Firecracker penstemon (Penstemon eatonii)

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Nomenclature

Firecracker penstemon (*Penstemon eatonii* A. Gray) was named for Daniel Cody Eaton (1834Ð1895), a Yale botanist, who discovered the species (Fagan 1998; Lindgren and Wilde 2003). It is a member of the family Scrophulariaceae, subgenus *Penstemon*, and section *Elmigera* (Freeman 2019).

Family

Scrophulariaceae Ð Figwort family

Genus

Penstemon

Species

eatonii

NRCS Plant Code

PEEA (USDA NRCS 2022).

Subtaxa

The following subspecies are recognized by Flora North America (Freeman 2019) and USDA NRCS (2022) *Penstemon eatonii* subsp. *eatonii*, *P. e.* subsp. *exsertus* (A. Nelson) D.D. Keck, and *P. e.* subsp. *undosus* (M.E. Jones) D.D. Keck.

Synonyms

P. centranthifolius sensu S Wats., *P. eatonii* var. *undosus* M.E. Jones, and *P. coccinatus* Rydb. (Cronquist et al. 1984).

Common Names

Firecracker penstemon, EatonÕs penstemon, EatonÕs firecracker penstemon, EatonÕs beardtongue, pride of the mountain, scarlet-bugler penstemon (Cronquist et al. 1984; Nold 1999; Ogle and Peterson 2003; St. John et al. 2011; Hitchcock and Cronquist 2018; DaveÕs Garden 2022).

Chromosome Number

2n = 16 (Cronquist et al. 1984).

Hybridization

P. xjonesii Pennell (*P. e.* var. *undosus* × *P. laevis* [southwestern beardtongue]) (Nold 1999; Welsh et al. 2016); *P. xcrideri* (CriderÕs penstemon, *P. pseudospectabilis* [desert penstemon] × *P. eatonii*), and *P. xmirus* (*P. palmeri* [Palmer penstemon] x *P. eatonii*) (Nold 1999). Wilson and Valenzuela (2002) reported a single, likely sterile, *P. centranthifolius* [scarlet bugler] × *eatonii* plant from the San Bernardino National Forest in California.

Distribution

Firecracker penstemon is native to northern Arizona, northwestern New Mexico, southern California, east central and southern Nevada, central and southern Utah, and southwestern Colorado (Munz and Keck 1973; Hitchcock and Cronquist 2018). It occurs in all North American deserts except the Chihuahuan and in the Colorado Plateau, Wasatch Mountains, Utah Canyonlands, San Bernardino Mountains, and Arizona mountains and sky islands (Cronquist et al. 1984; Taylor 1992; Taylor 1998; Xerces Society & USDA NRCS 2012). It has become naturalized in some areas outside

its natural range through its use in revegetation along highways and other seedings (Strickler 1997; Way and James 1998).

Subspecies *eatonii* occurs throughout the distribution of the species but is most common in the northern part of this range (Cronquist et al. 1984; Hickman 1993; USDA NRCS 2022). Subspecies *undosus* occurs across much of the speciesÕ range but is more common in southern Utah, New Mexico, Arizona, and southern California (Munz and Keck 1973; Cronquist et al. 1984; Hickman 1993; USDA NRCS 2022). Subspecies *exsertus* is limited to central Arizona (Cronquist et al. 1984; Strickler 1997; USDA NRCS 2022).

Habitat And Plant Associations

Firecracker penstemon grows on well-drained, slightly acidic to slightly basic sandy loams and gravelly to rocky sites on dry plains, slopes, and cliffs. It is often found on rocky canyon walls, mountain ridges, mesas, and talus slopes. It occupies these habitats in sagebrush (*Artemisia* spp.)-grassland, cold and mixed-desert shrub, blackbrush (*Coleogyne ramosissima*), creosote bush (*Larrea tridentata*); mountain brush, mountain mahogany (*Cercocarpus* spp.), pinyon-juniper (*PinusÐJuniperus* spp.), quaking aspen (*Populus tremuloides*), and ponderosa pine (*Pinus ponderosa*) vegetation types (Fig. 1) (Munz and Keck 1973; Whitney 1982; Shaw and Monsen 1983; Cronquist et al. 1984; Stevens et al. 1985; Fagan 1998; Dorn and Dorn 2007; Ogle et al. 2012). Firecracker penstemon prefers full sunlight and 10 in (250 mm) or more of annual precipitation. Plants can survive cold winter temperatures if insulated by snow (Ogle et al. 2012; Ley et al. 2018).

Figure 1. Firecracker penstemon growing at a forest edge in Mesa Verde National Park, Colorado. Photo: M. Lavin, Montana State University (MSU).

At the Nevada Test Site and in south-central Nevada, firecracker penstemon grows in open shrub-woodlands of

sagebrush and pinyon-juniper associations at 6,000 to 8,000 ft (1,800Ð2,400 m) in elevation with big sagebrush (*A. tridentata*), black sagebrush (*A. nova*), single-leaf pinyon (*P. monophylla*) and Rocky Mountain juniper (*J. scopulorum*) (Beatley 1976). In Clark Canyon in the Spring Mountains of southern Nevada, firecracker penstemon extends upward from sagebrush and pinyon-juniper communities to 7,000 to 8,000 ft (2,100Ð2,400 m) in elevation where it grows beneath a closed canopy of white fir (*Abies concolor*) and ponderosa pine. On Bald Mountain in the volcanic Groom Range of Nevada, it occurs with white fir at 8,000 ft (2,400 m) elevation (Beatley 1976).

In southern Utah, subspecies *undosus* grows in creosote, mesquite (*Prosopis glandulosa*), desert willow (*Chilopsis* spp.), blackbrush, joint-fir (*Ephedra* spp.), rabbitbrush (*Chrysothamnus* spp.), sagebrush, pinyon-juniper, buffaloberry (*Shepherdia* spp.), oak-maple-serviceberry (*Quercus*Ð*Acer*Ð*Amelanchier* spp.), ponderosa pine, and quaking aspen communities (Welsh et al. 2016). In the Uinta Basin of eastern Utah, subspecies *eatonii* occurs from the Tavaputs Plateau eastward to the Avintaquin and Currant Creek drainages on rocky slopes and roadcuts in mountain big sagebrush (*A. t.* subsp. *vaseyana*) communities at 7,300 to 7,500 ft (2,220Ð2,290 m) elevation (Goodrich and Neese 1986).

Elevation

Firecracker penstemon occurs over a wide elevation range. Baskin and Baskin (2020) reported a low elevation limit of 1,600 ft (500 m), and Blackwell (2006) reports that it occurs up to 11,000 ft (2,400 m) in elevation in central and eastern Nevada and western Utah (e.g., Toquima Range, Deep Creek Mountains). Lindgren and Wilde (2003) reported an elevation range of 2,750 to 6,000 ft (840Ð1,800 m) in Arizona, Utah, and the Mojave Desert, while Shaw (1995) provided an elevation range of 4,000 to 9,000 ft (1,200Ð2,700 m) in Utah. Subspecies *exserta* reportedly occurs over an elevation range of 2,000 to 7,000 ft (600Ð2,100 m) in Arizona (Xerces Society & USDA NRCS 2012). Subspecies *eatonii* grows at 4,500 to 9,700 ft (1,370Ð2,950 m) in elevation in Utah and Nevada, while subspecies *undosus* is found at 2,850 to 7,500 ft (870Ð2,290 m) in elevation in southern Utah (Welsh et al. 2016).

Soils

Firecracker penstemon is common on well drained silt loam to sandy soils and often occurs on gravelly and rocky sites (Fig. 2) (Stevens et al. 1985; Ley et al. 2018). Eldredge et al. (2013) listed its pH tolerance range as 7 to 8. It does not tolerate salinity.

Figure 2. Firecracker penstemon growing at a sandstone cliff edge in Mesa Verde National Park, Colorado. Photo: M. Lavin, MSU.

Description

Firecracker penstemon is a short-lived, clumping, semi-evergreen perennial forb that grows 1 to 3 (4) ft (0.3Ð0.9 [1.2] m) tall (Fig. 3) (Munz and Keck 1973; Shaw and Monsen 1983; Stevens et al. 1985; Eldredge et al. 2013). One to a few upright to ascending or reclining stems develop from a short-branched woody caudex (Cronquist et al. 1984; Dorn and Dorn 2007; Ogle et al. 2012). The plants produce a taproot and fibrous roots. Leaves are leathery, entire with wavy margins, and glabrous to puberulent (Fig. 4) (Munz and Keck 1973; Cronquist et al. 1984; Hickman 1993; Fagan 1998). Lower leaves are clustered, dark green, oblanceolate and 1 to 4 (8) in (3Ð10 [20]) cm long with petioles nearly as long. Cauline leaves are opposite, lanceolate to oblong, 2 to 4 in (4Ð10 cm) long, 0.4 to 1.2 in (1Ð3 cm) wide, and clasping to sessile upward (Munz and Keck 1973; Hickman 1993; Fagan 1998). Subspecies *eatonii* has glossy, glabrous foliage, while that of subspecies undosus is puberulent (Cronquist et al. 1984; Hickman 1993; Nold 1999). Subspecies *exsertus* has puberulent herbage and exserted yellow anthers (Cronquist et al. 1984; Nord 1999).

Figure 3. Firecracker penstemon plants growing on the roadside near Craters of the Moon National Monument, Butte County, ID. These plants were likely part of a seed mix applied near the road. Photo: M. Lavin, MSU.

Figure 4. Firecracker penstemon produces waxy leathery leaves with bases that clasp the stem. Photo: M. Lavin, MSU.

The inflorescence is terminal and about half the length of the stem with 4 to 12 verticillasters (whorls) of flowers, mostly on one side (Fig. 5) (Munz and Keck 1973; Dorn and Dorn 2007). The peduncles and pedicels are short and glabrous to puberulent. Calyx segments ([3.5] 4Ð5 [6] mm long) are ovate, glabrous, and acute to abruptly short-acuminate, with the margins scarious and entire to slightly erose (Strickler et al. 1997; Dorn and Dorn 2007). The corolla is red orange to bright red and 0.9 to 1.3 in (2.4-3.3 cm) long with the long, narrow tube gradually expanding apically and often drooping (Hickman 1993; Dorn and Dorn 2007). Flowers are slightly two-lipped with two lobes in the upper lip and three in the lower (Fig. 6) (Whitney 1982). The lobes are small, glabrous, ovate, subequal, and projecting forward to barely spreading (Munz and Keck 1973; Hickman 1993; Dorn and Dorn 2007). The staminode is white, included, and glabrous to sparsely bearded at the apex. The four fertile stamens are included, or they may reach the orifice (they are exserted in subsp. *exsertus*). Anther cells are hairy and dehisce distally to half to three-quarters of the cell length and are indehiscent at the connective. There are two nectaries at the base of the upper stamens. The stigma is capitate (Munz and Keck 1973). Capsules (10Ð14 mm long) are egg-shaped, septicidal, and contain numerous seeds (Munz and Keck 1973; Taylor 1998). Food reserves of the embryo are the leaf-like cotyledons and fleshy endosperm (AOSA 2010).

Figure 5. Firecracker penstemon inflorescences with flowers on primarily one side of the flowering stem. Photo: USFS.

Figure 6. Single firecracker penstemon flower is slightly two-lipped with two lobes in the upper lip and three in the lower. Photo: M. Lavin, MSU.

Reproduction

Firecracker penstemon reproduces from seed. Plants may be propagated from stem cuttings and division in spring or fall (Kratsch and Hunter 2009).

Phenology

Flowering dates depend on location and range from early spring through early fall (Munz and Keck 1973; Cronquist et al. 1984; Nord 1999; Lindgren and Wilde 2003; Ogle et al. 2012). Flowering in the Great Basin occurs from May to July (Blackwell 2006). At 4,000 to 9,000 ft (1,200Ð2,700 m) in elevation in Utah, firecracker penstemon flowers from May through early August (Shaw 1995). In Canyonlands, parts of the Colorado Plateau, and the Grand Canyon flowering occurs from April to July (Fagan 1998; Whitney 1982). In the Mojave and Sonoran deserts, parts of the Colorado Plateau and Arizona mountains and Sky Islands at 2,000 to 7,000 ft (610Ð2,100 m) in elevation, flowering occurs from February to June (Xerces Society & USDA NRCS 2012).

Breeding System

Firecracker penstemon flowers are perfect and cross pollinated by hummingbirds, butterflies, and bees.

Pollination

Firecracker penstemon is pollinated primarily by hummingbirds, bees, and butterflies (Ogle et al. 2012; Ley et al. 2018). Evolution to favor hummingbird attraction, nectar foraging, and pollination is indicated by the long, narrow

corolla tube with little flare and small corolla lobes (Fig. 7), lack of a scent, red coloration, abundant dilute nectar, and anthers and stigma positioned to pick up or place pollen on the facial feathers of hummingbirds (Bateman 1980; Taylor 1998; Thomson et al. 2000; Wilson et al. 2004). Bateman (1980), however, noted pollination by a few small members of the Formicidae, Halictidae, and Megachilidae. Small generalist bees such as sweat bees (*Lasioglossum* spp.) collect nectar and pollen from firecracker penstemon without affecting pollination (Cane and Dunne 2014). Cane and Dunne (2014) found that firecracker penstemon is pollinated by honeybees (*Apis mellifera*) as well as generalist (polylectic) native bees including the solitary anthophorine bee (*Anthophora ursina*). At a farmed field of firecracker penstemon near Worland, Wyoming, abundant seed crops resulted from primarily bee pollination. The slightly flared anther lobes, bright reflection of ultraviolet light by the anther rims, and the wide forward opening of the anther sacs appeared to favor access by these bees, but not by penstemon-specific bees. Floral structure facilitating pollination by both hummingbirds and bees may indicate that firecracker penstemon is intermediate on an evolutionary pathway from bee pollination to hummingbird pollination. A diversity of pollinators may provide more reliable visitation over time (Cane and Dunne 2014).

Figure 7. Individual firecracker penstemon flowers have long narrow corolla tubes. Photo: M. Lavin, MSU.

Ecology

Firecracker penstemon is adapted to rocky and gravelly disturbances (Fig. 8), but also occurs in later successional communities.

Figure 8. Firecracker penstemon plants growing where it was seeded near Craters of the Moon National Monument, Butte County, ID. Photo: M. Lavin, MSU.

Seed And Seedling Ecology

Seeds of firecracker penstemon exhibit physiological dormancy (Baskin and Baskin 2020). Kitchen and Meyer (1991) and Meyer (1992) found considerable variation in germination within populations. Some seeds germinated near 32 ¡F (0 ¡C), while others did not. This was assumed to be an adaptive characteristic for unpredictable environments.

Wildlife And Livestock Use

Information on wildlife and livestock use of firecracker penstemon is limited. Stevens and Monsen (2004b) listed firecracker penstemon as providing useful wildlife forage, but St. John et al. (2011) reported that it is not valuable livestock forage and use by big game is limited. Martin et al. (1951) reported that pronghorn (*Antilocapra americana*) feed on the foliage and stems. Flowers of firecracker penstemon attract hummingbirds, and its insect pollinators provide food for birds and other animals. Western rodents and rosy fin (*Leucosticte* spp.) eat the small seeds. Ground squirrels (Sciuridae) and Merriam kangaroo rats (*Dipodomys merriami*) consume seeds and foliage (Martin et al. 1951). The species is recommended for pollinator habitat in Nevada (Eldredge et al. 2013), and for silverspot (*Speyeria zerene*) and monarch butterfly (*Danaus plexippus*) habitat in Utah (Tilley et al. 2019).

Ethnobotany

Firecracker penstemon plants were associated with the east direction and were used by the Hopi in their 16-day Po-wa-mu (bean dance) ceremony (Colton 1974). Its flowers indicated the end of the watermelon planting season. The Kayenta Navajo used firecracker penstemon for spider bites, stomach troubles, backaches, and as a poultice for snake bites, hemostatic, fumigant, and lightning infection emetic (Wyman and Harris 1951). It was also used to cure livestock of colic. The Shoshoni used a decoction of the whole plant to relieve pain and heal burns (Train et al. 1941).

Horticulture

The showy scarlet flowers and heat and drought tolerance make firecracker penstemon a useful landscape plant, particularly where low water use is critical (Nold 1999; Stevens and Monsen 2004b; St. John et al. 2011; Cane and Kervin 2013). It is a popular ornamental and adds brilliant color to flower gardens, rock gardens, perennial borders, and parkways (Dorn and Dorn 2007). It has been used successfully in flower gardens in the Northwest, Rocky Mountains, and east coast gardens as far north as Maine. It is the earliest red penstemon to bloom in northern gardens and is recommended for use as a cut flower (Way and James 1998; Lindgren and Wilde 2003; Kratsch and Hunter 2009).

Firecracker penstemon is adapted to plant hardiness zones 3 to 8b (Kratsch and Hunter 2009; DaveÕs Garden 2022), though adaptation may vary among populations. Firecracker penstemon requires full sun to light shade and dry, well-drained soil. Supplemental watering may extend the flowering period, but excessive watering can lead to lodging (stalks sprawling or falling over) or root rot (Dorn and Dorn 2007; Kratsch and Hunter 2009). Plants are short-lived, but they reseed readily (Nold 1999). Strategies for obtaining uniform germination for production of nursery stock were developed by Allen and Meyer (1990) and Kitchen and Meyer (1991) (see Germination Biology section). Plants can also be propagated from stem cuttings and division (Kratsch and Hunter 2009).

Revegetation Use

Because of its bright scarlet to red flowers, ease of establishment, ability to grow on disturbed and rocky sites, tendency to reseed naturally, and pollination by hummingbirds and insects, firecracker penstemon has been recommended to provide diversity in herbaceous wind barriers, field borders, roadsides, hedgerow plantings, and range plantings (USDA NRCS 2012; Xerces Society & NRCS 2012). Adapted sources can be used in pinyon-juniper, mountain brush, big sagebrush, and ponderosa pine sites (Plummer et al. 1968; Stevens and Monsen 2004b). It has been evaluated as establishing easily; very good for ease of seed handling, seeding or transplanting, initial

establishment, and natural spread; and good for seedling growth rate, final establishment, and early spring and summer palatability (Stevens and Monsen 2004b).

Firecracker penstemon, especially the Richfield release, has been used extensively on steep and rocky roadside plantings within and beyond its natural range to provide erosion control and beautification (Way and James 1998; Lindgren and Wilde 2003; Ogle et al. 2012).

Developing A Seed Supply

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

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

Seed Sourcing

Because empirical seed zones are not currently available for firecracker 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 to moisture index). In Figure 9, 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 CenterÕs (USFS WWETAC 2020) 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.

Map

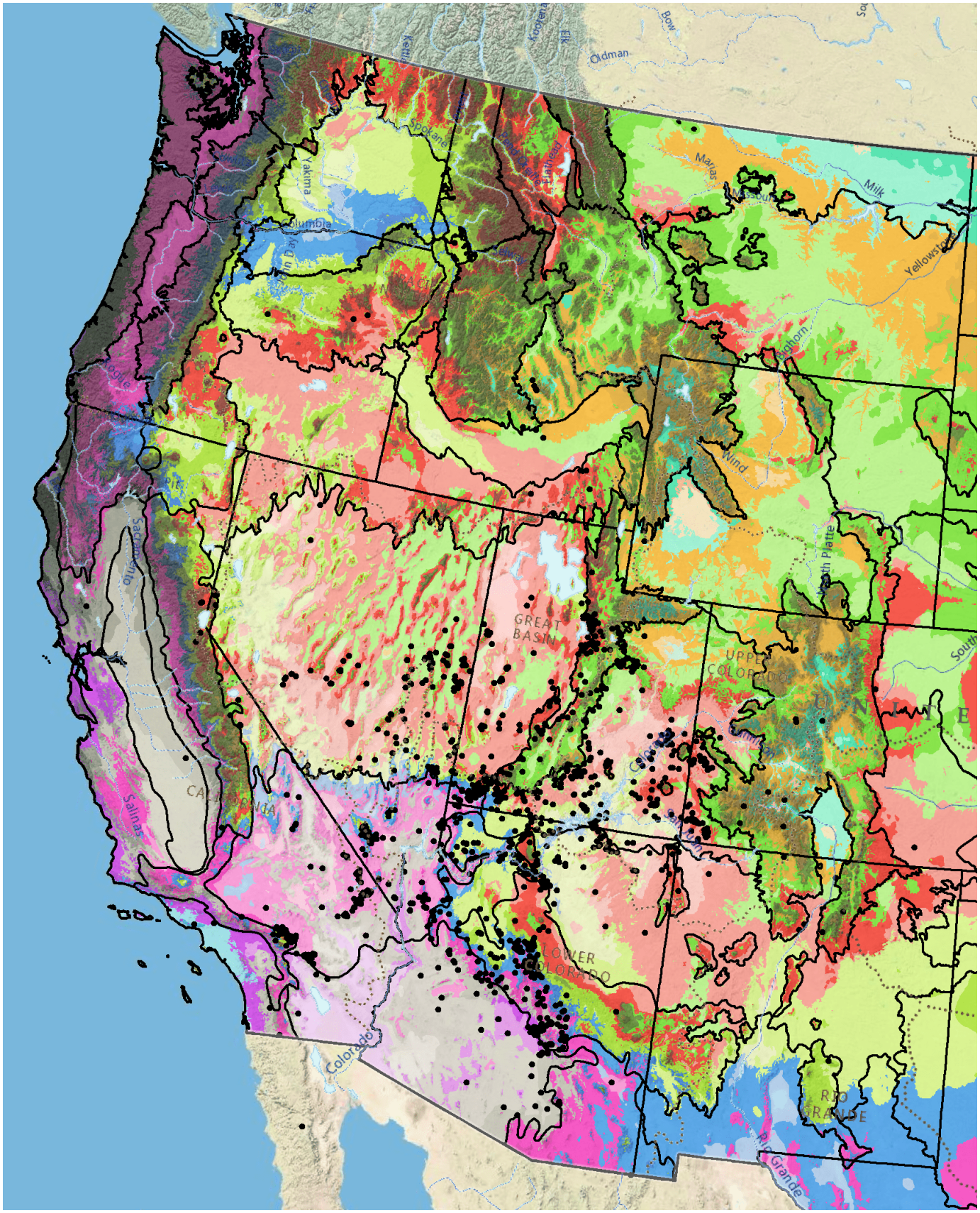

Figure 9. Distribution of firecracker penstemon (black circles) based on geo-referenced herbarium specimens and observational data from 1869Ð2018 (CPNWH 2020; SEINet 2020; USDI USGS 2020). Generalized provisional seed zones (colored regions) (Bower et al. 2014) are overlain by Omernik Level III Ecoregions (black outlines) (Omernik 1987; USDI EPA 2018). Interactive maps, legends, and a mobile app are available (USFS WWETAC 2017; www.fs.fed.us/wwetac/threat-map/TRMSeedZoneMapper2.php?). Map prepared by M. Fisk, USDI USGS.

Releases

Selected Class Germplasm Richfield firecracker penstemon was released in 1994 by the US Department of Agriculture, Aberdeen Plant Materials Center (IDPMC) in cooperation with the University of Idaho Agricultural Experiment Station (Lambert 2005; Ogle et al. 2012; USDA NRCS 2012). The release was originally collected near Richfield, Sevier County, Utah, on a gravelly loam sagebrush site at a 12- to 14-in (305Ð360 mm) precipitation zone and about 6,600 ft (2,000 m) elevation. Globemallow (*Sphaeralcea* spp.) and Indian ricegrass (*Achnatherum hymenoides*) were among the associated species. Richfield was one of 15 firecracker penstemon accessions tested at the IDPMC from 1981 to 1985. It was selected for its beauty, seed production, natural range of adaptability and minimum seed stratification requirement (USDA NRCS 2012). Compared to other accessions at this site, it exhibited the best stand establishment, longest survival, and greatest promise for use throughout its range of adaptation.

Richfield firecracker penstemon is used to control erosion, increase biodiversity, and improve the aesthetics of seedings. Richfield firecracker penstemon is recommended for use in sagebrush, juniper, and ponderosa pine zones at 3,300 to 8,000 ft (1,000Ð2,400 m) elevation that receive 10 to 16 in (250Ð400 mm) of annual precipitation. It can be used on well-drained, shallow, rocky loams and sandy to gravelly loams with pH 6.6 to 8.5. It grows in full sunlight and can withstand cold winters if covered by snow (Ogle and Peterson 2003; St. John et al. 2011; USDA NRCS 2012). Richfield firecracker penstemon is considered adapted to USDA Plant Hardiness zones 4a to 8b (USDA NRCS 2012).

Generation 0 (G0) and G1 seed is maintained at IDPMC. G2 seed is available through the University of Idaho Foundation Seed Program and the Utah Crop Improvement Association. Growers may produce G2 and G3 seed (USDA NRCS 2012).

Wildland Seed Collection

Wildland seed is hand harvested when capsules are dry. Populations should be identified early and monitored during seed maturation to determine whether adequate high-quality seed will be available for harvest (Fig. 10). Jorgensen and Stevens (2004) collected firecracker penstemon seed from July 1 through August 30 by hand stripping or beating inflorescences over a container.

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 (Young et al. 2020; UCIA 2015). Wildland seed collectors should become acquainted with state certification agency procedures, regulations, and deadlines in the states where they collect.

If wildland-collected seed is to be sold for direct use in ecological restoration projects, collectors must apply for Source-Identified certification prior to making collections. Pre-collection applications, 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

Firecracker penstemon can be harvested when the stalks and capsules are dry and straw colored (Fig. 10), and the mature seeds are hard and dark colored (M. Fisk, USGS, personal communication, March 2022). Although seed maturation is indeterminate (Fig. 10), pods do not shatter readily unless disturbed by wind of other disturbance. This

provides the potential for fewer consolidated harvests (K. Gunnell, Utah Division of Wildlife Resources, personal communication, May 2022). Plants on differing microsites within a population, however, will mature at different rates. Seed fill should be checked with a cut test or X-ray test. Collection dates vary with annual weather conditions, and variation in maturation date occurs among plants within populations. 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 (M. Fisk, USGS, personal communication, March 2022). Seed was collected in Sevier County, Utah, at 6,088 ft (1,856 m) on August 20, 2008, on a southeast aspect and on August 7, 2009, on a southwest aspect at a similar elevation. Seed was collected on August 19, 2015, at 9,699 ft (2,956 m) in Piute County, Utah (USDI BLM SOS 2017).

Figure 10. Firecracker penstemon producing fruits (left) and maturing fruits (right). Photo left: J. Cribbs, Bureau of Land Management. Photo right: M. Lavin, MSU.

Collection Methods

Seeds are most easily harvested from wildland stands by clipping inflorescences into collection bags, buckets, seed hoppers, or other containers when most capsules are dry and beginning to open (St. John et al. 2011; USDA NRCS 2012). 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. Capsules may also be stripped from the flowering stalks. Although this method simplifies seed conditioning, it is a much slower collection process and results in greater seed loss from open capsules (M. Fisk, USGS, personal communication, March 2022).

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 firecracker penstemon.

Collection Rates

Stevens and Monsen (2004b) noted that firecracker penstemon is not an abundant seed producer.

Post-Collection Management

Molding can occur if green leaves and stems or only partially dried fruits are collected along with the seeds,

particularly if collections are made during high humidity periods (M. Fisk, USGS, personal communication, March 2022). 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 (M. Fisk, USGS, personal communication, March 2022).

Seed Cleaning

Large samples can be cleaned using a hammermill or debearder to break up the capsules and release the seed (Stevens et al. 1996; Jorgensen and Stevenson 2004). Fine cleaning is accomplished using a clipper or seed blower followed by running the seed over a gravity table (Stevens et al. 1996; Meyer 2008). With proper equipment and practice, firecracker penstemon seed can be cleaned to purities of 95% or higher (Kitchen, USFS retired, personal communication May 2022).

Seed Storage

Firecracker penstemon seeds are orthodox (RBG Kew 2020) and can be stored for at least 7 years in a dry location. Longevity has been listed as 7 to 10 years (Shaw and Monsen 1983; Stevens et al. 1996) and up to 12 years (Stevens and Monsen 2004b). USDA NRCS (2012) found that viability was maintained for 7 to 8 years under cool dry storage, but declined gradually over time.

Seed Testing

Procedures and guidance related to testing for seed purity, viability, and germination of firecracker penstemon seed are provided below.

Viability Testing

General tests for seed viability of Plantaginaceae are provided by the Association of Official Seed Analysts (AOSA 2010) and the International Seed Testing Association (ISTA) (Moore 1985).

Allen and Meyer (1990) describe a technique to test the viability of firecracker penstemon seed. Seeds are imbibed on moist blotters for 12 hours, then pierced with a needle and soaked in a 1% tetrazolium chloride (TZ) solution for 48 hours. Seeds are then bisected longitudinally for examination. Viable embryos stain entirely red.

Purity Testing

About 0.1 oz (3.5 g) of seed are required to test purity, and 1.2 oz (35 g) are required to test for the presence of noxious weed seed. There are about 20,900 seeds/oz (735 seeds/g) (AOSA 2016).

Germination Testing

Germination is tested by incubating imbibed seeds on moist blotter paper at 50 to 68 ¡F (10Ð20 ¡C) (AOSA 2010). The first count is made at 7 or 14 days and the last count at 14 or 28 days. Germination is epigeal; the hypocotyl elongates, carrying the cotyledons above the soil surface. The primary and secondary root and root hairs may develop during the test period, but epicotyl development generally occurs later. Seedlings are considered abnormal if the 1) cotyledon tissue is more than half necrotic, decayed, or missing, 2) epicotyl is missing, 3) hypocotyl is malformed, watery or with deep cracks into the conducting tissue, 4) root is missing or with a weak, stubby, or missing primary root, or 5) seedling is albino or with one or more essentials structures impaired (AOSA 2010).

Germination Biology

Depth of physiological dormancy in firecracker penstemon varies among and within populations (Kitchen and Meyer

1991; Meyer 1992). Populations at low elevations have nondormant seeds. Montane populations have physiological dormancy which is broken by cold stratification (Meyer 1992).

While some studies reported that firecracker penstemon seeds afterripened for one month germinate over time without stratification (Stevens et al. 1996; Jorgensen and Stevens 2004), other studies indicated that stratification was necessary for germination (Allen and Meyer 1990; Kitchen and Meyer 1991; Dorn and Dorn 2007; Kratsch and Hunter 2009). Lindgren and Wilde (2003) found that seed germinated within 2 to 8 weeks if incubated at 40 ¡F (4 ¡C). Deno (1993) obtained only 16% germination when seeds were incubated at 70 ¡F (20 ¡C) but up to 100% germination within 2 to 10 weeks of incubation at 40 ¡F (4 ¡C).

Collection site climates affect seed germination requirements and responses to chilling temperatures. Meyer (1992) conducted laboratory tests on seed collected from warm desert fringes to subalpine meadows in Utah. Seeds were chilled at 32 ¡F (1 ¡C) for 0 to 24 weeks. Seed collected from cold-winter sites had longer chill requirements and were slower to germinate under continuous chill conditions than seeds from warm-winter sites. Seeds from variable-winter sites had a large percentage of seed that was unresponsive to chilling. Seed from a warm desert site with mild winters was largely non-dormant. Seed from populations growing in intermediate winter sites (southern Utah or mid-elevation montane habitats) had maximum germination after 12 or 16 weeks of chilling. Seed from the highest-elevation sites with the longest, most severe winters showed incremental increases in germination through 24 weeks of chilling. Over 95% of the variance in low temperature germination rates was accounted for by the winter severity index variable. An additional year of laboratory storage had no consistent effect on germination rate or percentage. Meyer (1992) suggests that site-specific germination responses are an adaptation for establishment and provide for between-year seed banking. Establishment may fail when seeds are planted at a site with a climate context not matching that of the seed source (Meyer 1992).

To identify species and ecotypes with desirable characteristics (i.e., minimal stratification requirement and uniform germination) for the horticultural market, Kitchen and Meyer (1991) subjected seed from two accessions of firecracker penstemon collected from elevations of 5,510 ft (1,680 m) and 8,070 ft (2,460 m [locations not specified]) to a variety of stratification (36 ¡F [2 ¡C] in dark) and gibberellic acid (GA_3) treatments (50Ð250 ppm). Seed was incubated at a constant 60 ¡F (15 ¡C) for 28 days following any individual or combination of pretreatments. Seeds from both elevations showed variability in dormancy, but most seed required long stratification periods. Germination of the low-elevation source was 35% at 12 weeks and increased to 84% at 16 weeks of stratification ($P < 0.05$). Germination of the high-elevation source was 4% at 12 weeks and increased to 75% at 16 weeks of stratification ($P < 0.05$). Treatment with 250 ppm GA_3 alone improved mean germination by 58% from seed treatments with water ($P < 0.05$). Combining stratification and 250 ppm GA_3 treatments reduced the time to 75% germination by 8 weeks compared to stratification alone. Kitchen and Meyer (1991) suggested that GA_3 treatments that brought about shorter stratification times could be useful in producing uniform nursery stock.

Allen and Meyer (1990) tested multiple cold stratification and incubation temperature treatments to break dormancy of firecracker penstemon seed. Testing was done on seed collected from field-grown plants (Caldwell, ID) harvested in 1984 and 1985 and stored until experiments were conducted in 1986. Most firecracker penstemon seed was dormant regardless of harvest date. Without stratification, seed germination was low (~20%) at incubation temperatures of 50 ¡F (10 ¡C) and 59 ¡F (15 ¡C) and almost 0% at incubation temperatures of 68 ¡F (20 ¡C), 77 ¡F (25 ¡C), and 86 ¡F (30 ¡C). After eight weeks of cold stratification at 41 ¡F (5 ¡C), germination of older seeds (1984) was 65%, not significantly different from viability (76%). Germination of fresh seed (1985) was 46%, significantly less than viability (87%, $P <0.01$). Seeds harvested in 1984 germinated more rapidly at lower temps than seeds harvested in 1985. Sixty percent of unstratified seed that failed to germinate with warm temperature incubation (77 ¡F [25 ¡C]) was germinated when moistened with 720 µM GA_3. Seedlings from GA_3-treated seed grew spindly and were difficult to maintain in the greenhouse. Researchers suggested that seeding firecracker penstemon outdoors in fall should overcome seed dormancy (Allen and Meyer 1990).

Wildland Seed Yield And Quality

Post-cleaning seed yield and quality of seed lots collected in the Intermountain region are provided in Table 1 (USFS BSE 2017). The results indicate that firecracker penstemon seed can generally be cleaned to high levels of purity and

seed fill and that viability of fresh seed is generally high. Elsewhere in the literature, 350,000 to 400,000 seeds/lb (770,000Ð881,800 seeds/kg) were reported for firecracker penstemon (Shaw and Monsen 1983; Stevens et al. 1985; Jorgensen and Stevens 2004; Walker and Shaw 2005; St. John et al. 2011) which falls within the range of pure live seeds/lb reported in Table 1.

Table 1. Seed yield and quality of firecracker 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).

Seed lot characteristic	Mean	Range	Samples (no.)
Bulk weight (lbs)	3.14	1.39Ð4.25	3
Clean weight (lbs)	0.48	0.33Ð0.94	3
Clean-out ratio	0.14	0.08Ð0.22	3
Purity (%)	96	94Ð97	3
Fill (%)[1]	88	86Ð90	3
Viability (%)[2]	93	89Ð96	3
Seeds/lb	356,558	331,090Ð378,306	3
Pure live seeds/lb	291,358	253,416Ð311,279	3

[1]100 seed X-ray test
[2]Tetrazolium chloride test

Marketing Standards

The recommended marketing standards for firecracker penstemon seed are 95% purity, 70% germinability, and 90 to 95% viability. Purity of 70% is acceptable for bulk seed (Jorgensen and Stevens 2004; Walker and Shaw 2005; Stevens et al. 1996).

Acceptable seed purity, viability, and germination specifications vary with revegetation plans. Purity needs are highest for precision seeding equipment used in nurseries, while some rangeland seeding equipment handles less clean seed quite well.

Agricultural Seed Production

Seed production test plots were grown by the U.S. Department of Agriculture, Natural Resources Conservation Service, Aberdeen Plant Materials Center in Idaho (IDPMC).

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 (Young et al. 2020; UCIA 2015).

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

Firecracker penstemon should be planted in well-drained, sandy to gravelly loam soils (Stevens et al. 1996). A firm, weed-free seedbed should be prepared prior to planting.

Weed Management

Weeds must be controlled prior to seeding or planting (USDA NRCS 2012). Hand weeding may be required within the seeded rows during the first season. Weeds can be cultivated between rows. Mowing rapidly growing broadleaf weeds before they flower will limit seed production and establishment of new populations. Weed barrier fabric can also be used to reduce weed competition and allows for closer spacing of rows. Herbicides have not been labeled for use with native forb species (USDA NRCS 2012).

Seeding

Firecracker penstemon seed germinates in early spring following sowing in fall or winter (Meyer 1992; Stevens et al. 1996; USDA NRCS 2012). Seed can be drill seeded then pressed 0.06 to 0.13 in (1.5Ð3.3 mm) into the soil to provide good seed-to-soil contact. The recommended seeding rate is about 1.3 PLS lbs/ac (1.5 kg/ha), or with 30 to 36 in (76Ð 91 cm) between rows to allow for mechanical cultivation (Stevens et al. 1996; USDA NRCS 2012). In seed production test plots grown at IDPMC, plant growth was maximized with 18-in (46 cm) spacings (USDA NRCS 2012). Seed fields can also be established using containerized seedlings.

Establishment And Growth

Meyer (1992) found that seed from warm winter sites had shorter chill requirements and established more rapidly than seed from cold winter sites. Mulching, irrigation, and weed barrier fabric can improve moisture availability and improve establishment in dry conditions. Some seed may not germinate until the second year, and full flowering and seed production generally do not occur until the plantÕs second growing season (USDA NRCS 2012).

Irrigation

Firecracker penstemon has a low irrigation requirement (12Ð16 in [305Ð406 mm] annual ppt), and seedlings are susceptible to disease with too much moisture (Stevens et al. 1996; Eldredge et al. 2013). Irrigation is recommended for establishment as needed. Mature plants require irrigation in early summer when soil moisture is not available, and at start of flowering. Overhead irrigation is not recommended when plants are flowering.

Pollinator Management

Because firecracker penstemon is insect- and bird-pollinated, stands should be managed to encourage pollinators (Stevens et al. 1996). At IDPMC large firecracker penstemon seed yields approaching 275 lbs/ac (308 kg/ha) were obtained by placing generalist *Apis* spp. and ground-dwelling beehives near the seed fields (USDA NRCS 2012).

Pest Management

Plants are susceptible to diseases such as soil-borne *Fusarium* spp. and *Rhizoctonia* spp. root rot associated with agricultural production, particularly alfalfa (*Medicago sativa*) and potatoes (*Solanum tuberosum*). Diseases are especially damaging in loam to clay-textured soils or with excessive irrigation (Stevens et al. 1996). Grasshoppers can also damage establishing stands (USDA NRCS 2012).

Seed Harvesting

Firecracker penstemon seed can be harvested by hand or mechanically (St. John et al. 2011; USDA NRCS 2012). Because flowering is indeterminate, there may be mature capsules and flowers present at the time of harvest (USDA NRCS 2012). Seed retention is good. Capsules remain on the plant but split open at the top as seed matures (Stevens et al. 1996). To optimize yields, growers can make multiple hand harvests or mechanically harvest when most seed capsules have begun to dry and open (USDA NRCS 2012). For mechanical harvests, plants can be swathed to allow encourage more uniform ripening and drying (USDA NRCS 2012) or cut stalks can be dried in the warehouse (Stevens et al. 1996). Fields should be swathed to a height above most leaves to capture flower stalks then dried for 4 to 5 days before combining (USDA NRCS 2012).

Seed Yields And Stand Life

Plants produce little to no seed in the first year, and yields are 50 to 75% the second year. Seed production peaks in year 3 (Stevens et al. 1996; USDA NRCS 2012). Reported seed yields vary from 100 to 275 lbs/ac (112Ð308 kg/ha) and were improved by managing with pollinators (USDA NRCS 2012).

Nursery Practice

Firecracker penstemon seedlings can be produced in the nursery by sowing seeds in flats or containers outdoors and covering them for overwinter stratification (St. John et al. 2011). Seeds artificially stratified for 8 to 12 weeks can be grown in the greenhouse for 8 to 12 weeks before outplanting. Covering container surfaces with fine- to medium-grade perlite or fine sand reduces surface moisture and damping off (St. John et al. 2011).

Home horticulture recommendations include starting seeds indoors after 112 days of stratification or sowing outdoors in the fall (Kratsch and Hunter 2009). Seed should be planted 0.1 in (2.5 mm) deep in well-drained medium soils. Mature plants can be divided in spring or fall by separating sections of mature plants with one or more buds and replanting them with the buds at the soil surface (Dorn and Dorn 2007; Kratsch and Hunter 2009).

At the Rancho Santa Ana Botanical Garden in California, plants were grown from wildland seed collections from San Bernadino County and seed lots from cultivated plants (Everett 1957). Seeds were planted in flats, then in 4-in (10 cm) containers filled with loam and peat. Container growth was good as long as containers were not over watered. Outplanted seedlings grew best in rocky, dry, porous soils and survived to a maximum age of 4 to 6 years. Flowering began in the first year, and some plants produced many flowering stems each year (Everett 1957).

Wildland Seeding And Planting

Firecracker penstemon is recommended for use in the revegetation of mountain brush, ponderosa pine, pinyon-juniper (> 15 in [381 mm] annual ppt.), big sagebrush, and three-tip sagebrush (*Artemisia tripartita*) habitats. Firecracker penstemon may not be native throughout all these habitat types (Stevens and Monsen 2004a), and its use should be limited to its native range.

Figure 11. Firecracker penstemon growing along highway 95 near Mann Creek in Idaho, beyond its natural range. Photo: C. Shock, Oregon State University, Malheur Experiment Station.

In wildland revegetation, firecracker penstemon makes up a minor component of seed mixes, and post-seeding management should be based on the major species in the mix or species desired on the site (St. John et al. 2011; USDA NRCS 2012). The recommended full-stand seeding rate is 3 lbs/ac (3.4 kg/ha), which can be adjusted to the desired percent of the mix desired. Shaw and Monsen (1983) note that the small size of firecracker penstemon seed is a consideration in seeding. It can be drill seeded separately, broadcast aerially by hand or mechanically and covered lightly, or cultipacked separately or in the mix (Shaw and Monsen 1983). It should be seeded in the fall and can be drilled or broadcast and pressed to a depth of 0.13 to 0.25-in (3Ð6-mm) in a firm seedbed. Good seed to soil contact is important for germination and establishment, and some seed may not germinate until the following growing season (St. John et al. 2011). Seedling vigor is often low (Ogle et al. 2012), and seeded areas should be protected from grazing for at least two growing seasons to allow for full stand establishment (USDA NRCS 2012). Weed control and removal can improve establishment. Damage from wildlife and rodents may also occur and require management (Ogle and Peterson 2003). Flowering of firecracker penstemon is unlikely before the second growing season (St. John et al. 2011). Seedlings are susceptible to soil-borne *Fusarium* spp. and *Rhizoctonia* spp. root rot, which can be severe in poorly drained loam- and clay-textured soils (St. John et al. 2011; USDA NRCS 2012).

Firecracker penstemon showed episodic establishment when it was one of 28 species seeded on a burned portion of Cave Creek Regional Park in Maricopa County, Arizona (Abella et al. 2009). This site is part of the upland subdivision of the Sonoran Desert (giant saguaro [*Carnegiea gigantea*], yellow paloverde [*Parkinsonia microphylla*], and cacti [*Opuntia* spp.]) occupying fine, mixed superactive hyperthermic soils and receives 13 in (330 mm) annual precipitation. The fire burned on June 1, 2005, and killed or top-killed most shrubs. The burned area was hydroseeded with a diverse (by lifeform and longevity) seed mix 60 days after the fire without any site preparation. The seeding rate was between 0.27 and 6.7 PLS lb/ac (0.3Ð7.5 kg/ha) and delivered in a slurry including a tackkifer (ground *Plantago* spp.), and ammonium phosphate ($16N_20{:}20P_20_5{:}K_20$, 100 lb/ac [112 kg/ha]). A mulch ((3,470 lb/ac [3,900 kg/ha] mulch straw + wood fiber (500 lb/ac [560 kg/ha]) + and tackifier (150 lb/ac [168 kg/ha]) was applied over the hydroseeded site. The seeded area received below normal (67%) precipitation for 21 months after seeding. Establishment of seeded species was evaluated five times after seeding. Penstemon (*P. eatonii* and *P. parryi* spp.)

emerged episodically. Seedlings established the first spring (68% frequency), subsequently disappeared, and were recorded again the following spring (28% frequency). Penstemon seedlings were absent the third spring. Penstemon did not occur in burned, unseeded or unburned, unseeded control plots. Seeded species comprised 54% of total plant richness per plot 21 months after seeding and 29% per plot 32 months after seeding. Nonnative, annual, common Mediterranean grass (*Schismus barbatus*) and red brome (*Bromus rubens*) were the most prominent volunteer species, and longer-term monitoring is needed to determine if seeded plants affected, or will affect, cover and persistence of the nonnative grasses (Abella et al. 2009).

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Literature Cited

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