oregon State University's Malheur Experiment Station (OSU MES), flowering began on May 23 and peaked on June 30. Seed was harvested on July 2 and again on July 22 in one harvest year (Shock et al. 2014c).

Seed production beyond the first year is variable. At the IDPMC, seed yield ratings for 15 accessions of first-year plants ranged from 3 to 5 on a scale of 1 to 9, where 1 indicated highest seed yields. While all plants regrew the following year, just 4 of 15 accessions produced flowers on more than 30% of the plants by mid-June (Tilley 2011). At OSU MES, Douglas' dustymaiden seed production was 5 to 8 times greater for first-year than for second-year plants (Shock et al. 2017b).

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 6. Douglas' dustymaiden seed production plot at the USFS Lucky Peak Nursey. Photo: J. Cane, USDA ARS.

Site Preparation. Douglas' dustymaiden should be planted in a weed-free seed bed. Weedy grasses were reportedly controlled with a selective herbicide (Tilley 2010), but neither the herbicide nor its active ingredient were named.

Seed Pretreatments. In experimental establishment studies conducted at OSU MES, Douglas' dustymaiden seed was pre-treated with a liquid mix of sulphur fungicides prior to planting (Shock et al. 2014a). Treated seeds typically produced better first year stands than untreated seeds (Shock et al. 2017a).

Weed Management. In studies of cultivated stands at OSU MES, none of the preemergence herbicides tested significantly reduced emergence of Douglas' dustymaiden when compared to untreated controls. However, this was when the effects of all herbicide treatments were averaged. Notably, percent emergence was 27.5% for untreated stands, 47% for stands treated with an S-ethyl dipropylthiocarbamate and 6.8% for stands treated with dimethenamid-P. For post-emergence herbicides, stand loss was 4.8% in untreated stands and 5.8% for treated stands (Shock et al. 2014b).

Seeding. General guidelines for seeding Douglas' dustymaiden were developed by the IDPMC with seeding in late fall recommended to allow natural stratification. Seeds are planted 9 to 18 inches (23-45 cm) apart into slightly roughened soil. Soil is then lightly packed around the deposited seeds. A target rate of 12 to 25 seeds/hole is recommended. A custom made "penstemon popper" seeder is used to manually plant Douglas' dustymaiden. It consists of a 3-inch (7.6 cm) diameter tube with a spur and a foot at the bottom. The spur roughens the soil before seeds are dropped down the tube. The foot then lightly compacts the soil around the seed (Tilley 2010).

At OSU MES, stands were established by seeding Douglas' dustymaiden in 30-inch (76 cm) rows using a custom small-plot grain drill with disk openers. Seed was planted on the soil surface at a rate of 20 to 30 seeds/foot (66-98/m) of row. Sawdust was applied in a narrow band over the seed at a rate of 0.26 oz/foot (24 g/m) of row. However, stand establishment was not successful after every seeding and to develop a good stand, hand planting of Douglas' dustymaiden in the thin sections was necessary (Shock et al. 2017b).

Establishment and Growth. The length of the establishment phase was as short as 1 month in seed production fields at the IDPMC (Tilley 2010). Establishment ranged from 66 to 98% for 15 accessions of Douglas' dustymaiden seed collected across the Intermountain West (UT, ID, and OR) when seed was fall planted at the IDPMC. The accession with the poorest establishment produced the tallest plants, the most flowers, and had a high seed yield rating. Plots were established in Declo silt loam soils with a pH of 8.4, and Douglas' dustymaiden was seeded into weed barrier fabric. There were 12 to 25 seeds/hole, and holes were 9 inches (23 cm) apart (Tilley 2011).

Over three years of testing various direct seeding systems at OSU MES, row cover consistently improved Douglas' dustymaiden stand production. When emergence trial results were averaged over the three years, the application of sand to keep the seed in place beneath the row cover yielded the best stands (Shock et al. 2017a).

Irrigation. In irrigation studies conducted at OSU MES, Douglas' dustymaiden seed yield varied greatly over a 2-year period, but was not related to irrigation rates. Irrigation was applied at about 2-week intervals from bud formation through flowering (Table 2; Shock et al. 2017b).

Table 2. Douglas' dustymaiden seed yield (lb/acre) with and without supplemental irrigation in seed production fields at Oregon State University's Malheur Experiment Station in Ontario, OR (Shock et al. 2017b).

Year	Irrigation Rate		
	0 inch	4 inches	8 inches
2015	132.1	137.6	183.3
2016	29.1	16.0	27.2
Average	80.6	76.8	105.2

Pollinator Management. The most practical, manageable bees to use to pollinate farmed crops of Douglas' dustymaiden are the cavity-nesting Asteraceae specialist (*Osmia californica*) and the European honey bee (*Apis mellifera*) (Cane et al. 2012), which could be transported to field locations in portable ground nests or hives. However, introducing new bee populations may not be feasible and encouraging and sustaining native bee populations where present can benefit production of many native plant crops (Cane 2008).

Seed Harvesting. Combines, flailvacs, or vacuum-type harvesters were used to collect Douglas' dustymaiden seed at the IDPMC. Jet combines (Jet Harvester) with fans running at 6,000 rpm ensured only ripe seed was harvested and allowed for multiple harvests throughout the season. Jet combine collections included only limited amounts of chaff and other inert material and made post-harvest cleaning easier (Tilley 2010; Bair and Tilley 2010). At OSU MES, Douglas' dustymaiden seed was collected from small research plots by hand or using a leaf blower in vacuum mode. Because of the long flowering duration, beginning in early May and ending mid-July, seed was collected weekly from mid-June to mid-July (Shock et al. 2017b).

Researchers at the IDPMC developed a unique non-destructive seed collection method for species producing indeterminate lightweight seed, which could be used for Douglas' dustymaiden. They attached a system of loose chains to the hood of a flail-vacuum harvester, which agitated plants and dislodged ripe seed from the flower heads when passed through seed production rows. This harvest method results in limited plant damage, allows for repeat harvests, and collects only a minimal amount of vegetative material (Simonson and Tilley 2016).

NURSERY PRACTICE

Containerized stock of Douglas' dustymaiden material has been produced for domestic horticulture and for restoration (Fig. 7; Link 1993; Majerus 1991; Tilley 2011; Shock et al. 2014a). The species is well suited for seeding or transplanting in parks, along roadways, and other low maintenance landscapes. In Yellowstone National Park, Douglas' dustymaiden seed was collected, then grown and outplanted at sites disturbed by road construction (Majerus 1991).

Container plants were produced in Boise, Idaho, by placing sown containers outside in December (DeBolt and Barrash 2013). Emergence began after 2 months and was complete after 4 months. Seedlings were transferred to 5.5-inch containers when secondary leaves developed. Seedlings were grown outside for 6 months, and when observed, flower stalks were removed to promote vegetative growth. Seedlings were outplanted in October.

Figure 7. Container-grown Douglas' dustymaiden seedlings. Photo: P. Winn, USFS LPN.

WILDLAND SEEDING AND PLANTING

Douglas' dustymaiden is a good choice when developing pollinator seed mixtures (Cane et al. 2012; Ogle et al. 2012). Its tolerance of disturbances and early seral conditions also make it a good choice for revegetation of burned rangeland sites where fire frequencies are expected to increase (IRFMS Team 2016).

Based on experience gained when growing seed crops of Douglas' dustymaiden, the IDPMC recommended a seeding rate of 3 lbs of pure live seed (PLS)/acre (3.4 kg PLS/ha) in fall at a seeding depth of 0 to 0.1 inch (0-0.3 cm). The 3 lbs/acre seeding rate is recommended for establishment of a pure stand, but Douglas' dustymaiden use in rangeland seedings is most likely as a component of seeding mixtures, making up less than 10% of the mix. Sites with medium- to coarse-textured soils with a pH of 4.2 to 8.0 that receive at least 7 inches (180 mm) of precipitation are considered best for Douglas' dustymaiden establishment and growth (Ogle et al. 2011, 2012).

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