

Thickleaf beardtongue (*Penstemon pachyphyllus*)

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PUBLICATION DATE

December 2022

Nomenclature

Thickleaf beardtongue (*Penstemon pachyphyllus* [A. Gray ex Rydb.]) belongs to the Scrophulariaceae family, *Penstemon* subgenus, and *Coerulei* section (Nold 1999; Lindgren and Wilde 2003; Freeman 2019).

Family

Scrophulariaceae – Figwort family

Genus

Penstemon

Species

pachyphyllus

NRCS Plant Code

PEPA6 (USDA NRCS 2022).

Subtaxa

The Flora of North America (Freeman 2019) recognizes two varieties: *P. p.* var. *congestus* and *P. p.* var. *pachyphyllus*.

Synonyms

P. acuminatus var. *congestus* M.E. Jones, *P. congetus* (M.E. Jones) Pennell, *P. nitidus* var. *major* Benth., *P. pachyphyllus* subsp. *congestus* (M.E. Jones) D.D. Keck (Freeman 2019).

Common Names

Thickleaf beardtongue, elephant ear penstemon, thickleaf penstemon, rockville penstemon (Ogle and Peterson 2000; Welsh et al. 2016).

Chromosome Number

2n = 16 is reported for both varieties, but they seem to differ in genome size (Broderick et al. 2011).

Hybridization

Hybridization was not reported in the reviewed literature.

Distribution

Thickleaf beardtongue has a limited distribution, occurring in Utah, east-central Nevada, and northern Arizona. Reports of the species in Wyoming and Colorado are likely referring to mucronate penstemon (*Penstemon mucronatus*), which was considered a thickleaf beardtongue variety by some taxonomists.

Variety *pachyphyllus* occurs in Carbon, Daggett, Duchesne, Uinta, and Wasatch Counties of Utah.

Variety *congestus* occurs from the calcareous region of

east-central Nevada to the Unita Basin in northeastern Utah, and through the Grand Canyon Plateau of northern Arizona (Freeman 2019). Holmgren (1978) reports variety *congestus* in the White Pine, Egan, Schell Creek, and Snake Ranges of east-central Nevada, and the Wah Wah and Pine Valley Mountains of south-central Utah above 6,600 ft (2,000 m) (Holmgren 1978). This includes White Pine County in Nevada, Tooele, Millard, Beaver, Iron, Washington, Kane, San Juan, Garfield, Piute, Wayne, Sevier, Emery, Sanpete, and Carbon Counties in Utah, and Mohave and Coconino Counties in Arizona.

Habitat And Plant Associations

Thickleaf beardtongue grows in a variety of shrubland, woodland, and forest communities. It is common in the Great Basin where annual precipitation ranged from 12 to 20 in (305–508 mm) (Ogle et al. 2014). It is associated with sagebrush (*Artemisia* spp.), winterfat-rabbitbrush (*Krascheninnikovia lanata*–*Chrysothamnus* or *Ericameria* spp.), mountain brush, pinyon-juniper (*Pinus*–*Juniperus* spp.), Gambel oak (*Quercus gambelii*), quaking aspen (*Populus tremuloides*), ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), and Great Basin bristlecone pine (*Pinus longaeva*) communities (Mee et al. 2003; Welsh et al. 2016; Freeman 2019).

In the eastern part of the Great Basin, the occurrence of thickleaf beardtongue is used to designate pinyon-juniper sub-associations. The singleleaf pinyon/black sagebrush (*P. monophylla*/*Artemisia nova*)/thickleaf beardtongue vegetation type occupies limestone geologic forms on south slopes at 7,220 ft (2,200 m) in the Bonneville Basin of Utah. The Utah juniper/Mormon tea (*Juniperus osteosperma*/*Ephedra viridis*)/thickleaf beardtongue type grows on andesitic geologic (igneous) forms at 6,560 ft (2,000 m) in the southeastern part of the Great Basin in Utah. The singleleaf pinyon/basin big sagebrush (*Artemisia tridentata* subsp. *tridentata*)/thickleaf beardtongue type grows on western slopes at 7,870 ft (2,400 m) on rhyolitic geologic (igneous) forms in the central Great Basin in Nevada (West et al. 1998).

Thickleaf beardtongue grows in dry conifer forests on the Kaibab Plateau of northern Arizona. It occurs in the understory of twoneedle pinyon (*P. edulis*)-Utah juniper woodlands in Kaibab National Forest where precipitation is monsoonal (Huffman et al. 2019). Frequency of thickleaf beardtongue averaged 13% in ponderosa pine/big sagebrush (*Artemisia tridentata*) vegetation on the South Rim but did not occur in ponderosa pine/grasslands on the North Rim of the Kaibab Plateau. At these sites annual precipitation averaged 27 in (686 mm) and fell primarily from December to March and July to September (Merkle 1962).

Elevation

Thickleaf beardtongue occupies sites from 4,300 to 10,500 ft (1,300–3,200 m), and there is little elevation range difference for the two varieties (Freeman 2019). In Utah, the elevation range of variety *congestus* is 5,600 to 10,100 ft (1,700–3,085 m) and variety *pachyphyllus* is 4,400 to 10,500 ft (1,340–3,200 m) (Welsh et al. 2016).

Soils

The soils in thickleaf beardtongue habitats are dry, gravelly, sands to loams (Fig. 1) (Pennell 1920; Lindgren and Wilde 2003; Mee et al. 2003; Kramer et al. 2011; Freeman 2019; Huffman et al. 2019). In northern Arizona, it is described as growing on shallow, limestone soils with rocky outcrops (Merkle 1962; Huffman et al. 2019).



Figure 1. Thickleaf beardtongue colonizing eroded material scooped out of a roadway and piled in a wash adjacent to a sagebrush and pinyon-juniper communities in Utah. Photo: BLM UT933 Seeds of Success (SOS).

Description

Thickleaf beardtongue is a tap rooted perennial with a branching woody caudex (Mee et al. 2003; Welsh et al. 2016). Plants produce single to multiple erect stems up to 24 in (60 cm) tall from a thick root crown (Fig. 2) (Nold 1999; Mee et al. 2003; Freeman 2019; Stevens et al. 2020). Herbage is glabrous to glaucous with a pale green to blue color (Pennell 1920; Welsh et al. 2016; Freeman 2019). Basal and stem leaves are entire, thick, and waxy (Lindgren and Wilde 2003). Basal leaves are petiolate, spatulate to lanceolate, 0.7 to 7.1 in (1.8–18 cm) long, 0.2 to 2.1 in (0.5–5.3 cm) wide, and persistent (Mee et al. 2003; Welsh et al. 2016; Freeman 2019). Stem leaves occur in two to five pairs (Freeman 2019). They are ovate to lanceolate, 0.6 to 3 in (1.5–8 cm) long, and 0.3 to 1.3 in (0.7–3.2 cm) wide (Welsh et al. 2016; Freeman 2019). Stem leaves near the base of the plant are short-petiolate, those further up the stem are sessile or clasping (Mee et al. 2003; Stevens et al. 2020). Reticulate leaf veining becomes evident with age (Pennell 1920).



Figure 2. Flowering thickleaf beardtongue plant growing on a rocky outcrop in a sagebrush and pinyon-juniper habitat in Utah. Photo: BLM UT933 SOS.

Bisexual flowers are produced in a terminal thyrse (inflorescence with indeterminate main axis and determinate flowering branches [verticillasters in *Penstemon*]). The thyrse for thickleaf beardtongue supports four to ten verticillasters (Fig. 3) (Lindgren and Wilde 2003; Mee et al. 2003; Welsh et al. 2016; Stevens et al. 2020). Thyrses are cylindric, congested to interrupted, and make up a third to a half of the plant height (Pennell 1920; Welsh et al. 2016). Verticillasters are three- to six-flowered cymes, two per node. Individual flowers are short campanulate, bilaterally symmetrical, and held horizontally (Stevens et al. 2020). The calyx is 0.2 to 0.3 in (5–7 mm) long, and the lavender to blue corolla is 0.6 to 0.8 in [1.7–2.0 cm]) long (Lindgren and Wilde 2003; Stevens et al. 2020). The two posterior lobes are about 0.2 in (5–6 mm) long, arched, and united to about a third of their length. The three anterior lobes are slightly longer and united at the base. All free portions of the lobes spread widely (Pennell 1920). Flower tubes are 0.15 to 0.2 in (4–6 mm) long with or without nectar guidelines. The sparsely to densely bearded stamens (8–12 mm long) reach the orifice or are slightly exserted (Mee et al. 2003; Welsh et al. 2016; Freeman 2019). Thickleaf beardtongue produces seeds in ovate, glabrous, pale brown capsules (10–14 by 5–7 mm) (Fig. 4) (Pennell 1920; Freeman 2019). Seeds are cinnamon-brown, glistening, 2 to 3 mm long, and semi winged. They are curved in outline with sharp angles at the ends (Pennell 1920; Freeman 2019).



Figure 3. Thickleaf beardtongue inflorescence with clasp green stem leaves. Photo: BLM UT080 SOS.

Thickleaf beardtongue varieties growing where distributions overlap in Utah (see Distribution section), can be distinguished by their staminodes.

Variety *pachyphyllus* produces a shorter (8 to 9 mm long) relatively wide, golden-bearded staminode that is densely villous with hairs up to 2.5 mm long (Nold 1999; Freeman 2019). Variety *congestus* produces a longer (10–12 mm), narrower, pale-yellow-bearded staminode that is densely villous with hairs to 1.5 mm long (Nold 1999; Freeman 2019).



Figure 4. Thickleaf beardtongue capsules (left) and seeds (right). Photo: BLM UT080 SOS.

Reproduction

Thickleaf beardtongue reproduces by seed. In a survey of 10 populations in sagebrush-steppe habitat in the southeastern Great Basin of Utah and Nevada (elevation range: 3,671–8,301 ft [1,119–2,530 m]), the size of thickleaf beardtongue populations ranged from 150 to 1,000+ plants (Kramer et al. 2011). Flowering commonly occurs from late May to July or August (Pennell 1920; Nold 1999; Freeman 2019). Flowering is determinate but killing frosts or lack of pollination can cause flowers to dry up without producing seed and monsoonal moisture patterns can result in a limited number of fall flowering stems (Fig. 5).



Figure 5. Thickleaf beardtongue exhibiting a single flowering stem and many shriveled flowering stems. This is not illustrating indeterminate flowering in the traditional sense (see Reproduction section for details). Photo: BLM UT080 SOS.

Breeding System

Thickleaf beardtongue produces protandrous flowers (male parts mature before female parts). Although flowers have at least some degree of self-compatibility (Kramer et al. 2011), experimentally selfed flowers produced fewer and smaller fruits and fewer seeds (Kramer 2009).

Pollination

In a pollination study conducted in Washington County, southwestern Utah, thistleleaf beardtongue plants were visited by dozens of different pollinator species including butterflies, wasps, and bees (Gray 2011). Large- and medium-sized bees were more common than small bees. Sweat bees (*Agapostemon* spp.) and bee flies (*Bombylius* spp.) made up 41% and 32% of all insect observations in unmanipulated stands and stands where 50% of the flowering stems were removed. Plants produced an average of eight seeds/fruit/stem regardless of flowering stem density (Gray 2011). Flowers in the Great Basin were pollinated by large-size bees including bumble bees (*Bombus* spp.) (Kramer et al. 2011).

Ecology

Thistleleaf beardtongue has been described as a short-lived (Ogle et al. 2014; Stevens et al. 2020) and long-lived (Kramer et al. 2011) perennial. With some loss in stand density, it persisted in seed production fields for more than 5 years in Utah (Jensen, USFS/RMRS, personal communication, October 2022). Very little was reported in the literature about the ecology of thistleleaf beardtongue. It commonly occurs in early-seral communities and disturbances like graded road edges, but it also among the last forbs persisting in phase three pinyon-juniper woodlands (Walker and Shaw 2005; Jensen, USFS/RMRS, personal communication, October 2022).

Seed And Seedling Ecology

Thistleleaf beardtongue seed (mean mass: 1.4 mg) is primarily gravity dispersed (Kramer et al. 2011).

A common garden study conducted by Kramer (2009) revealed many thistleleaf beardtongue seedling growth characteristics and climate relationships (Tables 1 and 2). Seedlings were grown in a greenhouse from seed collected from six different Great Basin locations and transplanted to common gardens in Boise, Idaho, and Kaysville, Utah. Transplanted seedling survival was significantly different by source population ($P \leq 0.0001$), and percent survival was significantly predicted by climatic distance between each study population and common garden site ($P = 0.0466$) (Kramer 2009).

Table 1. Survival of greenhouse-grown thistleleaf beardtongue from seed collected from populations in Nevada and Utah transplanted at two common gardens (Kramer 2009).

Seed origin, Elevation (ft)	Mean min temp (°F)	Mean max temp (°F)	Mean annual ppt (in)	BSU*		UBC*	
No. planted	Survival (%)	No. planted	Survival (%)				
sw UT, 6,960	15	83	17	32	72	32	78
sw UT, 3,670	27	98	12	33	76	32	69
w UT, 8,400	10	80	18	5	40	12	33
w UT, 7,970	11	81	16	5	40	10	50
w UT, 7,270	11	83	15	0	–	3	67
ec NV, 7,620	12	85	14	24	4	30	27
ec NV, 7,300	11	84	14	15	7	27	26
e NV, 6,550	12	86	12	25	16	30	10

*Common garden locations were Boise State University (BSU) in Boise, ID (2,723 ft [830 m] elevation, 13 in (330 mm) mean annual precipitation) and Utah Botanical Center (UBC) in Kaysville, UT (4,590 ft [1,400 m] elevation, 19.8 in (503 mm) mean annual precipitation).

Thistleleaf beardtongue plants from colder, high-elevation sites with more consistent temperatures and precipitation flowered earlier in warm common garden settings than those from seed collected from warm, low-elevation sites. In natural environments, however, populations from warm, low-elevation sites flowered earlier than those at cool, high-elevation sites (Kramer 2009).

Table 2. Thickleaf beardtongue seedling growth traits of seven populations measured at two common garden sites (Kramer 2009). See Table 1 for origin population climate and precipitation characteristics at the origin for each population.

Seed origin, Elevation (ft)	Total growth	Summer growth	Leaf area	Stem length	Flower height	Flower (%)	Fruit (no.)
sw UT, 6,960	0.7ab	0.6a	11.2a	51.2ab	21.9ab	0.2c	35.7a
sw UT, 3,670	0.5b	0.47abc	9.3a	59.6a	26.1a	0.1c	37.2a
w UT, 8,400	0.6ab	0.61ab	2.2abc	47.0ab	18.7ab	6.3b	42.3a
w UT, 7,970	0.8ab	0.41abc	2.5a	60.0a	23.7ab	5.4b	54.8a
ec NV, 7,620	1.0a	0.48abc	2.1ab	52.0ab	20.8ab	13.4ab	43.4a
ec NV, 7,300	0.6ab	0.32c	1.6c	48.8ab	17.3b	22.7a	37.3a
e NV, 6,550	0.6ab	0.36bc	1.7bc	45.0b	17.8b	11.8ab	36.2a

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

Wildlife And Livestock Use

In a review of plant foods used by North American wildlife, seeds of penstemon species were important to western rodents. They comprised 10 to 25% of the diets of ground squirrels (Sciuridae), wood rats (*Neotoma* spp.), and golden-mantled ground squirrels (*Callospermophilus lateralis*). Finches (*Haemorhous* spp.) also consumed seeds of penstemon species (Martin et al. 1951).

Ethnobotany

Havasupai people of north-central Arizona reported that deer hunters used folded thickleaf beardtongue leaves to mimic the sound of a baby deer. This was done by folding the leaves lengthwise, placing them in their mouths with the folded edge out, and drawing their breath in sharply (Whiting et al. 1985).

Horticulture

Thickleaf beardtongue and other penstemon species are commercially available in local garden centers and seed catalogs. Plants are relatively easy to cultivate and produce lovely blue-violet flowers attractive to pollinators. Plants grow well in non-irrigated landscapes, making them a good choice for roadsides, campgrounds, or other low maintenance areas (Way and James 1998; Mee et al. 2003). Under cultivation, thickleaf beardtongue seeds germinate within two or three months of 40 to 70 °F (4–21 °C) temperatures and live 3 to 4 years on average (Lindgren and Wilde 2003).

Revegetation Use

Thickleaf beardtongue is an attractive pollinator and nectar plant adapted to early-seral conditions (Walker and Shaw 2005; Tilley et al. 2019). It is recommended for dry sites receiving at least 12 in (305 mm) annual precipitation (Walker and Shaw 2005), although other sources suggest it may survive at sites receiving at least 6 in (152 mm) annual precipitation (Tilley et al. 2019).

Developing A Seed Supply

For restoration to be successful, the right seed needs to be planted in the right place at the right time. Coordinated planning and cooperation is required among partners to first select appropriate species and seed sources and then properly collect, grow, certify, clean, store, and distribute seed for restoration (PCA 2015).

Developing a seed supply begins with seed collection from native stands. Collection sites are determined by current or projected revegetation requirements and goals. Production of nursery stock requires less seed than large-scale seeding operations, which may require establishment of agricultural seed production fields. Regardless of the size and complexity of any revegetation effort, seed certification is essential for tracking seed origin from collection through use (UCIA 2015).

Seed Sourcing

Thickleaf beardtongue was a study species in two analyses of seed transfer zones. A Great Basin study evaluated how landscape features interacted with life history traits to influence population genetic structure of thickleaf beardtongue and two other *Penstemon* species. Thickleaf beardtongue had high genetic structure and low inferred gene flow (Kramer et al. 2011; Kucera et al. 2022). When experimental thickleaf beardtongue crosses were made from parents of the same population and parents from populations of increasing geographic distances, within population crosses had higher fitness measures than first generation progeny produced from more geographically distant parents. Significant outbreeding depression occurred at crossing distances of 62 to 124 mi (100–200 km) (Kramer 2009). Recent controlled crossing experiments including more populations across the species range suggest that the main driver of outbreeding depression is a geographically structured difference in genome size between populations in southern Utah (Washington and Kane counties) and northern Arizona (Mohave and Coconino counties), and the rest of the distribution. This genome size difference and the pattern of outbreeding depression suggests poor taxa delimitation (Urbina-Casanova and Kramer, CBG, personal communication, October 2022). When this information was used to test the relative suitability of seed transfer zones, researchers noted that local seed sourcing would be the best option for restoration, but that tested seed transfer zones are useful guides for moving seed, although the effectiveness decreases as zone size increases (Kramer et al. 2015).

Kucera et al. (2022) tracked the genetic diversity and structure of 19 wild populations from six mountain ranges through the production of a mixed-source seed lot. Seeds sourced directly from wild populations were increased in a nursery seed production field where outcrossing was allowed. Seeds harvested from the nursery were sown in commercial production fields and experimental restoration plots. Populations from all six mountain ranges were present in the production and restoration sites, but one mountain range population was overrepresented and two were underrepresented relative to their composition in the original seed mix. While the same seed mix was used for the production field and restoration sites, the composition of source populations varied among locations, suggesting that different conditions favored different populations (Kucera et al. 2022).

Because empirical seed zones are not currently available for thickleaf beardtongue, 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 to moisture index). In Figure 6, Omernik Level III Ecoregions (Omernik 1987) overlay the provisional seed zones to identify climatically similar but ecologically different areas. For site-specific disturbance regimes and restoration objectives, seed collection locations within a seed zone and ecoregion may be further limited by elevation, soil type, or other factors.

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

Occurrence Map

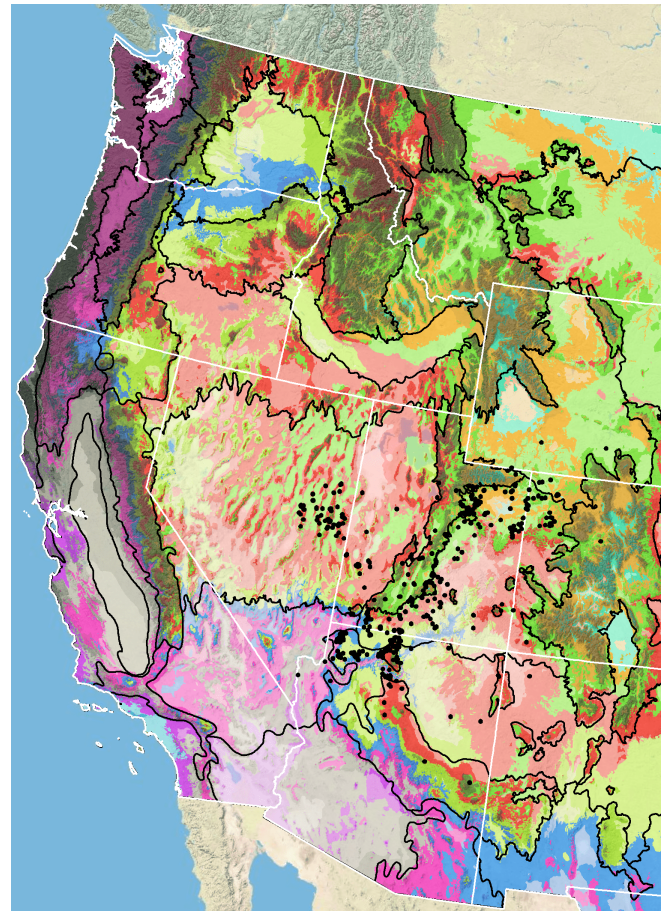


Figure 6. Distribution of thickleaf beardtongue (black circles) based on geo-referenced herbarium specimens and observational data from 1877–2013 (CPNWH 2017; SEINet 2017; USDI USGS 2017). Generalized provisional seed zones (colored regions) (Bower et al. 2014) are overlain by Omernik Level III Ecoregions (black outlines) (Omernik 1987; USDI EPA 2018). Interactive maps, legends, and a mobile app are available (USDA FS WWETAC 2017; research.fs.usda.gov/pnw/products/dataandtools/seed-zone-webmap). Map prepared by M. Fisk, USDI USGS.

Releases

As of 2022, there were no thickleaf beardtongue germplasm releases. Stock seed supplies originating from several generalized provisional seed zones (GPSZ) were provided to growers by the Great Basin Native Plant program beginning in 2012 with seed commercially available since 2014. Seed sources from (GPSZ) 15 – 20 Deg. F. / 3 – 6 originating in the central basin and range ecoregion of the Great Basin and a single source from the Colorado Plateau remain in production as of this date (Jensen, USFS/RMRS, personal communication, October 2022).

Wildland Seed Collection

Wildland thicketleaf beardtongue seed is collected by hand stripping or beating inflorescences over a container or cutting inflorescences with a scythe when stems and capsules are dry and tan (Fig. 7), which is typically August (Jorgensen and Stevens 2004; Jensen, USFS/RMRS, personal communication, October 2022).



Figure 7. Thickleaf beardtongue with mature capsules and some open capsules dispersing seed. Photo: BLM NV040 SOS.

Wildland Seed Certification

Verification of species and tracking of geographic source is necessary whether wildland seed is collected for immediate project use or as stock seed for cultivated increase. This official Source Identification process can be accomplished by following procedures established by the Association of Official Seed Certifying Agencies (AOSCA) Pre-Variety Germplasm Program (UCIA 2015; Young et al. 2020). Wildland seed collectors should become acquainted with state certification agency procedures, regulations, and deadlines in the states where they collect.

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

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

Collection Timing

Plants growing at warm, low-elevation sites flower and produce seed earlier than those at cool, high-elevation sites in the Great Basin (Kramer 2009). The USDI Bureau of Land Management's Seeds of Success collection crews made 23 thickleaf beardtongue harvests over 12 years in Utah (12), Nevada (10), and Arizona (1). Most collections were made in August (14), but harvests were also made in June (1), July (5), September (1), and October (2). Overall, the earliest collection date was June 28, 2016, in Beaver County, Utah, at 6,230 ft (1,900 m) elevation. The latest collection date was October 24, 2008, in White Pine County, Nevada, at 8,300 ft (2,530 m) elevation. At five of the sites, more than one collection was made. In the single year (2010) with the most collections made ($n=8$), the earliest harvest was August 4, in Sevier County, Utah, at 7,340 ft (2,240 m) elevation, and the latest was September 2, 2010, in White Pine County, Nevada, at 7,050 ft (2,150 m) elevation (USDI BLM SOS 2017).

Collection Methods

Cutting inflorescences with a scythe, hand stripping, or knocking seed from inflorescences into a container with a racquet is recommended for collecting wildland thickleaf beardtongue seed (Fig. 8) (Jorgensen and Stevens 2004).

Several collection guidelines and methods should be followed to maximize the genetic diversity of wildland collections: 1) collect seed from a minimum of 50 randomly selected plants; 2) collect from widely separated individuals throughout a population without favoring the most robust or avoiding small stature plants; and 3) collect from all microsites including habitat edges (Basey et al. 2015). General collecting recommendations and guidelines are provided in online manuals (e.g., ENSCONET 2009; USDI BLM SOS 2021).

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

Post-Collection Management

Seed collections should be thoroughly dried and protected from overheating. Freezing or adding insect pest strips is recommended to control pests in the seed collections, which should be stored away from rodents.

Seed Cleaning

Seed collections of dry capsules are cleaned by processing them through a Barley debearder to break up the capsules. This is followed by an airscreen separator, and finally a gravity table to remove trash and fine debris (Jorgensen and Stevens 2004).

Researchers at the Utah Division of Wildlife Resources, Great Basin Research Center (GBRC) in Ephraim, Utah, used the following procedure to clean thickleaf beardtongue seed (Landeem and Jensen 2022a). Mature seed stalks were harvested from wild stands using a sickle. Stalks were

processed through a debearder to separate the seed from the stems. Seed was then processed using an Office Clipper (top screen = 8 round, bottom screen = 4 × 24 wire mesh, air = low) followed by a Triangle Commercial Sieve (8/64 in). Seed cleaning was finished using a fractionating aspirator (Landeem and Jensen 2022a).



Figure 8. Clean thistleleaf beardtongue seeds (with magnification). Photo: U.S. Department of Agriculture, Forest Service, Bend Seed Extractory.

Seed Storage

Thistleleaf beardtongue is orthodox (RBG Kew 2022), and seed viability is retained for 10 or more years of storage. Germination was 74% at year zero and 68% after 14 years in a metal file cabinet in a warehouse where extreme temperatures ranged from -22 °F (-30 °C) to 101 °F (38 °C). Seed was hand-collected from native stands, dried, and cleaned to 85% purity or greater and put into cotton bags in a file cabinet drawer (Stevens et al. 1981).

Seed Testing

Procedures for testing the viability and germination of penstemon seeds are provided below.

Viability Testing

The Association of Official Seed Analysts (AOSA) provides a procedure for testing the seed viability of penstemon species (AOSA 2010). Seed is imbibed on moist media overnight at 68 to 77 °F (20–25 °C) then cut longitudinally leaving just enough seed coat at the distal end to keep the halves attached. Cut seeds are soaked in 0.1 to 0.5% tetrazolium chloride (TZ) for 24 to 48 hours at 86 to 95 °F (30–35 °C). Seed is considered viable if the entire embryo and endosperm stain evenly. Seed is nonviable when any essential part of the embryo or endosperm is unstained (AOSA 2010).

Germination Testing

To test the germination of penstemon species, AOSA (2016) recommends two methods. For method one, place 400 seeds on blotters moistened with gibberellic acid (GA₃ 500 ppm) and prechill for 60 days at 36 to 41 °F (2–5 °C). Germinate the seed for 14 days at 50 to 68 °F (10–20 °C). The first germination count is made at seven days and the last at 14 days for method one. Post-test viability of ungerminated seed is required. For method two, conduct a TZ test on 400 seeds then place them on water-moistened blotters and germinate in the light for 28 days. The first germination count is made at 14 days and the last at 28 days (AOSA 2016).

Germination Biology

Requirements for germination of thistleleaf beardtongue depend on the seed source. Seed from colder climates exhibit physiological dormancy and require stratification (Meyer et al. 1995; Kildisheva et al. 2019), while those from warmer climates germinate without stratification (Stevens et al. 2020). Gibberellic acid (GA₃) and aqueous smoke solution treatments can increase germination (Abella 2009; Love and Akins 2020). Seeds from habitats with severe winters required long chilling periods, while those from habitats with mild winters required short chilling periods. Meyer et al. (1995) reported germination percentages of 4 to 100% for penstemon species without chilling treatments. Penstemon seed was wild collected from Utah where the mean January temperatures ranged from 16 to 33 °F (-8.9–0.6 °C). Germination patterns were examined in the laboratory for seeds from 135 populations of 38 penstemon species growing in habitats from warm deserts to alpine tundra. The results for thistleleaf beardtongue seeds based on collection site are summarized in Table 3 (Meyer et al. 1995).

Table 3. Germination percentages for thistleleaf beardtongue after chilling treatments followed by 4-wk incubation at 50/68 °F (Meyer et al. 1995).

Collection (mean Jan temp °F)	Duration (wks) of continuous chilling at 34 °F					
0	4	8	12	16	24	
UT (25)	35c	70b	75b	90ab	97a	95a
UT (24)	15d	43c	63b	92a	96a	100a
UT (17)	11c	30b	31b	84a	91a	91a

Germination percentages within a row (collection location) followed by different letters are significantly different ($P < 0.05$).

Seed collected from more southern locations did not require stratification. Thickleaf beardtongue seed was collected from wild stands in south-central Utah at 7,100 ft (2,160 m) elevation (Table 4). Seed was collected in summer or fall 1986 and stored at 68 °F (20 °C) until germination testing, which began on December 26, 1986. Seed was cold stratified at 36 °F (2 °C) and then put into growth chambers (59 °F [15 °C] for 28 d). Cold stratification did not improve germination (Table 4; Kitchen and Meyer 1991).

Table 4. Germination of thickleaf beardtongue seed collected from south-central Utah with increasing duration of chilling (36 °F) (Kitchen and Meyer 1991).

Weeks	0	2	4	8	12	16
Germination (%)	71b	47cd	37d	43d	51bcd	65bd

Numbers followed by different letters are significantly different ($P < 0.05$).

Kramer (2009) likewise found that seed from cold, high-elevation populations required more days of cold stratification before germinating than populations from warm, low-elevation sites (Table 5). Thickleaf beardtongue seed was collected from various populations and stratified for 13 weeks (stratification conditions: 8 hrs light at 50 °F [10 °C], 16 hrs dark at 39 °F [4 °C]) and any seed that had not germinated was placed in warm conditions for an additional 4 weeks (12 hrs at 50 °F [10 °C] in dark and 12 hrs at 68 °F [20 °C] in light) (Table 5; Kramer 2009).

Table 5. Climatic conditions and days to germination for scabland penstemon seed from seven populations with cold stratification (20 wks with 8 hrs light at 50 °F and 16 hrs dark at 39 °F) (Kramer 2009).

Seed origin, Elevation (ft)	Climate mean at origin			Days to germinate with cold stratification
Min temp (°F)	Max temp (°F)	Annual ppt (in)		
sw UT, 3,670	27	98	12	55.1d
sw UT, 6,960	15	83	17	70.4c
w UT, 8,400	10	80	18	79.8bc
w UT, 7,970	11	81	16	97.9ab
ec NV, 7,620	12	85	14	89.6ab
ec NV, 7,300	11	84	14	85.6b
e NV, 6,550	12	86	12	99.9a

Numbers followed by different letters are significantly different ($P < 0.05$).

Kitchen and Meyer (1991) found that treatments of at least 50 ppm improved germination over water treatments. Thickleaf beardtongue seed was wild collected from south-central Utah at 7,090 ft (2,160 m) elevation in summer or fall 1986 and stored at 68 °F (20 °C) until testing that began on Dec 26, 1986 (Table 6; Kitchen and Meyer 1991). Kildisheva et al. (2019) similarly found germination was significantly greater ($P < 0.001$) when thickleaf penstemon was germinated in petri dishes with GA3 (1 mM) compared to water. Comparisons were made for seed collected from seed fields in east-central Nevada. Seed was dried and kept at 59 °F (15 °C) and 15% RH for up to three months before germination testing. Other researchers also reported increased germination with GA3 treatments (Johnson et al. 2017; Love and Akins 2020).

Table 6. Germination of thickleaf beardtongue seed with increasing concentrations of GA3 (Kitchen and Meyer 1991).

GA3 concentration (ppm)	0	50	150	250	500
Germination (%)	71b	92a	100a	91a	90a

Different numbers are significantly different ($P < 0.05$)

Emergence of thickleaf beardtongue was greater for seeds watered with aqueous smoke (30%) than water (3%) (Abella 2009). Thickleaf beardtongue seed was obtained from a local seed vendor and stored for four months at 23 °F (-5 °C) before emergence testing. Seed was lightly pressed into containers filled with sterile potting soil then watered with a 10%

concentrated aqueous smoke solution or pure water. Containers were kept in the greenhouse at 75 °F (24 °C) with 14 hours light (Abella 2009).

Wildland Seed Yield And Quality

Post-cleaning seed yield and quality of seed lots collected in the Intermountain region are provided in Table 7 (USDA FS BSE 2017). The results indicate that thistleleaf beardtongue seed can generally be cleaned to high levels of purity and seed fill and that the viability of fresh seed is variable.

Table 7. Seed yield and quality of thistleleaf beardtongue seed lots collected in the Intermountain region, cleaned by the Bend Seed Extractory, and tested by the Oregon State Seed Laboratory or the USDA Forest Service National Seed Laboratory (USDA FS BSE 2017).

Seed lot characteristic	Mean	Range	Samples (no.)
Bulk weight (lbs)	3.3	0.07–5.0	15
Clean weight (lbs)	0.5	0.04–3.0	15
Clean-out ratio	0.4	0.03–0.8	15
Purity (%)	95	92–98	15
Fill (%) ¹	91	85–98	15
Viability (%) ²	90	70–98	12
Seeds/lb	200,611	160,169–243,500	15
Pure live seeds/lb	172,157	132,620–201,618	12

¹100 seed X-ray test

²Tetrazolium chloride test

Marketing Standards

Acceptable seed purity, viability, and germination specifications vary with revegetation plans. Purity needs are highest for precision seeding equipment used in nurseries, while some rangeland seeding equipment handles less clean seed quite well. Walker and Shaw (2005) suggest seed viability of 70%, germination of 70%, and purity of 95% for contracted harvests of thistleleaf beardtongue.

Agricultural Seed Production

Thistleleaf beardtongue has been grown for seed increase by the Utah Division of Wildlife Resources, Great Basin Research Center (GBRC) in Fountain Green and Ephraim, Utah (Gunnell 2017) and by Oregon State University's Malheur Experiment Station (OSU MES) in Ontario, Oregon (Shock et al. 2021). Both parties successfully established seed fields. The highest seed yield in any year was 570 lbs/ac (640 kg/ha) at OSU MES, but average yields were closer to 200 lbs/ac (224 kg/ha). Stands produced seed at year two and crops were harvested for about three years (Shock et al. 2021).



Figure 9. Thistleleaf beardtongue seed production plots growing at Geertson Seed Farms in Adrian, OR. Photo: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station (USFS RMRS).

Basey et al. (2015) used the timing of thistleleaf beardtongue germination to illustrate how decisions made when working to increase seed availability can impact the conservation of genetic diversity. Seed collected at the same time from three thistleleaf beardtongue plants in the same population showed large differences in germination timing. Seed from plant one germinated over 48 to 70 days (mean: 62 d), plant two germinated over 66 to 80 days (mean: 78 d), and plant three germinated over 76 to 85 days (mean: 80 d). A nursery, seed orchard, or production field that utilizes only the first flush of germinants could suffer immediate genetic losses or unwanted shifts in genetic diversity. Losses can be minimized by utilizing a range of germination conditions and germinating as many

seeds as possible. Preserving the differences in germination timing and conditions between individuals is a way to ensure some seedlings survive regardless of seasonal fluctuations and microsite variation.

Agricultural Seed Certification

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

Seed growers apply for certification of their production fields prior to planting and plant only certified stock seed of an allowed generation (usually less than four). The systematic and sequential tracking through the certification process requires preplanning, knowing state regulations and deadlines, and is most smoothly navigated by working closely with state certification agency personnel. See the Wildland Seed Certification section for more information on stock seed sourcing.

Site Preparation

A firm, weed-free seedbed is recommended for cultivation of thistle beardtongue. GBRC researchers used two methods (transplanting plugs and direct seeding) to establish thistle beardtongue seed production plots in Ephraim and Fountain Green, Utah (Landeem and Jensen 2022b). Site preparation included creating a uniform seedbed and incorporating weed control, watering, and fertilizing mechanisms. Nursery beds (5 ft [1.5 m] wide and 85 ft [26 m] long) were centered over two rows of buried drip tape (8–10 in [20–25 cm] deep). Beds were tilled and shaped using a nursery bed maker in spring or fall in the year prior to planting. Weeds were controlled by spot spraying with glyphosate (41% ai). For the six hottest summer months in the year before planting, beds were solarized with tight covering of 2-mil clear plastic sheeting and a mulch layer. Beds were broadcast fertilized before planting and seeding. Plots were fertilized as needed again in the fall of each growing season (Landeem and Jensen 2022b).

Weed Management

At OSU MES, thistle beardtongue was grown from 2011 to 2020. Weeds were controlled in seed production plots by hand weeding each year. Additional weed control included broadcasting pendimethalin at 1 lb ai/ac on October 27, 2016, and applying pendimethalin at 1 lb ai/ac, dimethenamid-P at 0.98 lb ai/ac, and sethoxydim at 0.38 lb ai/ac on November 15, 2019 (Shock et al. 2021). It is important to note that there are no herbicides registered for use with native forbs. At GBRC, weeds were largely controlled by hand in seeded and planted plots. A mechanical Eco-Weeder was used early in the growing season when the soil was soft, and plants were small (Landeem and Jensen 2022b).

Seeding

At OSU MES, thistle beardtongue was fall seeded on the soil surface at 30 seeds/linear ft (100 seeds/m) in 30-in (76-cm) rows and covered with sawdust (0.26 oz/ft). Seeded plots were protected by row cover (N-Sulate, DeWitt Co, Sikeston, MO) until seedling emergence the following April (Shock et al. 2021).

Direct seeding by GBRC at Ephraim and Fountain Green, Utah, was done using a Hege precision cone type seeder. Seeds were sown 0.25 in (0.6 cm) deep in three 85-ft (26 m) rows at a target rate of 50 seeds/ft (160/m). After seeding, plots were covered with N-sulate fabric (1.5 oz) using a mulch layer. Fabric was removed in spring when freezing risk was minimal. While most germination occurred in the first post-seeding year, some was delayed until the second post-seeding year (Landeem and Jensen 2022b).

Planting. Thistle beardtongue plugs were mechanically transplanted using a Mechanical Transplanter Model 5000, configured to plant in three rows spaced 22 in (56 cm) apart with 6 in (15 cm) between plants (Landeem and Jensen 2022b).

Establishment And Growth

At OSU-MES, fertilization of thistle beardtongue seed production plots was limited in 10 years of cultivation, although a severe iron deficiency was noted in early spring 2012. On April 23, 2012, 50 lbs N, 10 lbs P, and 0.3 lb Fe/ac (56 kg N, 11 kg P, and 0.3 kg Fe/ha) was applied as liquid fertilizer through established irrigation drip tape. On April 29, 2014, 0.3 lb Fe/ac (0.3 kg Fe/ha) was applied again (Shock et al. 2021).

Thistle beardtongue seed from 21 accessions were grown at farms in Fountain Green and Ephraim, Utah. Plots (typically 5 × 80 ft [1.5 × 24 m]) supported between 14 and 348 plants that ranged in height from 20 to 39 in (50–98 cm). Peak flowering dates ranged from May 19 to May 25, and harvest dates ranged from July 21 to August 1 (Gunnell 2017).

Irrigation

Seed yield and plant water relations were evaluated for thickleaf beardtongue at OSU MES for 10 years (2011–2020) (Tables 8 and 9; Shock et al. 2021). Seed yield responded to irrigation only in years with lower-than-average precipitation (2013 and 2018). In those years, seed yield was maximized with 8 in (200 mm) of irrigation (Shock et al. 2021). Plots were seeded on November 25, 2009, and irrigated for 24 hours on Dec 2, 2009, to alleviate very dry soil conditions. Experimental irrigation treatments began in 2011 and tested additions of 0, 4, and 8 in (0, 100, and 200 mm) of subsurface drip irrigation. Plots were irrigated at 12 in (30 cm) deep in four bi-weekly increments starting at the time of flower bud formation (Shock et al. 2021).

Table 8. Flowering timing as related to timing of irrigation of thickleaf beardtongue seed production plots growing at Oregon State University's Malheur Experiment Station in Ontario, Oregon (Shock et al. 2021).

Year*	Flowering			Irrigation		
	Start	Peak	End	Start	End	Harvest
2011		10 May	30 May	20 June	13 May	23 June
2012		23 Apr	2 May	10 June	27 Apr	7 June
2013		26 Apr	—	21 May	24 Apr	5 June
2014		22 Apr	5 May	4 June	29 Apr	10 June
2015		24 Apr	5 May	26 May	21 Apr	3 June
2016		18 Apr	—	13 May	18 Apr	31 May
2017		1 May	15 May	7 June	2 May	20 June
2018		30 Apr	10 May	10 June	3 May	13 June
2019		26 Apr	—	28 May	3 May	13 June
2020		25 Apr	7 May	30 May	9 May	18 June

Table 9. Seed yield for thickleaf beardtongue in response to no additional irrigation and supplemental irrigation of 4 and 8 in at Oregon State University's Malheur Experiment Station in Ontario, OR (Shock et al. 2021).

Year	Supplemental irrigation (in/season*)		
	0	4	8
——Seed yield (lbs/ac)——			
2011		570	338
2012		280	215
2013*		159a	197ab
2014		292	239
2015		90	74
2016		143	186
2017		111	108
2018*		153a	133a
2019		131	144
2020		174	222
Average		210	186

*Seed yields significantly ($P < 0.1$) different.

Planted nursery beds at GBRC were irrigated using lawn sprinklers immediately following transplanting and periodically throughout the first 2 weeks to help establishment (Landeem and Jensen 2022b).

Pollinator Management

Thickleaf beardtongue is visited by a variety of bee species (Gray 2011). Any management that encourages and sustains native bee populations, where present, may benefit the production of native plant crops (Cane 2008). In areas lacking native bee populations, seed yield may be improved by providing cavity-nesting Asteraceae specialist (*Osmia californica*) and European honey bee (*Apis mellifera*) populations. These species can be transported to field locations in portable ground nests or hives (Cane et al. 2012).

Pest Management

Although penstemon seed growers have produced crops without apparent insect damage, if insects do appear, crop damage can be “catastrophic” (Hammon 2014). Penstemon weevils (*Hesperobarus ovulum*) or borer larvae (*Barus* spp.) are limited to southwestern Colorado, but the penstemon clearwing borer (*Penstemonia* spp.) is widespread and attacks multiple penstemon species (Hammon 2014). Clearwing borer larvae feed in the root crown and lower above-ground portions of the plant. A pheromone is available to monitor for adult clearwing borers. Other potentially significant pests include lygus bugs (*Lygus* spp.) and raceme-boring moths (Crambidae) (St. John et al. 2009). Many penstemon species are short-lived plants. Hammon (2014) hypothesized that the short life cycle may be attributed to borers and other insects and pathogens.

Thickleaf beardtongue is also susceptible to soil-borne fusarium and rhizoctonia root rot, these pathogens and their damage are most severe in poorly drained loam or clay soils (Ogle and Peterson 2000).

Seed Harvesting

At OSU MES, thickleaf beardtongue seed was harvested with a Wintersteiger small plot combine (Salt Lake City, UT) when stand densities were sufficient and by hand when densities were poor. Seed was cleaned using a small Clipper seed cleaner (A.T. Ferrell, Bloomington, IN) (Shock et al. 2021). Plots at Ephraim and Fountain Green, Utah, were also harvested mechanically using a Wintersteiger small plot combine (combine settings: 1270 rpm cylinder speed, 1480 rpm shaker air speed, 3 de-awner bars; concave settings: 4 front, 0 back, and medium sieve height). Combine air speeds were started at the highest setting and turned down until no good seed was being blown out the back. Seed was dried thoroughly on a concrete floor for several days before cleaning (Landeem and Jensen 2022b).

Seed Yields And Stand Life

Based on research conducted at OSU MES and GBRC, thickleaf beardtongue produced harvestable seed in year two (Shock et al. 2021; Landeem and Jensen 2022b). Seed production plots at GBRC began producing seed in year two. Seed capsules on the lower section of the inflorescence matured and split earlier than those near the top. Seed was retained as long as the stems were not excessively jostled by wind, rain, or pedestrian traffic. Seed yields were maximized by delaying harvests until the majority of capsules near the top were dry and splitting (Landeem and Jensen 2022b).

At OSU MES stands rarely produced high yield crops beyond three years. Seed yields averaged 210 lbs/ac (235 kg/ha) and ranged from 74 to 570 lbs/ac (83–639 kg/ha) in 10 years of study (Shock et al. 2021). At various aged seed increase plots in Ephraim and Fountain Green, Utah, seed yield ranged from 0.02 to 0.7 oz (0.7–20.7 g) of clean seed/plant (Gunnell 2017).

Nursery Practice

The following procedure was used to grow thickleaf beardtongue plugs (Q plug 30/50; 1.4 in top × 2.2 in deep) at GBRC (Landeem and Jensen 2022a). Clean, wild-collected seed was treated with gibberellic acid (250 ppm) for 24 hours prior to planting. Seeds were placed on paper towels saturated with the GA₃ solution in ziplock bags. Those that germinated were placed on the growth media and covered with 0.25 in of two parts sand and one part peat moss. Seed that did not germinate immediately was stratified in a cold room (36 °F [2 °C] for 12–20 wks). Seeded trays were put in a greenhouse and watered daily and fertilized biweekly (All purpose water soluble MiracleGro) until seedling establishment. Most germination occurred within 1 week in the greenhouse (65–85 °F [18–29 °C], 12 hr light/dark cycle). Plugs with more than once seedling were thinned to one and attempts to transplant thinned seedlings failed. Seedlings were considered established after two weeks in the greenhouse. Once seedlings were 2 in (5 cm) tall with their second set of true leaves, they were moved to a lath house for two weeks and watered as needed, which was almost daily. Seedlings were hardened for up to four weeks. Plugs were saturated prior to shipping in Hortiblock trays (Landeem and Jensen 2022a).

Wildland Seeding And Planting

Thickleaf beardtongue is recommended for pollinator and wildlife habitat and provides excellent soil protection at sites receiving 12 to 20 in (305–508 mm) of annual precipitation (Stevens and Monsen 2004; Tilley et al. 2013). It should be seeded in late fall or early winter at depths less than 0.14 in (0.4 cm) (Ogle et al. 2014). Drill seeding or broadcast seeding followed by covering the seed to ensure good seed-soil contact are recommended. Thickleaf beardtongue seeds are small and difficult to meter through most conventional drills (Stevens and Monsen 2004). It can be seeded in a mix with other forb species and if seeded alone, a carrier is often added to regulate planting rates. The pure stand seeding rate is 1 to 3 lbs/ac (1.1–3.4 kg/ha). The rate should be adjusted to provide the desired final stand compositions (Stevens and Monsen 2004; Ogle et al. 2014).

The Utah Division of Wildlife Resources has tested many species in restoration trials on depleted rangelands, roadcuts and fills, mine spoils, and seriously eroded hillsides (Plummer 1977). Based on knowledge gained through these trials, they rated thickleaf beardtongue as having very good establishment from seed or as transplants. Seed production and seedling growth rate were considered very good. Natural spread and adaptation to disturbance were rated good and soil stability was considered moderate (Plummer 1977).

A field study by Jensen et al. (2022) found that thickleaf beardtongue emergence decreased with increasing seeding depths and that this species is best suited to shallow seeding techniques like imprinting. The study

evaluated drill seeding depths of 0.5, 1, 1.4 and 1.6 in (1.4, 2.6, 3.6, and 4 cm) at three field sites. Sites were Wells, Nevada (2,677 ft [816 m]), with silt loam to loam soils, Orovada, Nevada (1,499 ft [457 m]), with very fine to silt loam soils, and Fountain Green, Utah (2,448 ft [746 m]), with silty clay loam soils. Site preparation included early fall harrowing followed by firming with a Brillion roller (Landoll Company, Marysville, KS). Emergence of thickleaf beardtongue decreased with increasing seeding depth by 24.7% at Wells, 26.4% at Orovada, and 44.8% at Fountain Green (Jensen et al. 2022).

Emergence of thickleaf beardtongue was among the highest of 10 forbs used in field trials testing the establishment of diverse forb islands. The forb species were seeded at Spanish Fork and Clarkston, Utah, and Virginia, Idaho, in November 2015 and experimental treatments to encourage establishment were evaluated. Treatments included snow fences to trap and create uniform snow drifts, and N-sulate fabric to moderate freezing and moisture conditions. Forb seedling emergence was highest at plots with snow fences in Spanish Fork and at control plots in Clarkston and Virginia. Thickleaf beardtongue was listed among the species with the highest seedling emergence at all three sites (Johnson et al. 2017).

Establishment of thickleaf beardtongue was low when seeded with a mix of six other forb species at four field sites in Utah (5,003 to 7,175 ft [1,525–2,187 m] elevation and 13 to 14 in [331–359 mm] annual ppt) (Table 9). Once seeded, plots at each site were covered with N-sulate fabric or left uncovered. Thickleaf beardtongue had low establishment regardless of treatment or site. Although emergence was improved on covered plots, the benefit of fabric was short-lived and did not result in seedling persistence (Landeem et al. 2021).

Table 9. Establishment of thickleaf beardtongue at four sites in Utah with and without N-Sulate fabric (Landeem et al. 2021).

Post-seeding yr	Fountain Green		Gordon Creek		Hatch Ranch		Lookout		Mean	
Treatment*	C	NC	C	NC	C	NC	C	NC	C	NC
1	0.25	0.11	0.99	0.32	0.66	0.05	0.17	0.09	0.52	0.14
2	0.01	0	0.39	0.31	0.07	0.12	0.01	0.01	0.12	0.11
5	0	0	0.03	0	0.03	0	0	0	0.02	0

*C: covered, NC: not covered. Bolded values were significantly different ($P < 0.1$).

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: Scott Jensen, USDA FS, Rocky Mountain Research Station and Rafael Urbina Casanova and Andrea Kramer, Chicago Botanical Garden.

This research was supported in part by the USDA Forest Service, Rocky Mountain Research Station. The findings and conclusions in this publication are those of the authors and should not be construed to represent any official USDA or U.S. Government determination or policy.

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How to Cite

Gucker, Corey L.; Shaw, Nancy L. 2022. Thicket beardtongue (*Penstemon pachyphyllus*). In: Gucker, C.L.; Shaw, N.L., eds. Western forbs: Biology, ecology, and use in restoration. Reno, NV: Great Basin Fire Science Exchange. <https://westernforbs.org/species/thicket-beardtongue-penstemon-pachyphyllus/>