

ROYAL PENSTEMON

Penstemon speciosus Douglas ex Lindl.
Plantaginaceae – Plantain family

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ORGANIZATION

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

Range, habitat, plant associations, elevation, soils.

Life form, morphology, distinguishing characteristics, reproduction.

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

Current or potential uses in restoration.

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

Recommendations/guidelines for producing seed.

Recommendations/guidelines for producing planting stock.

Recommendations/guidelines, wildland restoration successes/failures.

Primary funding sources, chapter reviewers.

Bibliography.

Select tools, papers, and manuals cited.

NOMENCLATURE

Royal penstemon (*Penstemon speciosus* Douglas ex Lindl.) is a member of family Plantaginaceae, the plantain family, subgenus *Habroanthus* (Keck) Crossw., section *Glabri* (Rydb.) Penn. Previously placed in the family Scrophulariaceae, the genus *Penstemon* was moved to Plantaginaceae based on DNA sequencing studies (see Olmstead 2002).

NRCS Plant Code. PESP (USDA NRCS 2017).

Synonyms. *Penstemon speciosum* Douglas ex Lindl., *P. glaber* var. *occidentalis* A. Gray, *P. glaber* var. *speciosus* Regel, *P. glaber* f. *speciosus* Voss, *P. kennedyi* A. Nels., *P. speciosus* subsp. *kennedyi* Keck, *P. piliferus* A.A. Heller, *P. speciosus* var. *piliferus* Munz & I.M. Johnston, *P. rex* Nels. & Macbr., *P. perpulcher* var. *pandus* Nels & Macbr., *P. pandus* Nels. & Macbr., *P. deserticola* Piper, *P. glaber* sensu A. Gray, *P. glaber* var. *utahensis* sensu Jepson (Cronquist et al. 1984).

Common Names. Royal penstemon, royal beardtongue, sagebrush beardtongue, sagebrush penstemon, showy penstemon (Cronquist et al. 1984; Tilley et al. 2009; LBJWC 2017; USDA NRCS 2017).

Chromosome Number. The species is diploid, $2n = 16$ (Crosswhite 1967; Hickman 1993).

Hybridization. Specific information on hybridization of royal penstemon with other members of the genus is not available. Lindgren and Schaaf (2007) reported some success with crosses between selected species of subgenus *Habroanthus* and with some crosses of *Habroanthus* species with members of subgenera *Penstemon* and *Dasanthera*. The species tested were not identified.

DISTRIBUTION

Royal penstemon occurs from the eastern slopes of the Cascade and Sierra Nevada Mountains eastward across central and southeastern Washington, eastern Oregon, and southwestern Idaho, and south through eastern California and Nevada to higher elevations in mountain ranges on the northern edge of the Mojave Desert (USDA NRCS 2017). A few populations are found in Utah.

Habitat and Plant Associations. Plants are found in openings in sagebrush (*Artemisia* spp.), antelope bitterbrush (*Purshia tridentata*), pinyon-juniper (*Pinus-Juniperus*), juniper, and mountain brush communities and ponderosa pine (*P. ponderosa*) and subalpine forests (Wright and Mooney 1965; Munz and Keck 1973; Cronquist et al. 1984; Hickman 1993; Strickler 1997).

Elevation. Royal penstemon grows over a broad elevational range of 700 to 11,300 feet (210–3,400 m) (SEINet 2017) that receives 8 to 24 inches (200–610 mm) of annual precipitation (USDA NRCS 2017).

Soils. Royal penstemon grows on loamy to sandy loam soils that are near neutral to slightly alkaline (Strickler 1997; Lindgren and Wilde 2003). It frequently colonizes eroding slopes and other disturbed sites with droughty, well-drained soils. Wright and Mooney (1965) found royal penstemon populations growing on sandstone and granite, but not on dolomite substrates at elevations above 9,000 feet (2,700 m) in bristlecone pine (*P. aristida*) communities of the White Mountains in California.

DESCRIPTION

Royal penstemon plants are highly variable, short-lived, tap-rooted perennial herbs that range from 6 to 16 (24) inches (15–40 [60] cm) tall (Hitchcock et al. 1959; Cronquist et al. 1984; Welsh et al. 1987). Stems are few to several, puberulent to sometimes glabrous, and range from erect to ascending or occasionally decumbent from a branched caudex (Hitchcock et al. 1959; Cronquist et al. 1984). Leaves are opposite, rather thick, entire, more or less sinuate, and glabrous or occasionally puberulent (Welsh et al. 1987; Hickman 1993). Basal leaves are clustered, petiolate, somewhat evergreen, up to 6 inches (15 cm) long and 0.5 (0.8) inches (1.2 [2] cm) wide, and vary from linear to lanceolate, obovate or spatulate (Hitchcock et al. 1959; Hickman 1993). Cauline

leaves are reduced upward, linear to lanceolate, subcordate, clasping, and folded lengthwise or flat (Cronquist et al. 1984; Hickman 1993). Leaves and stems may be purplish tinted. The inflorescence is an elongate, one-sided thyrse, an inflorescence with an indeterminate main axis and determinate subaxes (Fig. 1). There are sometimes thyrsoid branches from the lower nodes (Cronquist et al. 1984; Hickman 1993). Flowers are produced in 4 to 12 closely-spaced verticillasters (false whorls) along the inflorescence (Strickler 1997).



Figure 1. Royal penstemon plant in southeastern Oregon. Photo: USFS.

Flowers are complete and ascending to spreading. The five-toothed calyx is cuplike with the segments lanceolate to ovate with scarious and erose margins and acute to acuminate tips. The corolla is tubular, formed from five fused petals, 1.0 to 1.3 inches (2.5–3.2 cm) long, bilabiate, and glabrous. The corolla tube is swollen ventrally, and there are two ventral ridges. The two upper corolla lobes are spreading and the three lower lobes are spreading to reflexed. Color ranges from bright blue to purplish at the base, sky blue along the limb, and light blue to white in the interior. The four fertile stamens reach the apex with the longer pair sometimes extruded. Anther cells are divergent, 2 to 3 mm long and generally glabrous except for the papillate-toothed sutures. At maturity the anther cells dehisce along the

distal two-thirds of their length and twist into an S-shape (Hitchcock et al. 1959; Cronquist et al. 1984; Welsh et al. 1987). Glandular hairs near the bases of the upper stamens produce nectar (Straw 1966). The staminode is included and glabrous or sparsely bearded at the apex. It is attached apically to the roof of the corolla, but drops to the floor anterior to the ovary where it may provide some protection from insect herbivory (Straw 1966; Strickler 1997).

The fruit is a capsule, 0.2 to 0.6 inch (0.6-1.5 cm) long that opens apically. It becomes dry and parchment colored at maturity (Fig. 2). Seeds are brown, 2 to 2.5 (3.5) mm long, somewhat elongate and three-angled (Fig. 3; Cronquist et al. 1984; Hickman 1993; Hurd n.d.). The embryo is slightly curved and embedded in living endosperm (Fig. 4; Hurd n.d.). Seeds are gravity dispersed.



Figure 4. Royal penstemon seed: cross section and longitudinal sections. The embryo is surrounded by endosperm and the seed coat. Scale in mm. Photo: USFS.

Reproduction. Royal penstemon reproduces entirely from seed.

Breeding system. Cane (2006) found that royal penstemon set few seeds when pollinators were excluded. Manual pollen transfer more than doubled seed production compared with self-pollination, while insect pollination increased yields by more than five times. Royal penstemon flower attributes indicate insect rather than hummingbird pollination: corollas are blue to white and relatively short and wide, and pollen and concentrated nectar are dispensed slowly (Tepedino et al. 2011).

Floral phenology. Flowering may begin in the first or second year and occurs from May to August depending on location (Hitchcock et al. 1959; Hickman 1993). Flowering is indeterminate with flowers near the base of the inflorescence opening first. Flowering of the side branches is mostly determinate. Flowers are protandrous (the anthers mature before the stigmas) (Castellanos et al. 2002).

Castellanos et al. (2002) found the time from flower opening to fruit dehiscence averaged about 4.2 days in a royal penstemon population at 6,600 feet (2,000 m) in the southern Sierra Nevada Mountains of California. They described six stages of floral phenology: flower opening to (1) anterior anther dehiscence (0.2 day), (2) posterior anther dehiscence (0.4 day), (3) style tip bent $<45^\circ$ (1.3 days), (4) style bent $>45^\circ$ (1.6 days), (5) style bent 90° (1.9 days), and (6) corolla abscised (4.2 days). Style bending was assumed to indicate stigma receptivity as it positions the stigma to receive pollen carried by foraging bees or wasps after pollen from the same flower has been released, thus encouraging cross pollination (Chari and Wilson 2001). Nectar secretion began with corolla opening, slowing unless visited by a pollinator.



Figure 2. Royal penstemon with immature capsules (left) and mature capsule (right; scale in mm). Photos: USFS.



Figure 3. Royal penstemon seeds. Photo: J. Cane, USDA ARS.

Nectar was replaced within 3 to 4 hours following visitation, indicating some, though variable, homeostatic control (Castellanos et al. 2002). The process was repeated throughout the life of the flower, encouraging repeated visitation as the anthers released pollen. With abundant pollinator activity, Castellanos et al. (2002) predicted that most pollen would be removed by the time the stigmas become receptive and that the stigmas would be rapidly loaded.

Pollination. Cane and Love (2016) inventoried pollinator abundance and diversity at native forbs used in restoration to estimate their “pollinator friendliness.” Surveys were conducted at four Nevada sites in sagebrush steppe and its ecotones with pinyon-juniper woodlands. Solitary native bees of the genus *Osmia* (Mason bees) comprised half of the observed pollinators at royal penstemon (Cane and Love 2016), while the solitary pollen wasp (*Pseudomasaris vespoides*), which may sleep in the flowers at night (Nold 1999), accounted for 19.8% of the observed pollinators (Fig. 5). The remaining pollinators included the bee genera *Anthophora* (digger bees, 2.7%), *Bombus* (bumblebees, 8.1%), *Ceratina* (small carpenter bees, 0.9%), *Halictus* (sweat bees, 11.7%), *Hoplitis* (Mason bees, 1.8%) and *Lasioglossum* (sweat bees, 3.6%). Two Mason bees (*Osmia brevis* and *O. penstemonis*) and the solitary pollen wasp were pollen specialists



Figure 5. Royal penstemon visited by a solitary pollen wasp. Photo: Jim Cane, USDA ARS.

(oligoleges) that collect pollen for their offspring from a subset of penstemon species. *O. brevis*, for example, visited at least 42 penstemon species (Tepedino et al. 2011). The two Mason bees make shallow subterranean nests; the wasp makes free-standing mud nests on rock surfaces (J. Cane, USDA, ARS Logan, UT, personal communication, August 2017).

Compared to the other 16 forbs examined, royal penstemon exhibited moderate abundance and low diversity of pollinators (Cane and Love 2016). Eight genera were observed at royal penstemon compared to a range of 3 to 19 for the other 16 species examined. Abundance of pollinators at royal penstemon was 8.1 bees or wasps per 100 plants compared to 1.4 to 28.4 per 100 plants for the other forbs (Cane and Love 2016). In cultivation, flowers of royal penstemon were avidly sought out by diverse pollen-foraging bumblebees and sometimes by digger bees (J. Cane, USDA ARS, Logan, UT, personal communication, August 2017). Castellanos et al. (2002) noted hummingbird visits to royal penstemon flowers, but concluded they removed little pollen and were not important as pollinators.

ECOLOGY

Royal penstemon often colonizes steep and eroding slopes, road cuts and rights-of-way, and other disturbances (Tilley et al. 2009). It is adapted to well-drained soils and the low levels of competition encountered on such sites. Flowering royal penstemon in sagebrush communities of southern Idaho has been noted in the year following wildfire (Fig. 6; M. Fisk, USGS, Boise, ID, personal communication, June 2017). Although not a strong soil stabilizer, the species does provide ground cover, and it will reseed and reestablish itself unless more competitive vegetation establishes. Royal penstemon persists in later successional communities and may be found in openings in shrublands and forested areas where adapted.

Seed Ecology. Meyer and Kitchen (1994) examined the germination of 36 penstemon seed collections representing 13 *Penstemon* species in section *Glabri* of Subgenus *Habroanthus*. These were collected over an elevation range in Utah, Nevada, and Idaho. These collections included one royal penstemon population from a site at 5,940 feet (1,810 m) elevation in central Nevada. Seed of this collection incubated at 50 to 68 °F (10-20 °C) in light for 4 weeks exhibited high primary dormancy (1% germination). Prechilling at 34 °F (1 °C) for 12 weeks to simulate conditions

experienced under a snow pack followed by 4 weeks of incubation at 50 to 68 °F (10-20 °C) in light increased germination to 70%. Germination increased to 90% with 24 weeks of prechilling (Meyer and Kitchen 1994).



Figure 6. Royal penstemon one year after wildfire. Photo: Matt Fisk, USGS.

With a 4-week initial incubation of imbibed seeds at 50 to 68 °F (10-20 °C) as might occur with fall rains, 91% germination occurred following 12 weeks of prechilling. Chilling response was not cumulative if a 12-week prechilling was interrupted by periods of higher temperatures. This was simulated by 4-week incubations at 50 to 68 °F (10-20 °C) after either 4 or 8 weeks of prechilling, as might result from warmer periods in winter. Inadequate or interrupted prechilling in some years might permit some seed to remain dormant and be carried over in the soil seed bank (Meyer and Kitchen 1994).

Germination rate (days to 50% germination) during prechilling for the 13 penstemon species was negatively correlated to habitat as described by the mean January temperature at the collection site (Meyer and Kitchen 1994). Thus

seeds of species collected from sites with short winters tended to germinate more rapidly, while seed of species collected from sites with long winters germinated more slowly, possibly timing germination to early spring emergence. Dry after-ripening the seed for 1 year had little effect on these chilling responses (Meyer and Kitchen 1994). Whether royal penstemon seeds collected from populations over this entire elevation range exhibit a similar pattern is unknown.

When wild-collected seed of royal penstemon and five other section *Glabri* species were grown in a common garden, the parent populations and their progeny were characterized by generally similar levels of primary dormancy and responses to prechilling, suggesting a genetic basis for these responses (Meyer and Kitchen 1994). The size of the chill-responsive fraction of seeds was the most phenotypically plastic trait.

Species Interactions. Parkinson et al. (2013) examined competitive interactions of royal penstemon with native grasses or cheatgrass (*Bromus tectorum*) for 12 weeks in a greenhouse study. When grown alone, royal penstemon biomass was 1.5 ± 0.3 g. Its root system was distributed laterally and vertically with considerable branching throughout. The biomass of royal penstemon was not reduced, but its relative growth rate declined by 25% when grown with a single Sandberg bluegrass (*Poa secunda*) or squirreltail (*Elymus elymoides*) plant. When grown with a single cheatgrass plant, the biomass of royal penstemon was reduced by 91% and its relative growth rate by 80% compared to its growth alone. The decreases were attributed to the similar fibrous rooting morphologies of royal penstemon and cheatgrass and the higher growth rate of cheatgrass (Parkinson et al. 2013).

In a field experiment conducted at two sites in southern Idaho, royal penstemon biomass, but not density, was decreased by cheatgrass concurrently seeded at densities as low as 1.3 or 2.6 plants/ft² (14 or 28 plants/m²) (Parkinson 2008). In addition to the above factors, the earlier germination of cheatgrass (fall or early spring) compared to royal penstemon (early April) and the reported concentration of cheatgrass root mass in the upper 8 inches (20 cm) of soil in a study by Melgoza et al. (1990) may have contributed to its ability to compete effectively with later developing seedlings.

Wildlife and Livestock Use. Wildlife use of royal penstemon is not well documented. Parkinson found that Piute ground squirrels (*Urocitellus mollis*) began consuming emerging royal penstemon seedlings in a southern Idaho seeding

study in May (Parkinson 2008). All seedlings were consumed by late July.

Fajemisin et al. (1996) reported that royal penstemon constituted 0.1% of the ground cover in July on a Wyoming sagebrush steppe (*Artemisia tridentata* subsp. *wyomingensis*) site in south-central Oregon that supported a diversity of grasses and forbs. During a grazing trial, royal penstemon constituted 0.5% of the bites taken by Spanish goats (*Capra hircus*) in July, during the period of active growth. This figure increased to 2.3% of bites taken in August when forages had cured. This was consistent with the goat's overall greater preference for forbs over grasses (Fajemisin et al. 1996).

Horticulture. Royal penstemon can be used in gardens, parks, and urban landscaping to provide striking seasonal color. Tilley et al. (2009) and Way and James (1982) recommended that royal penstemon be treated as a biennial when used as a specimen plant for domestic landscapes. Nold (1999) noted that the lifespan of penstemon species in subgenus *Habroanthus*, section *Glabri*, can be prolonged by providing favorable growing conditions and removing the flowering stalks immediately after flowering. A few seed capsules can be allowed to develop to permit natural reseeding. For domestic plantings it may be necessary to improve drainage by adding sand or gravel to the planting beds.

There are no formal horticultural releases of royal penstemon. A dwarf form of the species found above 8,000 feet (2,440 m) in the Sierra Nevada and White Mountains of California is often grown in alpine gardens (Hickman 1993; Lindgren and Wilde 2003). The plants are generally less than 8 inches (20 cm) tall with grey-green leaves and large, deep blue flowers (Way and James 1982). Once known as *P. kennedyi* or *P. speciosus* subsp. *kennedyi*, these populations are now included in *P. speciosus* as they may sometimes be normal in height (Hickman 1993; Lindgren and Wilde 2003). The dwarf form is occasionally referred to as *P. speciosus* 'Kennedyi' in the commercial trade (Way and James 1982; Lindgren and Wilde 2003).

REVEGETATION USE

Royal penstemon can be seeded on road cuts and other unstable sites where it functions as an early seral species. It can be used to add diversity to seed mixes for community restoration following wildfire if competition from cheatgrass and other recovering or seeded vegetation is low during its establishment period. Royal penstemon can also

be used in recreation areas and low water-use landscaping projects to provide seasonal color. The species can be planted or seeded to provide habitat for its pollinators and other wildlife. Due to its brief flowering period, royal penstemon should be planted with species having different flowering phenologies to provide sequential pollen and nectar for its non-specialist pollinators, especially bumblebees, which will pollinate other species as well (J. Cane, USDA, ARS Logan, UT, personal communication, August 2017).

DEVELOPING A SEED SUPPLY

For restoration to be successful, the right seed must 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 select appropriate species and seed sources and to properly collect and grow, certify, clean, store, test, and distribute seed for use in revegetation projects.

Developing a seed supply begins with collection of seed 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 necessitate establishment of agricultural seed production fields. In all cases, seed certification is essential for tracking seed origin from collection through use.

Seed Sourcing. Because empirical seed zones are not currently available for royal penstemon, generalized provisional seed zones developed by Bower et al. (2014), may be used to select and deploy seed sources. These provisional seed zones identify areas of climatic similarity with comparable winter minimum temperature and aridity (annual heat:moisture index). In Figure 7, Omernik Level III Ecoregions (Omernik 1987) overlay the provisional seeds zones to identify climatically similar but ecologically different areas. For site-specific disturbance regimes and restoration objectives, seed collection locations within a seed zone and ecoregion may be further limited by elevation, soil type, or other factors.

The Western Wildland Environmental Threat Assessment Center's Threat and Resource Mapping (TRM) Seed Zone application (USFS WWETAC 2017) 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.

Wildland Seed Collection. Seed production in wildland royal penstemon populations varies widely from year to year, but affecting factors

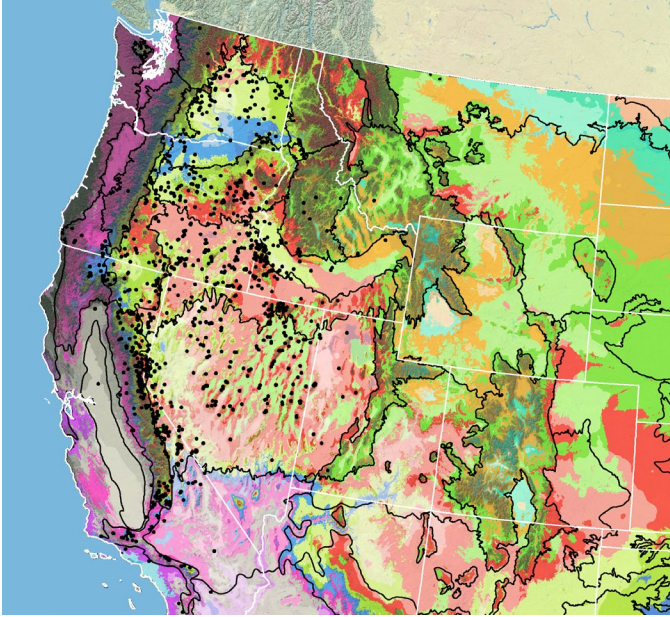


Figure 7. Distribution of royal penstemon (black circles) based on geo-referenced herbarium specimens and observational data from 1874-2016 (dates not provided for all points) (CPNWH 2017; SEINet 2017; USGS 2017). Generalized provisional seed zones (colored regions) (Bower et al. 2014) are overlain by Omernik Level III Ecoregions (black outlines) (Omernik 1987; USDI EPA 2017). 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.

have not been examined. Little or no seed may be present in some years. In the northern Great Basin, excellent seed crops have been noted in the year following wildfire (M. Fisk, USGS, Boise, ID, personal communication, June 2017).

Wildland seed certification. Wildland seed collected for direct sale or for establishment of agricultural seed production fields should be Source Identified through the Association of Seed Certifying Agencies (AOSCA) Pre-Variety Germplasm Program that verifies and tracks seed origin (Young et al. 2003; UCIA 2015). For seed that will be sold directly, collectors must apply for certification prior to making collections. Applications and site inspections are handled by the state where collections will be made. For seed that will be used for agricultural seed fields, nursery propagation or research, the same procedure must be followed. Seed collected by some public and private agencies following established protocols may enter the certification process directly, if the protocol includes collection of all data required for Source

Identified certification (see [Agricultural Seed Field 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.

Timing. Royal penstemon can be harvested when the stalks and capsules are dry and straw colored and the mature seeds are brown and firm. Seed fill should be checked with a cut or X-ray test. Variation in maturation dates occurs among plants within populations. Seed maturation within inflorescences is indeterminate. However, mature capsules open and seeds are dispersed slowly over time, so it is possible to delay collection until most or all capsules on a stalk or plant have matured. When possible, sites should be checked prior to harvest to determine whether an adequate seed crop is present for collection and to update harvest date predictions. Collection can occur over a 2- to 3-week period depending upon location and weather conditions. Harvest dates for 26 collections made at elevations from 2,203 to 6,152 feet (672-1,875 m) ranged from July 9 to August 16 over a 5-year period (USDI SOS 2017).

Collection methods. Seeds are most easily harvested from wildland stands by clipping mature inflorescences into collection bags, buckets, seed hoppers, or other containers. Gloves should be worn to protect the hands from cuts and splinters because the stalks are brittle. If capsules are opening, care must be taken to avoid seed loss by holding the stalks upright until they are deposited in a container to minimize spillage. Capsules may also be stripped from the flowering stalks. Although this method simplifies seed cleaning, it is a much slower collection process and results in greater seed loss from open capsules. Small quantities of nearly pure seed may be collected by shaking partially open capsules into a container, but this technique, in addition to being extremely time consuming, might reduce genetic diversity if only a fraction of the capsules have opened.

Several collection guidelines 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; collect from all microsites including the habitat edges, and avoid collecting from only the most robust plants (Basey et al. 2015). General collecting recommendations and guidelines are provided in online manuals (e.g. ENSCONET 2015; USDI BLM SOS 2017). As is the case with wildland collection of many other forbs, care must be taken to avoid inadvertent collection of weedy species,

particularly those that produce seeds similar in shape and size to those of royal penstemon.

Post-collection management. Molding can occur if green leaves and stems are collected along with the seeds, particularly if collections are made during high humidity periods. Vegetative material should be removed promptly by hand or with sieves. Harvested seed should be spread on racks in a protected area and thoroughly air dried in the field or following transport to a cleaning facility. 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 or use of appropriate chemicals.

Seed Cleaning. Very small seed lots of partially open capsules may be cleaned simply by shaking the seed from the capsules and sieving to remove fine debris. Larger samples can be cleaned using a hammermill or debarker to break up the capsules and release the seed (Fig. 6). Fine cleaning can then be accomplished using a clipper or seed blower (Meyer 2008). Personnel at the USFS Lucky Peak Nursery (USFS LPN 2017) remove debris using a scalper with a no. 6 top screen and 1/25 bottom screen. Material is then fed through a dewinger with a setting of 4 to move the stalks and capsules into the hopper, 6 for drum speed and 6 for the drum angle. The air is kept closed.

Barner (2007) recommended cleaning royal penstemon seed lots using a Westrup Model LA-H laboratory brush machine with a no. 7 mantel set at a medium speed. Material is then air-screened with an office clipper fitted with a no. 9 round or triangle top screen and a 1/24 round bottom screen and set at medium speed with medium air. A seed blower can be used to remove fine debris.

The cleanout ratio (clean seed weight:bulk collection weight) for seed lots of royal penstemon cleaned at the USFS Bend Seed Extractory and seed quality data for these lots are provided in Table 1 (USFS BSE 2017). Seeds are small, averaging more than 400,000/lb (882,000/kg) (Table 1). Other sources report similar values ranging from 309,800 to 429,000 seeds/lb (683,100-946,000 seeds/kg) (Maquire and Overland 1959; Shock et al. 2014; RGB-Kew 2017; USFS NSL 2017).

Marketing Standards. Walker and Shaw (2005) recommended a minimum of 95% purity and 66% viability as standards for royal penstemon seed purchases. Acceptable purity, viability, and germination specifications vary with revegetation plans. High purity and viability are required for precision seeding equipment used in nurseries

and agricultural seed fields. Lower purity may be acceptable for some wildland seeding techniques.

Table 1. Seed yield and quality of royal penstemon seed lots collected in the Intermountain region, cleaned by the Bend Seed Extractory, and tested by the Oregon State Seed Laboratory or the USFS National Seed Laboratory (USFS BSE 2017).

Characteristic	Mean	Range	Samples (#)
Bulk weight (lbs)	2.14	0.16 - 10.56	18
Clean weight (lbs)	0.48	0.06 - 3.73	18
Clean-out ratio	0.19	0.01 - 0.60	18
Purity (%)	92	57 - 99	18
Fill (%) ¹	93	82 - 99	18
Viability (%) ²	91	76 - 96	13
Seeds/lb	437,698	231,428 - 743,590	18
Pure live seeds/lb	366,441	206,314 - 677,708	13

¹100 seed X-ray test

²Tetrazolium chloride test

Seed Storage. Penstemon seeds are orthodox and store well in dry conditions (Meyer 2008). Data is not available for royal penstemon, but Stevens et al. (1981) found that seed of Palmer's penstemon (*P. palmeri*) germinated to 50% following 15 years of storage in an open warehouse. Lindgren and Schaaf (2004) monitored germination of four penstemons: foxglove penstemon (*P. digitalis*), large beardtongue (*P. grandiflorus*), Rocky Mountain penstemon (*P. strictus*) and 'Prairie Splendor' (a selection developed from *cobaea* beardtongue [*P. cobaea*] x Heller's beardtongue [*P. triflorus*] for 11 years of storage at 61 to 64 °F (16-18 °C) and 35% relative humidity. Emergence percentages were maintained for 4 to 5 years under these conditions.

Seed Testing. Testing methods are available for penstemons. A viability test is often used as a measure of seed quality due to the long stratification requirement for germination.

Purity and noxious weeds. A minimum sample size of 2.75 g of cleaned royal penstemon seed is recommended for estimating purity and the presence of noxious weeds (USFS NSL 2017). Purity tests are conducted following Association of Official Seed Analysts procedures (AOSA 2016).

Viability. Instructions for estimating the viability of family Scrophulariaceae species are provided in the AOSA Tetrazolium Testing Handbook (AOSA 2010). These instructions apply, even though the *Penstemon* genus has been moved to Family Plantaginaceae. In summary, imbibed seeds are pierced with a needle near the center of the seed adjacent to the embryo and soaked in 1% tetrazolium chloride (TZ). Seeds are then

sliced in half and evaluated for complete and even staining of the embryo and endosperm. Seeds are classified as nonviable if the embryo or the endosperm are unstained, any essential part of the embryo is unstained, the radicle is not completely stained or there is a dark coloration that may be indicative of disease problems.

Germination. Germination recommendations prescribe prechilling as a pretreatment to relieve physiological dormancy in royal penstemon. Lindgren and Wilde (2003) recommended an 8 to 12 week prechill. Maquire and Overland (1959) recommended a 1 to 4 week prechill at 37 °F (3 °C) followed by incubation at 68 °F (20 °C) in the dark.

The AOSA Rules for Testing Seed (AOSA 2016) includes a general rule that is used for testing all penstemon species. Specific rules for individual species are not available. Two tests are conducted to provide an estimate of viability and nondormant seed:

1. Viability (live seed percentage). Viability may be determined using the TZ test. As an alternative, seeds may be prechilled and treated with gibberellic acid (GA_3), a plant hormone, to relieve dormancy. Following incubation, germinated seeds are counted and nongerminated seeds are tested for viability. The sum of the germinated seed plus nongerminating viable seed is the live seed percentage.

2. Germinable (nondormant) seed percentage. Seeds are incubated without pretreatment. Only nondormant seeds will germinate. The difference between the two tests (viability minus germinable seed) is the percentage of dormant seed.

AGRICULTURAL SEED PRODUCTION

Only limited supplies of royal penstemon are collected from wildland stands. Cultural practices for producing royal penstemon seed have been developed and seed has been produced commercially (Fig. 8).

Agricultural Seed Field 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 procedures. State seed certification offices administer the Pre-Variety Germplasm (PVG) Program for 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.

Establishment. Studies begun in 2005 by Shock et al. (2015c) examined cultural practices for seed production of royal penstemon at the Oregon State University Malheur Experiment Station (OSU MES) located in southeastern Oregon (elevation: 2,260 feet [689 m], mean annual precipitation: 11.1 inches [279 mm]). Stands were seeded in fall (late October or November) to provide for overwinter cool prechilling and early spring seedling emergence.

Establishment studies initiated in 2012 and 2013 examined seven combinations of seed treatment with fungicides Thiram and Captan, seed covers (sawdust, sand) and mulch (N-sulate, a plastic mulch; hydroseeding, a paper mulch) (Shock et al. 2014, 2015a). Seeds were planted at a rate of about 30/linear foot (76/linear m) in November each year to provide for overwinter cool prechilling and early spring seedling emergence. .

In 2013 establishment was improved ($P < 0.05$) relative to the control (0.1% stand) only by combinations that included row cover and seed treatment. The addition of sawdust or sand did not result in further significant increases. The range for these treatments was 27 to 33.1% (Shock et al. 2014). In April 2014, only the combination of row cover, seed treatment, sawdust and sand (12.2% stand) improved stand compared to the control (0.7% stand) ($P < 0.05$) for plots planted in fall 2013 (Shock et al. 2015a).



Figure 8. Royal penstemon irrigation test plots at OSU MES, Ontario, Oregon. Photo: USFS.

At the NRCS Aberdeen Plant Material Center, seed fields of royal penstemon were established from greenhouse-grown container seedlings (Tilley et al. 2009). Weed barrier fabric was used to reduce weed problems. Seedlings were planted in holes 3 to 4 inches (8-10 cm) in diameter at 9- to 16-inch (23- to 41-cm) spacings.

Crop Phenology. Adequate flowering for seed harvesting occurred in the first year following seeding at OSU MES (Shock et al. 2016). Over the 10-year period from 2006 to 2015, flowering was initiated between April 28 and May 25 (\bar{x} = May 7), peak flowering occurred between May 5 and 30 (\bar{x} = May 17, 7 years of data), and flowering was completed by May 30 to June 30 (\bar{x} = June 17). Seed was harvested between June 30 and July 29 (\bar{x} = July 15) (Shock et al. 2016).

Weed Control. Weed control was accomplished at OSU MES primarily by hand rouging and cultivation (Shock et al. 2015b). Research was conducted to identify herbicides effective for weed control and plant tolerance on local soils (Shock et al. 2007, 2008, 2009a, 2009b, 2010a, 2010b, 2011). Herbicides are not registered for this species, and the results do not constitute an endorsement of specific companies or products or recommendations for use. The research, however, could contribute to future registration efforts.

Preemergent herbicide trial results (Shock et al. 2008, 2011) indicated that royal penstemon plant stand was not reduced by Treflan HFP (0.375 lb ai/acre), Balan 60 DF (1.2 lb ai/acre), Outlook 6.0 EC (0.656 lb ai/acre), or Lorox 50 DF (1.0 lb ai/acre) applied in fall (late November) after seeding. Plant stand was reduced by Prefar 40 EC (5 lb ai/acre), Kerb 50 WP (1.0 lb ai/acre) and Prowl H2O 3.8 SC (0.75 lb ai/acre). Considerable plant injury resulted from Prowl and to a lesser extent from Balan applications. A follow-up study indicated that activated charcoal (Gro-Safe[®], Norit Americas, Atlanta, GA, 48 lbs/acre) applied over the seed rows protected emerging royal penstemon from Prowl H₂O[®] 3.8 SC (0.75 lb ai/acre) when used as a preemergent compared to rows without the charcoal (34.8% emergence with charcoal compared to 3.3% without) (Shock et al. 2011).

Seven herbicides were evaluated for postemergent weed control with treatments repeated annually from 2006, the establishment year, through 2008 (Shock et al. 2009b, 2010b, 2011). In 2006 plant stand was not reduced by any of the herbicides compared to the untreated check. Extensive plant injury resulted from Caparol FL 4.0 (0.8 lb ai/acre) and lesser amounts from Lorox 50 DF (0.5 lb ai/acre) applications. Buctril

2.0 EC (0.125 ai/acre), Goal 2XC (0.125 lb ai/acre), Select 2.0 EC + Herbimax (0.094 lb ai/acre + 1% v/v) and Outlook 6.0 EC (0.656 lb ai/acre) caused only limited damage while Prowl H₂O 3.8 SC (1.0 lb ai/acre) damage was marginal. Relative to the check, seed yields were reduced by Bactril, Goal, Caparol and Lorox applications in 2007, but none of the herbicides reduced yields in 2008.

Promising herbicides for development of a weed control program for native forbs were further tested at various rates and in combinations (Shock et al. 2009a, 2010a, 2011). These included: (1) Select 2.0 EC (0.094 lb ai/acre) to provide foliar-active grass control; (2) Separate treatments with Outlook (0.84 or 0.98 lb ai/acre) or Prowl (0.95, 1.19 or 1.43 lb ai/acre), both broad spectrum soil-active herbicides to provide season-long control; and (3) Combinations of Prowl at 0.95 or 1.19 lb ai/acre with Outlook at 0.66, 0.84, or 0.98 lb ai/acre. Seed yield of all treatments was similar to the control.

Insect Pests. Lygus bugs (*Lygus hesperus*, western tarnished plant bug) will attack royal penstemon. Lygus bugs have sucking mouth parts and can cause extensive loss of flowers, developing seeds, and leaves. Black tar-like drops (penstemon tears) (Fig. 9) are produced near royal penstemon flower buds damaged by lygus bugs. These insects are common in alfalfa (*Medicago sativa*) fields and on smotherweed (*Bassia* spp.) and other weeds. They can be expected to migrate into nearby fields or native populations of penstemon (Hammon 2014). Hammon (2014) reports that sweeps capturing one or more immature lygus bugs pre-bloom and increased catch sizes over time can indicate a need for control measures in valuable crops. Several insecticides available for control of lygus bugs in alfalfa can be applied to royal penstemon before or during bloom (Hammon 2014). Pyrethroids applied pre-bloom provide residual control of immigrating lygus bugs without harming pollinators. Dibrom[®] (a.i.: Naled, an organophosphate), when applied at night, will kill insects, but has a short residual. Rimon[®] (a.i.: Novaluron, a growth regulator), affects immature insects as they molt, but will not affect adult insects. Prompt and appropriate timing of applications is critical to effectively control lygus bugs, protect pollinators, and provide for human safety. Local individuals with expertise in producing alfalfa seed can advise on herbicide selection and treatment timing (Hammon 2014).

At the OSU MES, the first hatch of lygus bugs appears when 250 degree-days accumulate (52 °F [11 °C] base) (Shock et al. 2015b). From 1995 to 2010, the average first hatch date was May 18, which coincided with the period of early to

peak flowering for royal penstemon. Prolonged infestation and low seed set resulted from an early hatch in 2007 that was not adequately controlled by the insecticide treatment (Aza-Direct® [ai.: azadirachtin] at 0.0062 lb ai./ha, applied in May). Capture at 0.1 lb/acre and Orthene at 8 oz/acre (a contact and residual systemic) were applied during flowering or pre-flowering in subsequent years to control lygus bugs (Shock et al. 2016).



Figure 9. Royal penstemon “tears” (arrow). These are black tar-like drops produced near flower buds following lygus bug predation. Photo: USFS.

Pollinators. In cultivated gardens, four *Bombus* (bumble bee) species: Great Basin bumble bee (*B. centralis*), yellow bumble bee (*B. fervidus*), brown-belted bumble bee (*B. griseocollis*), and Hunt’s bumble bee as well as a digger bee, all generalist (polylectic) bees, were observed to sonicate (buzz pollinate) royal penstemon flowers for pollen (Fig. 10; Cane and Love 2016). Honey bees (*Apis mellifera*) placed within a royal penstemon plot did not visit its flowers. Because of the high cost of commercial bumblebee colonies, locating royal penstemon seed production fields near suitable habitat or creating suitable habitat for unmanaged bumblebees and ground nesting bees may be

required to insure pollination. Careful use of insecticides and restriction of cultivation during the period of bee nesting is recommended (Cane 2008).

Irrigation. Subsurface drip Irrigation requirements for royal penstemon were examined at OSU MES using subsurface drip irrigation (Shock et al. 2015b). This system provides precise application of water directly to the root system and away from crown tissues. This minimizes water use and reduces water availability to weed seeds. Drip lines were placed 12 inches (30 cm) deep between alternate rows (30-inch [76-cm] row spacing). Zero, 4, or 8 inches (0, 100, 200 mm) of supplemental water was added in four equal applications at 2-week intervals beginning with flowering. From 2006 to 2015, irrigation began between April 19 and May 20 (\bar{x} = May 5) and ended between June 3 and June 5 (\bar{x} = June 18). Seed yield of royal penstemon demonstrated a quadratic response to irrigation with the maximum response with 5 inches (130 mm) of irrigation. Irrigation of 4 to 8 inches (100–200 mm) supplemental water was recommended for warm, dry years, and none for cool, wet years (Shock et al. 2016).



Figure 10. Royal penstemon flower pollinated by a bumblebee (*Bombus* spp.). Photo: Jim Cane, USDA ARS.

Harvest, Cleaning, and Yields. Seed was harvested at the OSU MES with a Wintersteiger Nurserymaster small-plot combine with an alfalfa seed concave (Shock et al. 2015b). Seed was threshed by the combine and further cleaned with a clipper seed cleaner.

Yields from small plots over 10 years averaged 108.3 lbs of cleaned seed/acre (121.4 kg/ha) with no irrigation, 177.8 lbs/acre (199.3 kg/ha) with 4 inches (100 mm) of applied water and 151.1 lbs/acre (169.4 kg/ha) with 8 inches (200 mm) of applied water (Shock et al. 2016). In 2007 yields

were drastically reduced by lygus bug infestations. Poor vegetative growth in 2007 and 2009 resulted in very low seed set, and root rot negatively affected plants receiving the higher irrigation rates. Natural reseeding occurred within plots and increased subsequent production. However, if natural reseeding in an agricultural seed field exceeds certification limits and is not controlled in any year, then the generation designation for the field must be increased. Based on 10 years of data, Shock et al. (2016) estimated stand life at 3 years with expected yields of 25 to 350 lbs/acre (30-390 kg/ha).

NURSERY PRACTICES

Nursery stock of royal penstemon has largely been produced for domestic horticulture and research. Seedlings could also be used to improve aesthetics in parks, along roadways, and other low-maintenance landscaping. Container seedlings of native wildflowers are beginning to see increased use for forb island plantings on wildland sites. Forb islands are clusters of plants planted in favorable locations where site preparation and management are most feasible. The aim is to provide for eventual spread from limited supplies of expensive seed.

Seed used for production of container stock must first be prechilled to release dormancy. Alternatively, dormancy can be relieved by watering with 250 ppm gibberellic acid (Tilley et al. 2009). Pretreated seeds or germinants can then be planted in containers filled with standard soil mixes. Cropping time is about 3 months. Detailed information on propagation of native plants can be found in Landis et al. (1989-2010) and Dumroese et al. (2012). Seedlings should be carefully acclimated before outplanting. Stock may also be held outdoors until needed.

WILDLAND SEEDING AND PLANTING

Careful planning is required to develop seed supplies of royal penstemon for use in native seedings. Sources can be developed by harvesting seed from multiple locations within a provisional seed zone (Bower et al. 2014) or other area of interest. Seed increase via contracting for production in agricultural fields is generally required as adequate seed cannot be harvested from wildland populations, which are often limited

in size and should not be over collected. Increased seed can be used directly on planned projects or stored for inclusion in seed mixes for post-fire or other unforeseen disturbances within the collection area. Past wildfire and seeding records for individual provisional seed zones can be used to aid in estimating future seed needs.

Because of the low competitive ability of royal penstemon with cheatgrass (Parkinson 2008, Parkinson et al. 2013), it should be seeded in areas where cheatgrass seed density has been reduced by wildfire or other treatments and is not expected to recover rapidly (Ott et al. 2016b). To avoid competition with more rapidly growing seeded grasses and forbs having similar root morphologies, royal penstemon should be seeded in separate rows or areas, either alone or with other slow growing species with different rooting habits (Fig. 11; Parkinson 2008). This would reduce spatial overlap and interspecific competition for resources while increasing the diversity of species and life forms. Cane et al. (2007) suggested that royal penstemon pollinators *Osmia brevis* and *O. penstemonis* may have shallow underground nests, in which case they and the surface nesting *Pseudomasaris vespoides* would be susceptible to soil heating by wildfires (Cane and Neff 2011) or soil disturbance resulting from mechanical site preparation practices. Loss of specialist pollinators would restrict seeding of royal penstemon to areas near native vegetation that are likely to harbor the pollinators (Cane and Love 2016).



Figure 11. Royal penstemon in a post-fire study plot in southern Idaho.

Fall seeding is essential to provide the prechilling required to release seed dormancy (Meyer and Kitchen 1994). The small seeds require near

surface planting and firming into the soil. This can be accomplished using a billion-type seeder, imprinter units, or other equipment modifications that preclude planting the seeds too deep (Ott et al. 2016b). Seeding rates depend on seed availability and the nature of the seeding mix, specifically the number of other forbs included and the desired composition of the resulting community (Ott et al. 2016b).

Ott et al. (2016a, 2017) examined the use of two rangeland drills (minimum-till and conventional) for seeding diverse native seed mixes after fire in Wyoming big sagebrush communities in the northern Great Basin. Larger seeds (primarily grasses) were seeded in alternate rows in each plot. Grasses, forbs, and shrubs with small seeds were either: 1) concurrently drill seeded in the remaining rows, 2) hand broadcast immediately following fall seeding of the large-seeded species, or 3) hand broadcast in mid-winter. Broadcasting simulated aerial seeding. Royal penstemon was seeded at a rate of 1.4 pure live seeds (PLS)/ft² (15 PLS/m²) with other small-seeded species at one site in southern Idaho. For plots where small-seeded species were drill seeded, the disks of each drill lifted and the seed was broadcast along the row through the seed drops. The minimum-till drill pressed the seeds into the surface with patterned imprinter wheels. The conventional drill covered the seed with drag chains. After 2 years, establishment of royal penstemon was greater when seeded with the minimum-till drill (0.06 ± 0.01 seedling/ft² [0.7 ± 0.1 seedlings/m²]) than the conventional drill (0.04 ± 0.01 seedlings/ft² [0.4 ± 0.1 seedlings/m²]). Drill seeding was more effective than hand broadcast seeding in fall or winter. Hand broadcast seeding in fall was more effective than broadcast seeding in mid-winter (J. Ott, USFS Rocky Mountain Research Station, data on file, June 2017).

Seedlings emerge in mid-spring and develop a rosette of leaves in the first season (Fig. 12). In southern Idaho, following a cool, moist spring, some seeded plants flowered in their first season (N. Shaw, USFS, Boise, ID, data on file). Plants are not long-lived (Shock et al. 2016), but spread from seed may occur if competition from other vegetation is not excessive. Management to control seedling predation may be required, and livestock grazing should be deferred until all seeded species and recovering native plants have reached maturity. Monitoring can provide valuable data for improving management and strategies for future seedings.

If seed supplies are limited, royal penstemon seed should be planted only in the most favorable sites for establishment. As an alternative, seedlings can

be planted in spots prepared to limit competition. Initial watering may be required for planted seedlings if the soil is dry.



Figure 12. Royal penstemon seedling emerging from a post-fire seeding in southern Idaho. Photo: USFS.

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HOW TO BE A SEED CONNOISSEUR

<http://www.utahcrop.org/wp-content/uploads/2015/08/How-to-be-a-seed-connoisseur20May2015.pdf>

OMERNIK LEVEL III ECOREGIONS

<https://www.epa.gov/eco-research/ecoregions>

SEEDLOT SELECTION TOOL

<https://seedlotselectiontool.org/sst/>

SEED ZONE MAPPER

<https://www.fs.fed.us/wwetac/threat-map/TRMSeedZoneMapper.php>

COLLABORATORS



RESOURCES

AOSCA NATIVE PLANT CONNECTION

https://www.aosca.org/wp-content/uploads/Documents///AOSCANativePlantConnectionBrochure_AddressUpdated_27Mar2017.pdf

BLM SEED COLLECTION MANUAL

https://www.blm.gov/sites/blm.gov/files/programs_natural-resources_native-plant-communities_native-seed-development_collection_Technical%20Protocol.pdf

ENSCONET SEED COLLECTING MANUAL

https://www.kew.org/sites/default/files/ENSCONET_Collecting_protocol_English.pdf