Small-leaf globemallow (Sphaeralcea parvifolia)

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Nomenclature

Sphaeralcea parvifolia A. Nelson is commonly referred to as small-leaf globemallow and is part of the the Malvaceae or Mallow family and the *Eusphaeralcea* subgenus (Kearney 1935).

Family

Malvaceae Ð Mallow family

Genus

Sphaeralcea

Species

parvifolia

NRCS Plant Code

SPPA2 (USDA NRCS 2017).

Subtaxa

The Flora of North America does not currently recognize any varieties or subspecies (La Duke 2016).

Synonyms

Sphaeralcea arizonica A. Heller ex Rydberg, *S. marginata* York ex Rydberg, *S. ambigua* subsp. *rugosa* Kearney, *S. ambigua* var. *rugosa* (Kearney) Kearney (Holmgren et al. 2005; La Duke 2016).

Common Names

Small-leaf globemallow, small-flower globemallow, Nelson globemallow (Vernon et al. 2005; USDA NRCS 2017; LBJWC 2018).

Chromosome Number

Chromosome numbers are: 2n = 10, 20 (La Duke 2016).

Hybridization

There is frequent hybridization and polyploidy within the *Sphaeralcea* genus, which results in indefinite and overlapping species boundaries and can make accurate identification difficult in some areas (Kearney 1935; La Duke 2016). Hybrids between small-leaf globemallow and MunroÕs globemallow are common (Kearney 1935).

Distribution

Small-leaf globemallow occurs in the Central Basin and Range and Colorado Plateau ecoregions (Lambert 2005). It occurs naturally in Nevada, the southern two-thirds of Utah, western Colorado, northwestern New Mexico, northern and central Arizona, and adjacent California (Kearney 1935; Holmgren et al. 2005; La Duke 2016; USDA NRCS 2017). It has been grown in southern Idaho (Pendery and Rumbaugh 1990) but is not native there. On the high plateaus of central and northern Arizona, small-leaf globemallow is the most abundant globemallow species (Kearney 1935). Although the distributions of small-leaf and MunroÕs globemallow overlap in Nevada, Utah, and Colorado, it is common to find small-leaf globemallow in more southern and MunroÕs globemallow in more northern locations (Sriladda et al. 2012).

Habitat And Plant Associations

Dry slopes, mesas, washes, and roadsides are common small-leaf globemallow habitats (Munz and Keck 1973, Holmgren et al. 2005, La Duke 2016; LBJWC 2018). Associated vegetation in these habitats includes greasewood (*Sarcobatus* spp.), saltbush (*Artiplex* spp.) blackbrush (*Coleogyne ramosissima*), sagebrush (*Artemisia* spp.), pinyon-juniper woodlands (*Pinus*Ð*Juniperus* spp.), and mixed mountain brush (Fig. 1) (Munz and Keck 1973; Welsh et al. 1987; Holmgren et al. 2005).

Figure 1. Small-leaf globemallow growing in Colorado. Photo: USDI Bureau of Land Management (BLM) CO150A, Seeds of Success (SOS).

Globemallows (small-leaf, desert [*S. ambigua*], gooseberryleaf [*S. grossulariifolia*], and RusbyÕs [*S. rusbyi*]) were common in vegetation on the rim of Montezuma Well (an artesian fed lake) and in a natural limestone sink in central Arizona. These species occurred in a quarter of the plant communities dominated by broom snakeweed (*Gutierrezia sarothrae*) and mariola (*Parthenium incanum*) on southern exposures, with cover reaching a high of 0.7% (Clark and Burgess 1966). In a study of climate and vegetation patterns in vegetation representing a transition between Mojave and Great Basin deserts at the Nevada Test Site north of Las Vegas, small-leaf globemallow occurred with minor cover (0.1%) in vegetation dominated by ShockleyÕs desert-thorn (*Lycium shockleyi*). It did not occur in communities dominated by creosote bush (*Larrea tridentata*). Shrub and herbaceous cover was low in this area. Total cover of herbaceous perennials was 1.9% in creosote bush and 0.9% in ShockleyÕs desert-thorn shrublands (Beatley 1975).

Elevation

Although it occurs at elevations of 2,000 to 9,000 ft (600Ð2,700 m) (Holmgren et al. 2005; La Duke 2016), small-leaf globemallow is rare below 4,000 ft (1,200 m) (Kearney 1935). In California, the elevation range for small-leaf globemallow is 5,000 to 7,000 ft (1,500Ð2,100 m) (Munz and Keck 1973), and in Utah it is 2,700 to 8,900 ft (820Ð2,700 m) (Welsh et al. 1987).

Soils

Soils were described as shallow, dry, and well-drained in the few studies that describe small-leaf globemallow habitats. The species occurs on sites having at least 6 in (15 cm) of soil (Jameson et al. 1962; Schmutz et al. 1967). Soil texture ranged greatly from sandy to clay loam, with rocks as a common component (Kearney 1935; Jameson et al. 1962; LBJWC 2018).

On the Hopi Indian Reservation in northeastern Arizona, small-leaf globemallow made up 1% of the species composition on coppice dunes but did not occur in dune interspaces. Soils at both locations were loamy fine sands, but the depth to sandstone was 12 to 36 in (30Ð91 cm) on the dunes and 3 to 5 in (8Ð13 cm) in the interspaces. CutlerÕs jointfir (*Ephedra cutleri*) dominated the dunes and Indian ricegrass (*Achnatherum hymenoides*) dominated the interspaces (Hodgkinson 1983). At Boysag Point on the Grand CanyonÕs North Rim, small-leaf globemallow occurred on swales (0.4% cover) and slopes (0.2% cover) but not on ridges. Soils on the swales and slopes were moderately developed calcareous, gravelly loams with lime accumulations at about 20 to 26 in (51Ð66 cm) deep. Soils on the ridges were undeveloped and reached depths of only about 6 in (15 cm) (Schmutz et al. 1967).

In an evaluation of vegetation and soils at Fishtail Mesa in the Grand Canyon, small-leaf globemallow occurred with Utah juniper (*J. osteosperma*), twoneedle pinyon (*P. edulis*), and big sagebrush (*A. tridentata*) in shallow (12-18 in [30Ð46 cm]), poorly developed, sandy to clay loam soils with pH levels of 8.2 to 8.7 (Jameson et al. 1962).

Description

Small-leaf globemallow is a perennial with a large taproot and a branching, stout, woody caudex (Fig. 2) (Kearney 1935; Welsh et al. 1987). Plants produce several to many erect stems up to 3.3 ft (1 m) tall (Munz and Keck 1973; Holmgren et al. 2005; La Duke 2016). Stems are slender (² 5 mm in diameter at the base), unbranched or more commonly short-branched, and densely covered with stellate hairs, at least when young (Kearney 1935; Holmgren et al. 2005). Basal leaves are lacking; stems leaves are alternate (Munz and Keck 1973; Welsh et al. 1987; Holmgren et al. 2005). Larger leaves are 0.6 to 2.2 in (1.5Ð5.5 cm) long and about as wide with 0.4 to 2-in (1Ð5 cm) long petioles (Welsh et al. 1987). Leaf blades are thick and lack lobes or have three (sometimes five) shallow, broad, rounded lobes (La Duke 2016; LBJWC 2018). Leaves are covered with a stellate pubescence (La Duke 2016), prominently five-veined on the under sides, and have rounded and regularly toothed margins (Fig. 3) (Kearney 1935).

Figure 2. Small-leaf globemallow growing in Utah. Photo: BLM UT040 SOS.


Figure 3. Small-leaf globemallow growing in Utah. Photo: BLM UT391 SOS.

Figure 4. Small-leaf globemallow inflorescence on a plant growing in the Uintah Basin of Utah. Photo: S. Young, Utah State University (USU).

Flowers are numerous, clustered, and crowded in panicles (Fig. 4) (Munz and Keck 1973; LBJWC 2018). There are distinct internodes between the flower clusters and commonly more than one flower per node. Flower buds have a distinct beak (Kearney 1935; Welsh et al. 1987; La Duke 2016). The pedicel measures 2 to 10 mm long and is shorter than the densely pubescent calyx, which is 4 to 8 mm tall at anthesis (Kearney 1935; Munz and Keck 1973). Flowers have five orange to red petals each 7 to 18 mm long (Kearney 1935; Welsh et al. 1987; La Duke 2016). Flowers have many stamens. The filaments are united forming a column, which surrounds the pistils. The fruit is a segmented schizocarp (Fig. 5). The united stamen column and segmented schizocarps are characteristic of the Malvaceae (Weber 1976). Schizocarps are 4 to 5.5 mm in diameter and divided into 9 to 12 mericarps each with two or sometimes one seed. Mericarps are ellipsoid, 3 to 5 mm high, and half or more as wide (Munz and Keck 1973; Holmgren et al. 2005; La Duke 2016). Seeds are kidney shaped, dark brown to black with a fine network of veins, 1.7 to 2 mm long, and more or less pubescent (Kearney 1935; Holmgren et al. 2005).

Figure 5. Small-leaf globemallow schizocarps on plants growing at the Vermillion Cliffs area, near the Utah-Arizona border. Photo: S. Young, USU.

Because of hybridization, polyploidy, and morphological changes in response to environmental conditions (especially rainfall), globemallow species can be difficult to distinguish. Plants growing in Arizona are considered particularly difficult to identify (La Duke 2016). Small-leaf and MunroÕs globemallow (*S. munroana*) are easily confused since they share many morphological characteristics, hybridize, and have overlapping distributions in Nevada, Utah, and Colorado. Small-leaf globemallow can be distinguished by its shallow leaf lobing and wide mid- and secondary leaf-lobe widths (Sriladda et al. 2012).

Reproduction

Small-leaf globemallow reproduces by seed. Its flowers are pollinated by insects, largely bees. Flowering is indeterminate and common from April through July (Ogle et al. 2011; LBJWC 2018).

Ecology

Small-leaf globemallow tolerates harsh conditions, disturbances, and grows rapidly (Ehleringer et al. 1991; Ogle et al. 2011; Huffman et al. 2013). In a study evaluating species growth and physiological survival strategies, small-leaf globemallow was classified as a suffrutescent subshrub with major summer dieback and near total dormancy during the summer drought between rainy spring and fall seasons (Comstock et al. 1988). Plants can green up if moisture interrupts dry weather (Pendery and Rumbaugh 1986). Small-leaf globemallow was monitored for 16 months beginning in April 1985 at two sites in western Arizona where it flowered in both the spring and fall. During this period, plants were not deciduous and produced considerable growth through the winter, which was unusually warm and mild. Plants maintained an above-ground woody caudex and had a robust growth form with stout, erect stems and relatively large leaves. Although most photosynthesis occurred in the leaves, the stems exhibited positive but low photosynthetic rates (Comstock et al. 1988). In a follow-up study assessing seasonal water use among different life forms, small-leaf globemallow competed directly with other life forms for limited water during drought conditions (Ehleringer et al. 1991). It utilized summer precipitation better than woody perennials in desert scrub vegetation in UtahÕs Glen Canyon National Recreation Area. Researchers predicted that as summer precipitation is a larger component of total water input, small-leaf globemallow may compete more successfully than woody perennials (Ehleringer et al. 1991).

Although tolerant of harsh, dry, growing conditions, studies suggest that small-leaf globemallow abundance and seed production may be improved with higher moisture conditions (Pendery and Rumbaugh 1990; Beno 2009). When vegetation composition was compared on cleared and untreated pinyon-juniper stands on a ranch in Seligman, Arizona, abundance of small-leaf globemallow was not associated with treatments and was greatest on the most level site. Frequency of small-leaf globemallow ranged from 0 to 1% on treated and untreated sites with slopes of 10 to 30%. Frequency was 28% at a recently logged oneseed juniper (*Juniperus monosperma*) site with almost no slope. The researcher suggested that reduced water runoff on the level site may have been most important to the high frequency of small-leaf globemallow (Beno 2009). When plant growth was compared at two experimental pasture sites, one in southern Idaho and the other in northern Utah, small-leaf globemallow seed production was much greater at the Utah site receiving more precipitation over the 4-year study (Pendery and Rumbaugh 1990).

Globemallows are disturbance tolerant. When hazardous fuels treatment effects were evaluated for the understory of twoneedle pinyon-Utah juniper woodlands in northern ArizonaÕs Kaibab National Forest, globemallows were detected only after burning (3.3%) or burning and thinning (0.8%) operations. Globemallows remained at the treated sites for at least 5 years following treatments (Huffman et al. 2013).

While moderate disturbances are tolerated, pollution exposure may harm small-leaf globemallow. In experiments, plants were 20% injured after exposure to 0.5 ppm of sulfur dioxide, a common air pollutant from coal-fired power plants. Small-flower globemallow was one of the most sensitive species of the 87 native cold desert species evaluated (Hill et al. 1974).

Wildlife And Livestock Use

Globemallows are utilized by a variety of large and small mammals, birds, and reptiles (Gullion 1960; Hansen et al. 1976; Spaulding 1991; Beno 2009; Ogle et al. 2011). Small-leaf globemallow is considered good forage for cattle, pronghorn, and other wildlife (Beno 2009). Although species were not identified for the following studies, globemallows were recovered from packrat (*Neotoma* spp.) middens in the southeastern Mojave Desert in Nevada (Spaulding 1991). GambelÕs quail (*Callipepla gambelii*) feed on globemallow seeds and herbage (Gullion 1960). In the Lower Grand Canyon, Arizona, globemallows were 21% of the diets of desert tortoises (*Gopherus agassizii*) as determined from fecal analyses. Globemallows comprised 6% of the desert tortoise fecal samples collected from ArizonaÕs New Water Mountains but were not recovered from feces collected from Beaver Dam Wash in southwestern Utah (Hansen et al. 1976).

In the Harquahala Mountains of western Arizona, globemallows made up a large part of bighorn sheep (*Ovis canadensis*) and mule deer (*Odocoileus hemionus*) diets (Table 1). It was also a minor component (0.1-0.5%) of burro diets (Krausman et al. 1989).

Table 1. The percentage of bighorn sheep and mule deer diets comprised of globemallow species. Diets of male and female bighorn sheep were evaluated separately (Krausman et al. 1989).

Season	Spring	Summer	Fall	Winter
	ÑÑÑÑÑÑÑdiet %ÑÑÑÑÑÑÑÐ			
Bighorn sheep (male)	19.5	4.4	19.0	8.1
Bighorn sheep (female)	6.5	7.3	19.4	8.2
Mule deer	9.4	6.7	24.0	13.2

Globemallow plant fragments made up a high percentage of the density of bighorn sheep feces (52.2%) but less of cattle (5.1%) and burro (4.1%) feces collected from the western end of the Lower Grand Canyon, Arizona (Hansen and Martin 1973).

The effects of grazing on small-leaf globemallow have been studied on a variety of sites in the West. In a new pasture near Kimberly, Idaho, sheep preferred alfalfa (*Medicago sativa*) over globemallows and globemallows over grasses in the spring but preferred alfalfa and grass over globemallows in the fall (Rumbaugh et al. 1993b). The pasture was transplanted with 3-month-old plants in April 1988, fall grazed in 1988 and 1989, and spring grazed in 1990 and 1991 by 10 to 15 ewes. Mortality of small-leaf globemallow plants between October 1988 and May 1989 averaged 57% for grazed plants and 40% for ungrazed plants. For the seven small-leaf globemallow accessions, mortality ranged from 36 to 75% for grazed and 0 to 75% for ungrazed plants (Rumbaugh et al. 1993b). Near the North Rim of the Grand Canyon, small-leaf globemallow was more abundant on less grazed sites when compared to heavily grazed sagebrush-dominated sites (Schmutz et al. 1967). The less-grazed site received some livestock grazing for about 20 years prior to the study and before that was grazed by about 40 sheep for 2 months per year. The heavily grazed site received livestock (sheep and cattle) and deer use continuously since the time of settlement. Cover of small-leaf globemallow was 0.2% at the largely ungrazed and 0.1% on the grazed site. Percent composition was 0.8% on the ungrazed and 0.3% on the grazed site (Schmutz et al. 1967).

Nutritional Value

Globemallows are palatable to deer and livestock (Parkinson 2003), and several studies have evaluated their nutritional content. Average protein content of globemallows varies by season and site (Table 2; Krausman et al. 1989; Albert and Krausman 1993).

Table 2. Seasonal protein content (percent) of globemallows growing in the Harquahala (Krausman et al. 1989) and Belmont mountains (Albert and Krausman 1993) of Arizona.

Season	Harquahala Mtns.	Belmont Mtns.
	ÑÑÑÑprotein content %ÑÑÑÑÐ	
Spring	12.7	17.6
Summer	15.7	12.4
Fall	No data	15.6
Winter	16.7	11.5

Small-leaf globemallow growing with alfalfa or crested wheatgrass in new pastures near Kimberly, Idaho, met the nutrient requirements for domestic sheep and medium-sized, yearling heifers in the fall and spring (Table 3; Rumbaugh et al. 1993a).

Table 3. Nutritional content (evaluated and averaged for fall and spring) of small-leaf globemallow plants growing near Kimberley, Idaho (Rumbaugh et al. 1993a).

Measurement	Microminerals (µg/g)					Macrominerals (mg/g)				
Element	Cu	Fe	Mn	Na	Zn	Ca	Mg	N	P	K
Leaves	15	1400	60	240	42	25	5.7	38	3.6	18
Stems	16	440	23	470	32	14	5.4	22	2.3	22

Ethnobotany

The Havasupai and Hopi people used small-leaf globemallow for a variety of purposes (Moerman 2003). Weber and Seaman (1985) indicated that the Havasupai mixed clay with juice of the plant before molding it into a pot. Colton (1974) noted that the Hopi chewed the roots or boiled them with cactus root to help ease constipation in adults and babies. The author also indicated that small-leaf globemallow plants were used to treat sores, cuts, wounds, and broken bones as well as in mid-winter ceremonials.

Horticulture

All globemallows are drought tolerant, readily grown from seed, and produce an abundance of red-orange flowers, even in dry soils, making them potentially good horticulture plants. At a native plant garden in Boise, Idaho, globemallow plants grew well when provided supplemental water four times each month in the establishment year and once a month in subsequent years. Plants that were cut back after flowering were compact and bloomed prolifically (Parkinson 2003).

Revegetation Use

Tolerance of harsh growing conditions and disturbances makes small-leaf globemallow a good choice for semi-arid and arid land restoration.

Developing A Seed Supply

Substantial amounts of small-leaf globemallow seed can be harvested from native stands (S. Young, Utah State University [retired], personal communication, August 2018). Though production is sporadic, seed has been harvested using mechanical methods on extensive stands south of the Vermillion Cliffs in northern Arizona and in the south-central part of UtahÕs Uintah Basin (Fig. 6).

In a study of the spatial and landscape genetics of native plant species in Arches and Canyonlands National Parks, research was conducted on 22 small-leaf globemallow populations. Total genetic variation was 84% within and 16% among small-leaf globemallow populations, which was significantly different from the random expectation ($P < 0.001$). The association between genetic and geographic distances was poor, suggesting a high level of gene flow among populations separated by relatively large geographical areas through pollinator-mediated, long-distance pollen transfer (Choo 2012).

Figure 6. Extensive stand of small-leaf globemallow growing in the south-central portion of UtahÕs Uintah Basin. Photo: S. Young, USU.

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 small-leaf globemallow, 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 CenterÕs (USFS WWETAC 2017) Threat and Resource Mapping (TRM) Seed Zone application provides links to interactive mapping features useful for seed collection and deployment planning. The Seedlot Selection Tool (Howe et al. 2017) can also guide restoration planning, seed collection, and seed deployment, particularly when addressing climate change considerations.

In transplanted pastures in northern Utah and southern Idaho, survival and growth of 17 small-leaf globemallow accessions and three small-leaf × MunroÕs globemallow hybrids were compared. Average transplant survival to about 1.5 years for all small-leaf globemallow accessions was high (92%), but was only 71% for one accession from seed collected from southern Utah. Researchers suggested that seed from this southern location was poorly adapted to more northern conditions (Pendery and Rumbaugh 1990).

Map

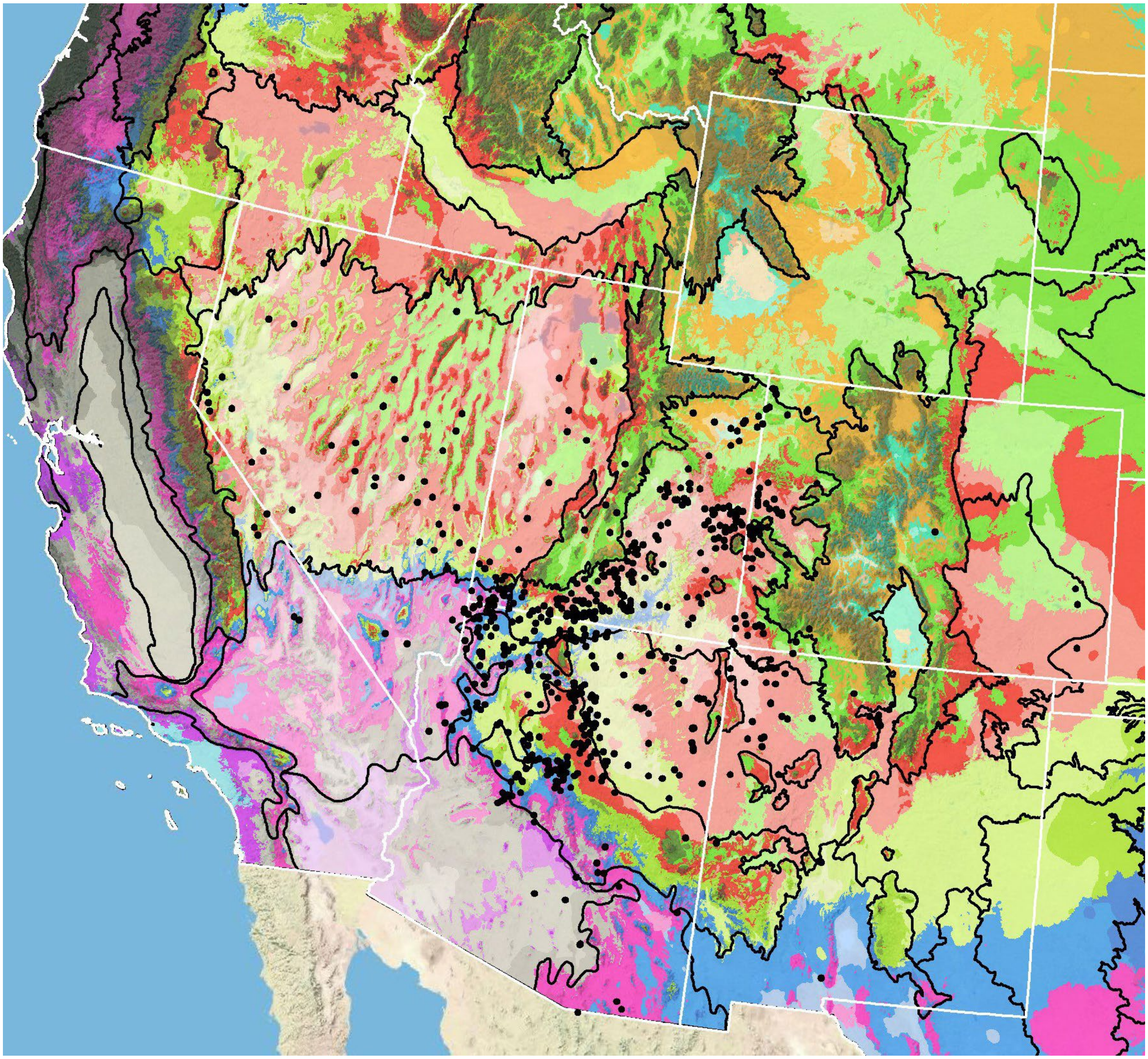

Figure 7. Distribution of small-leaf globemallow (black circles) based on geo-referenced herbarium specimens and observational data from 1911-2016 (CPNWH 2017; SEINet 2017; USGS 2017). Generalized provisional seed zones (colored regions) (Bower et al. 2014) are overlain by Omernik Level III Ecoregions (black outlines) (Omernik 1987; USDI EPA 2018). Interactive maps, legends, and a mobile app are available (USFS WWETAC 2017; www.fs.fed.us/wwetac/threat-map/TRMSeedZoneMapper2.php?). Map prepared by M. Fisk, USGS.

Releases

As of 2018, there were no releases of small-leaf globemallow.

Wildland Seed Collection

Several collection guidelines and methods should be followed to maximize the genetic diversity of wildland collections: collect seed from a minimum of 50 randomly selected plants; collect from widely separated individuals throughout a population without favoring the most robust or avoiding small stature plants; and collect from all microsites including habitat edges (Basey et al. 2015). General collecting recommendations and guidelines are provided in online manuals (e.g. ENSCONET 2009; USDI BLM SOS 2017). As is the case with wildland collection of many 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 small-leaf globemallow.

Wildland Seed Certification

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

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

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

Collection Timing

Small-leaf globemallow flowers indeterminately with flowers lower on the inflorescence opening before the upper flowers. This creates a wide harvest window at some locations (Fig. 5). Mechanical harvests are possible in dense native stands (Fig. 8). Dense stands growing near the Utah-Arizona border have been harvested mechanically using strippers with hoppers (Figs. 9, 10). In less dense or less easily accessible stands, wildland seed can be hand collected by clipping or plucking ripe schizocarps (Fig. 5).

Collections can be maximized by harvesting the schizocarps when the lowest ones have started to split and the majority of schizocarps are just starting to open. At this time, schizocarps will be light green to brown and about 25% of the seeds will be mature (Pendery and Rumbaugh 1993). Because seeds disperse once schizocarps are fully mature, populations should be monitored closely once plants begin to flower (Shock et al. 2008). Seed harvests may also be impacted by weevils (Apionidae), some of which are specialist globemallow seed predators. They can severely limit seed production and their populations should be monitored when inspecting stands for potential harvest (CSUE 2016).

Based on data from 42 collections made over 8 years by BLM SOS field crews, the earliest harvest date was May 26, 2015 from a site at 4,588 ft (1,398 m) elevation in Grand County, Utah (USDI BLM SOS 2017). The latest harvest date was August 11, 2010 from a site at 6,317 ft (1,925 m) elevation in Coconino County, Arizona. Of the 42 collections made over an elevation range from 4,196 to 7,262 ft (1,279Ð2,213 m), 37 were harvested in June or July. Thirty-five collections were from Utah and the others came from Nevada, Arizona, and Colorado (USDI BLM SOS 2017). In small-leaf globemallow stands established from transplants, flowering dates varied by site and plant age (Pendery and Rumbaugh 1990). First flowering was earlier at a northern Utah (early June) than at a southern Idaho site (late June). Average date of first flowering at both sites was 1.5 months earlier (June 1) for second year plants than it was for plants in their establishment year (July 15). Researchers also reported drier conditions in the second year (Pendery and Rumbaugh 1990).

Figure 8. Dense wildland stand of small-leaf globemallow setting seed at the Vermillion Cliffs area near the Utah-Arizona border. Photo: S. Young, USU.

Figure 9. Strippers with hoppers used to mechanically harvest dense small-leaf globemallow stands growing near the Utah-Arizona border. Photo: S. Young, USU.

Weather patterns in western Arizona may allow for spring and fall seed harvests (Comstock et al. 1988). When small-leaf globemallow was monitored at two Mojave Desert sites, plants flowered in both the spring and fall, which coincided with the bimodal rainy periods. Flowering peaked in April. Plants in this area experienced considerable dieback and were essentially dormant through the summer drought conditions. The winter during this one-year study period was also uncharacteristically warm and mild (Comstock et al. 1988).

Figure 10. Mechanically harvested small-leaf globemallow seed from dense stands growing near the Utah-Arizona border. Photo: S. Young, USU.

Collection Methods

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 small-leaf globemallow.

Post-Collection Management

Seed collections should be dried fully. If collections include plant material, which greens up following summer precipitation, drying may be a longer process. Because the seed is attractive to weevils (*Macrophoptus* spp.), it should be inspected prior to storage and treated or frozen to suspend further insect damage. Storage areas should be protected from insects and small mammals (Pendery and Rumbaugh 1986).

Seed Cleaning

Dry seed can be cleaned using a debearder to remove seeds from the schizocarps. If necessary, a clipper or fanning mill can be used to further clean the seed (Pendery and Rumbaugh 1993). Cleaned seed are shown in Fig. 11.

Seed Storage

Small-leaf globemallow seed is orthodox. Seed viability was 95% after seeds were dried and stored at 68 ¡F (20 ¡C) for about 2 years (RBG Kew 2017).

Seed Testing

There is no AOSA germination protocol for small-leaf globemallow (AOSA 2016), but AOSA guidelines for tetrazolium chloride (TZ) viability testing of the *Sphaeralcea* genus are available. Seed is prepared by soaking it overnight at 68 to 77 ¡F (20Ð25 ¡C) followed by staining with 0.1 or 1% TZ concentrations. Seed is nonviable if any part of the embryo or endosperm is unstained. Clipping prior to soaking and staining is recommended for hard seeds (AOSA 2010).

Figure 11. Clean small-leaf globemallow seed. Photo: BLM CP2 SOS.

Germination Biology

Scarification is generally necessary to obtain rapid and high levels of small-leaf globemallow germination. Low temperature exposure following scarification may improve germination of seed collected from more northern locations. High levels of germination (95%) were reported after 28 days when a small seed sample was scarified and then incubated at 59 ¡F (15 ¼C) or 68 ¡F (20 ¡C) with 8/16 hr light/dark cycle. Seed scarification involved partial removal or chipping of the seed coat with a scalpel (RBG Kew 2017).

Scarification followed by cold temperature exposure (34 ¡F [1 ¡C] for ³4 wks) resulted in the greatest germination (³ 70%) of small-leaf globemallow seed collected from Uinta County, Utah. Unscarified seeds subjected to extended periods of cold (12 weeks) had lower germination percentages (² 35%), and scarified seed exposed to warmer temperatures (³41 ¡F [5 ¡C]) for 12 weeks also had lower germination percentages (² 30%). The scarification method was not described (Kramer and Foxx 2016).

Germination of small-leaf globemallow was improved by mechanical scarification; stratification treatments provided no additional improvement (Table 4; Seglias et al. 2018). The study was conducted to identify relationships between source climate, species identity, and germination to improve seed sourcing decision in restoration; small-leaf globemallow was one of several species evaluated. Seed came from eastern Utah where annual temperature averages 48 ¡F (8.9 ¡C) and precipitation averages 18 in (465 mm) and from near Flagstaff, Arizona, where annual average temperature was similar (54 ¡F [12 ¡C]) but precipitation was less (9 in [229 mm]). Seed was afterrippened for 2 weeks, dried, scarified with sand paper (15Ð30 s), and then exposed to various stratification treatments mimicking long winter, spring germination; short winter, spring germination; and short summer monsoon and fall germination conditions followed by spring, summer, or fall germination temperatures (Table 4; Seglias et al. 2018).

Researchers at the Great Basin Research Center reported that no pre-treatments were necessary to germinate small-leaf globemallow seed. Collection location, seed storage conditions (if any), and germination conditions were not reported (Vernon et al. 2006).

Table 4. Germination of afterripened (2 wks) and mechanically scarified seeds exposed to selected stratification and incubation conditions (4 replicates of 25 seeds per treatment. No statistical analysis was conducted (Seglias et al. 2018).

Simulated conditions	Control		Long winter, spring germ		Short winter, spring germ		Short summer monsoon, fall germ	
Stratification (time, temp):	none		8 wks, 37 ¡F		3 wks, 37 ¡F		3 wks, 86 ¡F	
Incubation*:	cool	warm	cool	warm	cool	warm	cool	warm
Seed source	ÑÑÑÑÑÑÑÑÑÑÑÑÑÑÑ-germination %ÑÑÑÑÑÑÑÑÑÑÑÑÑÑ							
Flagstaff, AZ	75	79	38	36	38	59	68	71
Eastern UT	86	85	74	80	47	48	44	64

*Cool (spring/fall) incubation was 68/50 ¡F (20/10 ¡C) and warm (summer) was 77/59 ¡F (25/15 ¡C) with 12/12 dark/light cycle.

Wildland Seed Yield And Quality

Post-cleaning seed yield and quality of small-leaf globemallow seed lots collected in the Intermountain region are provided in Table 5 (USFS BSE 2017). The results indicate that small-leaf globemallow can generally be cleaned to high levels of purity and seed fill but that viability of fresh seed is variable. Other sources (Ogle et al. 2011; USFS GBNPP 2014; RBG Kew 2017) reported that small-leaf globemallow seed weights fell within the range reported in Table 5.

Table 5. Seed yield and quality of small-leaf globemallow 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)	1.11	0.15Ð2.44	36

Clean weight (lbs)	0.15	0.01Ð0.46	36
Clean-out ratio	0.13	0.01Ð0.27	36
Purity (%)	98	87Ð99	36
Fill (%)[1]	92	80Ð99	36
Viability (%)[2]	93	55Ð98	33
Seeds/lb	399,837	230,722Ð612,972	36
Pure live seeds/lb	356,356	189,486Ð576,500	33

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

Marketing Standards

Acceptable seed purity, viability, and germination specifications vary with revegetation plans. Purity needs are highest for precision seeding equipment used in nurseries, while some rangeland seeding equipment handles less clean seed quite well. In 2007, the standardized market price for small-leaf globe mallow was $60/lb PLS (Young and Bouck 2007).

Agricultural Seed Production

Small-leaf globemallow seed production fields were grown successfully the Oregon State UniversityÕs Malheur Experiment Station (OSU MES). Harvestable crops were produced for 5 years. Irrigation increased seed yields but not significantly. Methods for concentrating the seed production period were developed to allow for single annual harvests, but multiple hand harvests resulted in greater yields than single mechanical harvests (Shock et al. 2015).

Agricultural Seed Certification

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

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

Weed Management

At OSU MES, weeds in seed production plots were controlled by hand weeding (Shock et al. 2015). In a study evaluating rehabilitation of cheatgrass (*Bromus tectorum*)-invaded shrublands, findings suggest that small-leaf globemallow may be sensitive to imazapic herbicides (Owen et al. 2011). Small-leaf globemallow was a dominant in this mixed shrub area on the Kaibab Plateau in northern Arizona burned about 11 years prior to initiation of the study. Rehabilitation treatments included: a fall herbicide treatment with imazapic, drill seeding with big sagebrush and Mexican cliffrose (*Purshia mexicana*), a combined treatment, and a control. An evaluation of the nontarget effects revealed average cover of small-leaf globemallow was half as much on herbicide and herbicide-seeded plots as on untreated and seeded plots ($P < 0.0001$) and was reduced for at least 2 years (Owen et al. 2011).

Seeding

Fall seeding is recommended for small-leaf globemallow. Seeding in the spring (April) resulted in poor stand emergence. Spring sowing was done using non-scarified seed soaked in distilled water, rinsed in bleach solution, and stratified for about 2.5 months. Sowing untreated seed in the fall resulted in good small-leaf globemallow stands (Shock et al. 2008, 2015). At OSU-MES, 30 seeds were planted per foot of row in weed-free fields (Shock et al. 2015).

Irrigation

Based on subsurface drip irrigation trials, researchers concluded that small-leaf globemallow needed less than 4 in (102 mm) of supplemental irrigation per year when growing at OSU MES in Ontario, Oregon (Shock and Feibert 2016). Seed yield of seed production fields at OSU MES increased, but not significantly, with supplemental annual irrigation beyond water provided during the establishment period (Table 6; Shock et al. 2015). Irrigation research findings suggested that natural rainfall in Ontario, Oregon, allowed for maximum seed production in weed-free conditions (Table 7).

Table 6. Seed yield (lbs/ac) for fall-seeded (November 2006) small-leaf globemallow in response to no or 0, 4, or 8 in irrigation at Oregon State UniversityÕs Malheur Experiment Station in Ontario, OR (Shock et al. 2015).

Year	Supplemental irrigation (in/season*)		
	0	4	8
	ÑÑÑÑÑÑyield (lbs/ac)ÑÑÑÑÑÐ		
2007**	1062.6	850.7	957.9
2008	436.2	569.1	554.7
2009	285.9	406.1	433.3
2010	245.3	327.3	257.9
2011	81.6	142.5	141.2

*Irrigation season was from floral bud to seed set and water was delivered through a subsurface drip irrigation system.
**2007 data represents the total of three separate hand harvests. Data for 2008Ð2011 represent single combine harvests.

Table 7. Weather conditions at Oregon State UniversityÕs Malheur Experiment Station in Ontario, OR (Shock et al. 2015).

Year	Precipitation (in)		Growing-degree hrs (50-86 ¡F)
	Jan-Jun	Apr-Jun	Jan-Jun
2006	9.0	3.1	1120
2007	3.1	1.9	1208
2008	2.9	1.2	936

2009	5.8	3.9	1028
2010	8.3	4.3	779
2011	8.3	3.9	671
Mean	5.8	2.7	1042

Pollinator Management

Small-leaf globemallow is pollinated by bees. One or more European honey bee (*Apis mellifera*) hives can be transported to field locations, where they may help pollinate crops, although European honey beeÕs attraction to small-leaf globemallow and its subsequent pollination value are unknown at present (J. Cane, USDA Agricultural Research Service, personal communication, February 2019). If introducing new bee populations is not feasible, management options to encourage and sustain existing native bee populations are available (Cane 2008).

Pest Management

Small-leaf globemallow is host to several pests that are capable of reducing plant growth and seed production. At OSU MES, a rust fungus, *P. sherardiana*, infected stands and caused substantial leaf loss and reduced vegetative growth in plants for 2 of the 5 years of production (Shock et al. 2015). Other fungal pathogens that utilize globemallow hosts include: *Puccinia sherardiana*, *P. sphaeralceoides*, *Synchytrium* spp., *Sphaerella stenospora*, *Puccinia platyspora*, and *P. interveniens* (Farr and Rossman 2017). Some weevils (Apionidae) are specialist globemallow seed predators and can severely limit seed production (CSUE 2016).

Seed Harvesting

In an effort to maximize seed harvests, researchers evaluated seed yield and germination of immature to mature schizocarps in seed production plots in Utah. Immature schizocarps yielded the smallest percentage of ripe seed (3%), but this seed germinated best (50%). More mature, but not fully mature, schizocarps yielded 40% mature seed, which germinated at 28%. Fully mature schizocarps yielded the highest amounts of mature seed (45%) but had the lowest germination (12%). Seeds from the least mature schizocarps may have had thinner seed coats or less well developed seed dormancy. More mature schizocarps may have required treatments not applied in this germination experiment (Meyer and Vernon 2008).

For small-leaf globemallow seed production stands growing at OSU MES, seed yield was greatest in the establishment year following fall seeding, but this was primarily the result of multiple hand seed collections. In following years, crops were flailed each fall to concentrate timing of flowering, reduce duration of flowering, and allow for a single mechanical harvest with a combine in the following year (Table 8; Shock et al. 2015). Plants produced harvestable seed for 5 years (Shock et al. 2012, 2015), but by the fifth year seed production was greatly reduced. In the sixth year, growth was poor and the stands were eliminated (Shock et al. 2015).

Table 8. Flowering dates, harvest dates, and seed yields for seed production fields provided no supplemental irritation at Oregon State UniversityÕs Malheur Experiment Station in Ontario, OR (Shock et al. 2015).

Year	Start of flowering	End of flowering	Harvest date(s)	Seed yield (lbs/ac)
2007	5 May	30 Sept	20 June, 10 July, 13 Aug	1062.6*
2008	5 May	15 June	21 July	436.2
2009	1 May	10 June	14 July	285.9
2010	10 May	25 June	20 July	245.3
2011	26 May	14 July	29 July	81.6

*Seed yield represents multiple hand-harvests, which is likely the reason for high yields and not year, plant age, etc.

Nursery Practice

Small-leaf globemallow has been grown successfully in the greenhouse (Pendery and Rumbaugh 1990; Vernon et al. 2005). Vernon et al. (2005) reported excellent emergence after direct seeding small-leaf globemallow into flats in the greenhouse. Scarified seed was planted 0.25 to 0.5 in (0.6-1.3 cm) deep. Pendery and Rumbaugh (1990) planted sand paper-scarified seed in 9 in^3 (150 cm^3) cones filled with four parts sand, two parts peat moss, and one part vermiculite to produce seedlings for research studies.

Wildland Seeding And Planting

Although wildland seeding successes or failures for small-leaf globemallow were not reported in the literature, there are several seeding recommendations for globemallows in general. Fall seeding in medium to coarse soils is recommended (Monsen and Stevens 2004; Ogle et al. 2011). Seed can be broadcast, drill, or compact surface seeded as part of a seeding mixture or interseeded in existing vegetation provided enough area is cleared. Small-leaf globemallow is compatible with most other seeded species, and it has moderate seedling vigor and growth rates (Monsen and Stevens 2004).

Monsen and Stevens (2004) recommend planting small-leaf globemallow seed 0.12 to 0.25-in (0.3-0.6 cm) deep in rows spaced 15 to 18 in (38Ð46 cm) apart. Ogle et al. (2011) suggested slightly deeper seeding (0.25Ð0.5 in [0.6Ð1.3 cm]) and wider row spacing (24Ð48 in [61Ð122 cm]). The recommended pure stand seeding rate is 2 lbs PLS/ac (2.25 kg/ha) (Ogle et al. 2011).

Transplant survival of small-leaf globemallow was high (92%) a year after planting in outdoor dryland pastures planted for livestock grazing studies in southern Idaho and northern Utah (Pendery and Rumbaugh 1990). After 3 months of growth in the greenhouse, seedlings were planted into clean-tilled sites in mid-April 1987. In summer 1988, small-leaf globemallow transplants averaged 114 g (range: 82Ð139 g), 17 stems (range: 10-23), and had a maximum stem length average of 19 in (47 cm) (range: 5Ð22 in [12Ð55 cm]). Plant biomass was greater, plants flowered earlier, and seed production was greater at the Utah site where annual precipitation was 2 to 16 in (59Ð405 mm) greater between 1985 and 1988 (Pendery and Rumbaugh 1990).

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