MOJAVE DESERT NATIVE PLANTS: BIOLOGY, ECOLOGY, NATIVE PLANT MATERIALS DEVELOPMENT, AND USE IN RESTORATION

Desert Chia

Salvia columbariae (Benth.)

Lamiaceae – Mint family

Ashlee Wolf and Molly Wiebush |2023

ORGANIZATION

NOMENCLATURE

Desert chia (*Salvia columbariae* Benth.) (SEINet 2022) belongs to the Lamiaceae or mint family.

NRCS Plant Code.

SACO6 (USDA NRCS 2022).

Synonyms.

Pycnosphace columbariae (Benth.) Rydb. (Tropicos 2022), *Salvia columbariae var. ziegleri* Munz (Averett 2012).

Common Names.

Desert chia, chia, California sage, golden chia (NRCS 2022, SEINet 2022).

Subtaxa.

The Integrated Taxonomic Information System (ITIS) accepts three varieties of chia (ITIS 2022):

var. *ziegleri* Munz- Although accepted as distinct by ITIS (accessed December 2022), this variety is considered a synonym in the Jepson Manual treatment (Averett 2012). It is known only from the San Jacinto Mountains in Southern California (NatureServe 2022). It was a candidate for listing under the Endangered Species Act (the Act) but was determined to not meet the criteria to be considered a species under the Act (USFWS 1985).

var. *argillaceae* S.L. Welsh & N.D. Atwood- This variety has a narrow distribution in Washington and Kane County, Utah where it grows on gypsum and other harsh saline substrates in the Chinle formation (Welsh 2008). It is considered Critically Imperiled in Utah (NatureServe 2022).

var. *columbariae*- This variety is absent from the Jepson Manual. Herbarium records (accessed via SEINET, December 2022) show this variety occurring in the Mojave and Sonoran Desert regions of Arizona and California.

Because these varieties have unclear validity across sources and no readily accessible dichotomous key to distinguish among them in a practical setting, this publication addresses *Salvia columbariae* as the primary taxonomic unit.

Chromosome Number.

The chromosome number for desert chia is 2n=26 (Epling et al. 1962, Ranjbar et al. 2015).

Hybridization.

Despite unequal chromosome numbers between the two species, Chia has occasionally hybridized with California black sage (*Salvia mellifera*) where the two species co-occur. Fertility of the resulting hybrids is not indicated (Epling et al. 1962).

DESCRIPTION

Desert chia is an annual forb, generally growing 3-70 cm tall (height correlated with rainfall), with short, sparsely distributed hairs and a minty to skunky scent (Averett 2012, Baldwin et al. 2002). Its basal leaves are 1-2 times pinnately divided with irregularly rounded lobes (Figure 1). One to four scapose inflorescence stalks will bear 1-2 whorled floral clusters with several blue tubular flowers held in green to purplish, spiny, awn-tipped calyces (Figures 2-3) (Immel 2009). The flowers have two lips—the lower lip is divided into 3 lobes with the center lobe being larger in size, white-tipped and dotted with purple nectar guides (Immel 2009). The fruits are single-seeded, indehiscent nutlets (1.5-2 mm long) with a tan to grey coat with black mottling. The seeds become mucilaginous when wet (Epple and Wiens 2012).

Figure 1: Pinnately-lobed basal leaves of desert chia. Photo: Patrick Alexander

Figure 2: Desert chia growing in Arizona. Note the pinnately lobed basal leaves and scapose inflorescence stalk. Photo: Sue Carnahan

Figure 3: Desert chia inflorescences. Note the whorled flower clusters with purplish calyx bracts. Photo: BLM SOS NV052

Varieties or Subspecies.

See Subtaxa section. Insufficient information is available on validity and description of desert chia varieties.

DISTRIBUTION AND HABITAT

Desert chia occurs in the Western U.S. and northern Mexico. Its distribution extends from Central California southward to Baja California and from the Pacific Coast, and west into southern Arizona. Some populations occur in the Great Basin ecoregion in western Nevada (Figure 4). It commonly occurs in Mediterranean California ecoregions and in the warm desert habitats of the Mojave and Sonoran Basin and Range ecoregions (Figure 4). Desert chia is found scattered more sporadically in the ecoregions that make up the edges of its range including the Madrean Archipelago, Central California Valley, Sierra Nevada, Arizona New Mexico Mountains, Colorado Plateaus, Wasatch and Uinta Mountains, and the California Coast Range. Anthropological accounts suggest that desert chia was once more common throughout its range but may have declined due to development, overgrazing, and fire suppression (Timbrook et al. 1982).

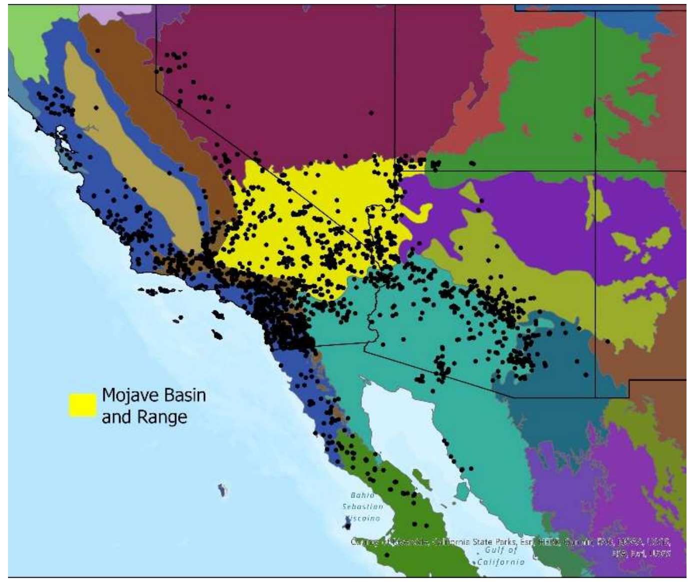

Figure 4: Distribution of desert chia based on georeferenced herbarium specimens and verified observations (black circles, SEINet 2022) with EPA Level III Ecoregions (US EPA 2015). The Mojave Basin and Range ecoregion is shown in yellow.

Habitat and Plant Associations.

Desert chia is generally found in dry, disturbed sites, including sandy washes, roadside cuts, and steep alluvial slopes (Averett 2012, SEINet 2022). Desert chia can form extensive stands, along with an assortment of spring annuals. It occurs in warm desert scrub and xeroriparian plant communities of the Mojave and Sonoran Deserts, as well as chapparal and sage scrub communities along the Pacific Coast. Figures 5-8 show desert chia in a variety of habitats.

Warm Deserts

Desert chia occurs in both the Mojave and Sonoran Deserts. In these warm desert habitats, it is associated with creosote bush (*Larrea tridenta*) and white bursage (*Ambrosia dumosa*) desert scrub, Joshua tree (*Yucca brevifolia*) and juniper (*Juniperus californica*) woodlands, and xeroriparian communities that occur along ephemeral drainages. Additional associated species in these habitats may include Joshua tree (*Yucca brevifolia),* Mexican bladdersage (*Salazaria mexicana*)*,* brittlebush (*Encelia farinosa,*) golden prickly pear (*Opuntia basilaris*)*,* Mojave yucca (*Yucca schidigera*)*,* blackbrush (*Coleogyne ramosissima*)*,* desert willow (*Chilopsis linearis*)*,* turpentinebroom (*Thamnosma montana*), and desert lavender (*Hyptis emoryi*) (BLM SOS 2022, SEINet 2022).

Figure 5: Desert chia in a creosote scrub habitat in California. Photo: BLM SOS CA930A

Chaparral and Coastal Sage Scrub

Desert chia can also be found in the foothill woodland, coastal sage scrub, and chaparral plant communities that extend along the California coast and into Baja California. In these habitats, it can occur on grassy foothill slopes, dry creek beds, and roadside cuts (SEINet 2023). It is often observed after fire in chapparal habitats (SEINet 2023). Associated species in these habitats may include manzanita (*Arctostaphylos* spp.)*,* sagebrush (*Artemisa* spp.)*,* wedge-leaf buckbrush (*Ceanothus cuneatus*)*,* chamise (*Adenostoma* sp.)*,* bigleaf maple (*Acer macrophyllum*)*,* oak (*Quercus* spp.)*,* Pacific poison oak (*Toxicodendron diversilobum*)*,* and Eastern Mojave buckwheat (*Eriogonum fasciculatum*) (SEINet 2023).

Climate.

The Mojave Desert is characterized by low annual precipitation (5 – 25 cm in valley areas), with most rainfall occurring in the winter and a smaller amount during summer thunderstorms (Randall et al. 2010). Heterogenous climate patterns across the region are influenced by large-scale patterns and regional topography and are important drivers of local adaptation and intraspecific variation (Shryock et al. 2018, Baughman et al. 2019) and phenological events (Beatley 1974). Specifically, the reproductive phenology of many desert plant species is highly responsive to pulses in rainfall over short time scales (Bowers and Dimmitt 1994, Zachmann et al. 2021).

Figure 6: Desert chia habitat among a Joshua tree woodland in California. Photo: BLM SOS CA650

Figure 7: Desert chia habitat on a steep slope in California. Photo: BLM SOS CA930A

As a winter annual, desert chia population cycles are also highly responsive to the timing and amount of rainfall, with precipitation events in early fall driving germination and establishment (Bowers 1987, 2005).

Climate information is derived from the climate-based provisional seed transfer zones (PSZs) where desert chia occurs (Shryock et al. 2018; Table 1). According to herbarium specimen locations (SEINET 2022), desert chia occurs in all PSZs in the Mojave Desert ecoregion but is most abundant in Zones 25 and 26 and least abundant in Zone 24 (Table 1). The average annual precipitation in the PSZs where desert chia occurs in the Mojave Desert ecoregion is 17.2 cm (6.8 inches), with an average of 5.9 cm (2.3 inches) falling in the summer and an average of 11.4 cm (4.5 inches) falling in the winter. Note, herbarium specimen locations may not represent the full distribution and abundance of desert chia due to sampling bias towards accessible locations and ephemerality of this desert annual.

Elevation.

Desert chia is generally found at elevations less than 2500 m (8200 ft) and most commonly below 1200m (3937 ft; Averett 2012, Immel 2009).

Soils.

Desert chia is typically found in sandy, silty, or gravelly soils derived from a variety of parent materials including granite, tuff, and limestone or dolomite with calcium carbonate fragments (Immel 2009, BLM SOS 2022). These soils typically have low-fertility and are well-drained (Immel 2009). No associations with biological soil crusts were noted in the literature.

Figure 8: Desert chia habitat in a sandy wash. Photo: BLM SOS NV052

Table 1: Climate of the provisional seed zones (PSZ) where desert chia occurs within the Mojave Desert ecoregion (Shryock et al. 2018).# = the number of herbarium or verified observations of desert chia within the PSZ (SEINet 2022); MAP=mean annual precipitation; SP=summer precipitation, or the mean precipitation that falls in the summer (May-October); WP= winter precipitation, or the mean precipitation that falls in the winter (November-April); MAT=monthly average temperature; Range= Average of the monthly temperature ranges (monthly maximum minus monthly minimum).

PSZ	#	MAP (cm)	SP (cm)	WP (cm)	MAT (C)	Range (C)
25	102	16.5	6.2	10.3	18.9	34.6
26	75	14.5	2.7	11.8	16.8	34.9
29	65	25.5	4.2	21.4	13.8	31.7
20	57	25.5	10.5	14.9	15.3	34.5
21	52	15.6	6.2	9.4	18.8	38.4
27	49	9.6	3.3	6.3	20.0	36.7
23	38	15.8	5.4	10.4	16.1	35.9
24	38	10.7	2.8	7.9	18.8	38.6
28	5	7.8	2.4	5.3	22.3	41.3
22	2	36.1	13.3	22.8	10.0	32.4

ECOLOGY AND BIOLOGY

In general, winter annuals make up at least 40% of the Mojave Desert flora (Johnson et al. 1978) and fill an important niche by providing pollinator and wildlife forage, ground cover, and potential competition for invasive annual grasses (Brooks 2000, Casady et al. 2013, Esque et al. 2021a). With abundant winter rains, desert chia can form extensive stands, making up picturesque springtime superblooms along with other desert annuals (Bowers 2005). Desert chia is able to thrive in disturbed, open habitats (Immel 2009, Averett 2012) and germinate in response to charred organic matter or smoke (Keeley and Fotheringham 1998, Baskin and Baskin 2002), suggesting it may readily establish after fire.

Reproduction.

Breeding System.

Desert chia is both outcrossing and capable of self-fertilization (Visco and Capon 1970). The flowers (Figure 9) are protandrous with flower development that can facilitate self-pollination. The anthers emerge first, bearing large amounts of free pollen, followed by the pollen-receptive stigma which, as it emerges and matures, curls upwards past the anthers and captures pollen in the process (Visco and Capon 1970).

Figure 9: Desert chia blooms. Photo: BLM SOS CA650

Reproductive Phenology.

Desert chia plants produce floral buds as early as January (observation data from iNaturalist 2022) and flowers primarily in the spring (March-June; Averett 2012). Seeds mature in late spring to early summer (Capon et al. 1978).

Pollination.

Desert chia, similar to other *Salvia* species, is predominately pollinated by bees, with observations of active pollen gathering by *Anthophora linsleyi, Anthophora sp., Apis mellifera, Bombus crochii,* and *Osmia sp.* (Visco and Capon 1970).

Seed and Seedling Ecology.

Desert chia seeds are shed from mature plants by late spring, after which they undergo a quiescent period of temperature-mediated after-ripening during the warm summer months (Capon et al. 1978). Desert chia seeds primarily disperse by falling out of the dried inflorescence and traveling short distances via gravity, wind, and surface flow (Immel 2009). Further dispersal by granivores is also likely (Brayton and Capon 1980). Many desert chia seeds will germinate after heavy winter rains, with seedlings emerging as early as November-December (Capon et al. 1978). Populations along elevational gradients may exhibit distinct germination response to temperature cues: lower elevation populations increase in germination after exposure to heat pre-treatments (50 °C/120 °F) that mimic warm soil temperatures following the natural springtime dispersal period (Capon et al. 1978). Increase in germination in the presence of charred wood and smoke, along with its preference for disturbed and open areas, indicate that desert chia is adapted to germinate after fire in its natural setting (Keeley and Fotheringham 1998, Baskin and Baskin 2002, Esque et al. 2021a).

The seeds of desert chia are nutrient rich and are thus sought after by a variety of granivorous animals, including squirrels, ants, birds, and small rodents (Brayton and Capon 1980). Ants (*Pogonomyrmex subnitidus* and *Formica pilicornis*) likely account for the majority of seed depletion from desert chia populations (Brayton and Capon 1980). However, desert chia has several adaptations to mitigate granivory. Seed color within desert chia populations is often matched to the dominant soil color where plants occur due to granivore-driven selection pressure (Brayton and Capon 1980). This camouflaging, along with irregular mottling and striations that help seeds blend in with soil, has been confirmed to reduce seed loss to birds, ants, and rodents (Brayton and Capon 1980). Further, desert chia seeds excrete a mucilaginous coating when wet which acts like a glue, binding to soil particles even after it dries (Fuller and Hay 1983). By adhering to soil particles, the seeds are both physically armored and better camouflaged, effectively reducing seed loss to granivores (Fuller and Hay 1983, LoPresti et al. 2019).

Species Interactions.

Belowground Interactions.

Desert chia did not significantly respond to inoculation with mycorrhizal fungi in a study in coastal sage scrub ecosystem (Aprahamian et al. 2016). No additional examples of desert chia's associations with belowground organisms were found in literature or personal communications.

Parasites and Predation.

See Seed and Seedling Ecology section for a discussion of desert chia seed predation. No examples of parasites specific to desert chia were found in literature or personal communications.

Wildlife and Livestock Use.

Desert chia is noted as a cover species for desert tortoise (*Gopherus agassizii*) but has not been recorded as a forage species (Esque et al. 2021). Its aromatic foliage suggests it may not be palatable to most herbivores (Borders 2009). Several species of insects, birds, and small mammals eat desert chia seeds (Brayton and Capon 1980, Immel 2009).

Other Notable Species Interactions.

Although desert chia doesn't typically establish in microsites directly underneath perennial host plants, it has been shown to benefit from the increased nutrients provided by litter deposition from nearby perennial plants at hyper-arid sites, indicating some degree of positive facilitation (Filazzola et al. 2020). Desert chia is a larval host plant for the *Pyrausta dapalis* moth (Robinson et al. 2010).

Disturbance Ecology.

Desert chia can thrive in naturally disturbed sites such as ephemeral washes and steep hillslopes. Desert chia is also commonly observed to increase in abundance after fires in both coastal scrub and desert ecosystems (Immel 2009, SEINet 2023).

California coastal indigenous groups strategically burned desert chia gathering areas to stimulate population productivity (Timbrook et al. 1982), suggesting the species benefits from regular burn intervals in the chaparral and coastal sage scrub ecosystems. While fire has historically been rare in the Mojave Desert (Esque et al. 2010, 2021b, Vamstad and Rotenberry 2010, Barrows et al. 2014, Lybbert et al. 2017), herbarium notations from specimens within the Mojave Basin and Range ecoregion describe desert chia as being common in burned areas as soon as one year after a fire (SEINet 2023).

Ethnobotany.

Similar to the more widely cultivated chia (*Salvia hispanica*), the tiny seeds of desert chia pack significant amounts of protein and oil, serving as a potent source of energy and nutrition (Hodgson 2001). The seeds are also high in fiber, mucilaginous substances and polysaccharides--all constituents used for treating diabetes and related complications (Hodgson 2001). For these reasons, desert chia is an important traditional food of many Native American tribes in California, Arizona, and Northern Mexico. Groups noted to use desert chia include the Kumeyaay, Soboba, Hia C-eḍ O'odham, Salinan, Apache, Yavapai, Ohlone, Mohave, Chumash, Mahuna, and Cahuilla (Hodgson 2001, Immel 2009, NAEB 2022). Desert chia was likely encouraged by native peoples via prescribed burning and loose cultivation since it is often found in high abundance near ancient villages (Timbrook 1986, Hodgson 2001).

Indigenous groups used desert chia in several ways. Ground seeds were soaked in water and prepared as a pinole or warm porridge (Immel 2009). The Cahuilla people would use a few teaspoons of desert chia seed meal to boost the nutrition and improve the flavor of alkaline water (Hodgson 2001). Desert chia seeds were also used to enhance the flavor of tortillas and other wheat products introduced by Europeans (Mason 1912). In addition to being an excellent food source, desert chia seeds have several topical applications for medicinal purposes. Many tribes used the seeds as a poultice to reduce inflammation in wounds or to treat fevers (Bean and Saubel 1972, as cited in NAEB 2022). Whole or mashed seeds were used to remove foreign objects in the eye because the gelatinous seeds absorb the object and provide anti-inflammatory effects (Zigmond 1981, as cited in Immel 2009).

Spanish and Anglo settlers also made use of desert chia as a food source. Attempts to market the desert chia commercially in the 20th century mostly failed due to lack of familiarity among potential consumers compared to commonly available grains (Doyle 1963, Hodgson 2001).

Horticulture.

Desert chia is available for commercial purchase in small seed packets from several vendors and can be included in native wildflower seed mixes for use in pollinator gardens with other annual and perennial plants (CNPS Calscape 2023).

DEVELOPING A SEED SUPPLY

A robust and stable supply of genetically appropriate seed is needed to meet restoration demands in response to expanding environmental stressors from land degradation, invasive species, and climate change. Restoration success is, in part, predicated on applying the right seed in the right place, at the right time (PCA 2015). Developing a restoration seed supply involves coordination across many partners in all steps of the process: from conducting wildland collections to propagating materials in nurseries and agricultural fields to eventual seeding or outplanting at restoration sites. Appropriate protocols for preserving genetic diversity and adaptive capacity should be in place (Erickson and Halford 2020) and seed origin should be documented for certification purposes and other seed planning considerations.

Seed Sourcing.

Empirical seed transfer zones have not been developed for desert chia. The Desert Southwest Provisional Seed Zones (PSZs) may be used to plan seed sourcing in absence of species-specific information (Figure 10). The Desert Southwest PSZs use twelve climatic variables that drive local adaptation to define areas within which plant materials may be transferred with higher probability of successful establishment and reduced risk of introducing maladapted ecotypes (Shryock et al. 2018). Overlaying PSZs with Level III ecoregions can serve to further narrow seed transfer by identifying areas of both climate similarity inherent in the PSZs and ecological similarity captured by the ecoregion, namely vegetation and soils.

Within the PSZs and ecoregion areas, further site-specific considerations such as soil, land use, species habitat and microclimate affinities, and plant community may be relevant to seed sourcing decisions.

The USGS Climate Distance Mapper Tool incorporates the Southwest Deserts Seed Transfer Zones with climate models and can serve to guide seed sourcing according to current and projected climate conditions.

Commercial Seed Availability and Germplasm Releases.

Desert chia is sometimes available for purchase from large-scale commercial seed vendors. However, availability may be inconsistent, and sources may be limited to a narrow range of appropriate seed zones. Commercially available seed may not be Source Identified, and source seed zone information may not be available. There have been no conservation plant releases of desert chia.

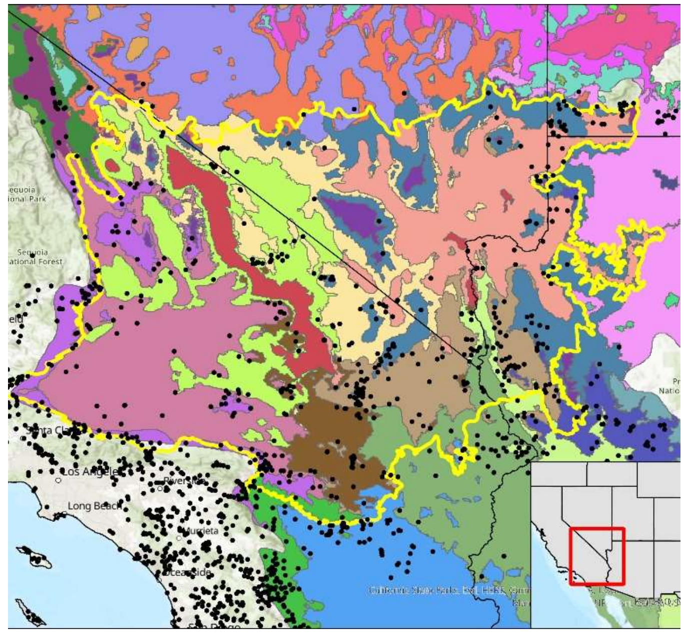

Figure 10: The distribution of desert chia across the Desert Southwest Provisional Seed Zones (Shryock et al. 2018). Occurrences (black dots) are based on georeferenced herbarium specimens and verified observations (SEINet 2022). The Mojave Basin and Range Level III ecoregion (yellow outline) is buffered up to 100km in all directions. PSZs do not always extend a full 100km beyond the Mojave ecoregion.

Figure 11: A dense patch of desert chia. Photo: Patrick Alexander

Wildland Seed Collection.

Wildland seed collection involves visiting naturally occurring populations of target species to provide source seed for propagation, restoration, and research. Ethical practices are intended to prevent overharvesting by limiting harvesting no more than 20% of available seed (BLM 2021). However, in arid regions and in drought conditions, it may be best to adapt this guidance to collect no more than 10% of available seed due to limited regeneration and low-density populations (Asbell 2022, personal communication). Several practices are in place to ensure proper genetic diversity is captured from the source population. These include collecting from the entire population uniformly, sampling a diversity of phenotypes and microclimates, and collecting in various time windows to capture phenological and temporal diversity (BLM 2021).

Seed Collection Timing.

Desert chia is typically collected between April-June with the majority of collections made in mid-May (BLM SOS 2022). Figure 12 shows desert chia at a proper stage for collection.

Collection Methods.

Desert chia seeds do not immediately disperse upon ripening and a good portion can remain in the bracts until optimal collection time across a population area (Brooks and Gault 2023, personal communication). Seeds can be collected by snapping whole inflorescence stems by hand, or snipping with clippers or scissors, and placing upside down into paper bags. The papery inflorescences can be gently crushed by hand during collection to break up the floral bracts and release seed into the bag (Thomas et al. 2022, personal communication). Figures 13 and 14 show examples of collected material.

Figure 12: Desert chia ready for collection. Photo: BLM SOS NV052

Post-Collection Management.

If whole floral stems are collected, place them upside down in paper bags to dry and allow seeds to drop into the bag (Wall and MacDonald 2009). Immediately following collection, seeds should be properly managed to avoid damage or declines in viability during transport and temporary storage. Seed should be dried and ventilated to prevent molding (Pedrini and Dixon 2020). Ventilation can be achieved by collecting and storing seed in breathable containers, such as paper or cloth bags.

Figure 13: Collected seed of desert chia with inflorescence remnants; scale shown in cm. Photo: BLM SOS NV052

Figure 14: Collected seed stalks of desert chia. Photo: BLM SOS CA930C

To dry material before storage or processing, spread it in a single layer on trays or newspaper indoors in a well-ventilated room, or outdoors in a shaded area (BLM 2021). Collected material should be visually inspected for seed-predating insects (Pedrini and Dixon 2020). If seed predation is observed, consider fumigation with No-Pest Strips. After collection, prevent exposure to excessively hot or cold temperatures during transportation and temporary storage by keeping seed in a dry, insulated container (e.g., a cooler) in a shaded area while in the field (BLM 2021).

Seed Cleaning.

Desert chia seeds can be cleaned down to nearly pure seed with sieves alone (Brooks and Gault 2023, personal communication). A seed blower may be used to further remove the smallest chaff (Wall and MacDonald 2009). First, rub the inflorescence whorls through a screen to break down the dried material and release any seeds that remain in the calyxes. Then, run the seeds through #16 and #25 sieves. Lastly, a blower machine run at 1.5 speed or a light winnow with a low-speed fan can remove any remaining chaff (Wall and MacDonald 2009).

At the Bend Seed Extractory, desert chia seed has been cleaned by first using a brush machine (Westrup Model LA-H), with a #30 mantel, at medium speed. Then the lot was air-screened using a Clipper machine with 1/12 round top screen and 1/20 bottom screen at medium speed with medium air (Barner 2008). Figure 15 shows fully cleaned desert chia seeds.

Figure 15: Clean desert chia seed. Photo: Bend Seed Extractory

Seed Storage.

In general, seeds should be stored in cool and dry conditions, out of direct sunlight, to maintain viability. Optimal conditions for medium-term storage of orthodox seeds (up to 5 years) are 15% relative humidity and 15° C (59° F). For long-term storage (>5 years), completely dried seeds should be stored at -18° C (0° F) (De Vitis et al. 2020, Pedrini and Dixon 2020).

Desert chia seed is orthodox (SER SID 2023). Seeds stored for 17 years under optimal conditions at the Kew Royal Botanic Gardens retained high germination rates (77-100%; SER SID 2023). In a seed longevity study designed to run for 360 years, Went and Munz (1949) found that chia seeds had a 63% germination rate after 12-years of storage in poor conditions (a glass jar exposed to direct sunlight and occasional extreme heat). The same seed lot was tested again in 1967 after 20 additional years in vacuum storage (32 years since the original collection year) and exhibited 64% germination (Went 1969). Repeat tests on the same lot in 1997 are summarized by Christiansen 2000 (as cited by Wall 2009) reported 0% germination over 60 years after their original collection.

Seed Testing.

After collection, a representative sample of each seed lot must be tested in an appropriate seed lab to ensure purity and germination meet minimum standards defined by Association of Official Seed Analysts (AOSA) (2016) and species standards from state-level certification programs as available. A set of "principles and standards for native seeds in ecological restoration" (Pedrini and Dixon 2020) outlines further guidelines specific to native plants, including procedures for obtaining representative samples of seed lots and incorporation of dormancy measures into seed testing and labels.

The AOSA does not list specific guidelines for testing germination or purity of desert chia seed, although several perennial *Salvia* species are included in AOSA rules (AOSA 2016). A tetrazolium test protocol for the Lamiaceae family may be followed to assess desert chia seed viability (AOSA 2010). These methods involve placing seeds in a moist media for 2-4 hours at 20-25 °C to allow moisture imbibition, then cutting seeds longitudinally and placing them in a 1% tetrazolium solution overnight at 30-35°C. Viability can then be quantified by assessing the percentage of seeds with embryos that are either evenly stained or have more than half of their cotyledons stained (AOSA 2010).

Wildland Seed Yield and Quality.

Wild-collected desert chia seed is generally high quality, with an average of 97% fill, 99% purity and 95% viability indicated by tetrazolium tests across 19 Seeds of Success collections (BLM SOS 2022, Table 2). Wild collections contain an average of over 380,000 PLS/lb (BLM SOS 2022, Table 2). Wall (2009) notes that small-seeded, annual species tend to have high percentages of viable seed and wild-collected desert chia seeds are highly viable with less than 10% sterile seeds on average.

Table 2: Seed yield and quality of desert chia seeds collected in the Mojave Basin and Range Ecoregion, cleaned by the Bend Seed Extractory and tested by the Oregon State Seed Laboratory or the USFS National Seed Laboratory (BLM SOS 2022). Fill (%) was measured using a 100 seed X-ray test. Viability (%) was measured using a tetrazolium chloride test.

	Mean	Range	Samples
Bulk weight (lbs)	0.9	0.15-3.12	19
Clean weight (lbs)	0.23	0.04-0.77	19
Purity (%)	99	99-99	19
Fill (%)	97	91-99	19
Viability (%)	95	89-98	19
Pure live seeds/lb	380,139	124,965-505,197	19

Wildland Seed Certification.

The Association of Official Seed Certifying Agencies (AOSCA) sets the standards for seed certification and provides guidance on production, identification, distribution, and promotion of all certified seed, including pre-varietal germplasm. Pre-varietal germplasm (PVG) refers to seed or other propagation materials that have not been released as varieties (AOSCA 2022). Pre-varietal germplasm certification programs for Source Identified materials exist in several states encompassing the Mojave Desert ecoregion including California (CCIA 2022), Utah (UTCIA 2015), and Nevada (NDA 2021). Arizona does not have a PVG certification process at this time. Source Identified (SI) germplasm refers to seed collected directly from naturally occurring stands (G0), or seed grown from wildland-collected seed in agricultural seed increase fields (G1-Gx) that have not undergone any selective breeding or trait testing. These programs facilitate certification and documentation required for wildland-collected seed to be legally eligible for direct sale or seed increase in an agricultural setting. Certified SI seed will receive a yellow tag, also referred to as an SI-label, noting key information about the lot including the species, the generation of seed (G0-Gx), source location, elevation, seed zone, etc. (UTCIA 2015, NDA 2021, CCIA 2022).

Wildland seed collectors should be aware of documentation required for seed certification. The Seeds of Success data form and protocol (BLM 2021) include all appropriate information and procedures for site documentation and species identification verification to meet certification requirements for wildland sourced seed. Seed certifying agencies may also conduct site inspections of collection locations prior to certification—specific requirements for inspections vary by state and are at the discretion of the certifying agency.

AGRICULTURAL SEED PRODUCTION

Desert chia will grow best in sandy, well-drained soils with a PH range between 6-8 and full sun exposure (Calscape 2023).

Agricultural Seed Field Certification.

As with wildland source seed (see Wildland Seed Certification section), seed grown in an agricultural seed increase field must also be certified by an official seed certifying agency, where programs exist. Field grown seed is also certified and labeled as Source Identified (SI), as long as it has not undergone selective breeding or testing. Seed field certification includes field inspection, seed testing for purity and germination (see Seed Testing section), and proof of certification for all source or parent seed used to start the field (AOSCA 2022). The SI-label or "yellow tag" for seed from a seed increase field denotes information about source seed, field location, and generation level (G1-Gx) indicating if there is a species-specific limitation of generations allowed to be grown from the original source (e.g., in a species with a three-generation limit, G1/G3, G2/G3, G3/3) (AOSCA 2022). Fields must be free of any prohibited noxious weeds. Restricted noxious weeds and common weeds difficult to separate must be controlled. Fields may be refused certification due to unsatisfactory appearance caused by weeds, poor growth, poor stand, disease, insect damage, and any other condition which prevents accurate inspection or creates doubt as to identity of the variety.

Table 3 outlines the pre-variety germplasm certification standards for desert chia seed in the state of California with a minimum of ¼ lb sample size to be submitted for testing (Schlosser 2021). The Nevada and Arizona Departments of Agriculture do not specify standards for PVG crops. The Utah Crop Improvement Association does not specify standards for PVG crops, but may apply standards of similar species or crop groupings (UCIA 2023).

Table 3: Pre-varietal Germplasm (PVG) standards for seed analysis results of desert chia seed increase crops in California.

Factor	G1	G2	G3 to G10
Pure Seed (minimum)	90%	90%	90%
Inert Matter (maximum)	10%	10%	10%
Total Other Crop Seed (maximum)	0.20%	0.30%	0.50%
Weed Seed (maximum)	None	None	None
Noxious Weed	None	None	None
Germination and Hard Seed (minimum)	65%	65%	65%

Isolation Distances.

Sufficient isolation distances are required to prevent cross-pollination across seed production crops of desert chia from different sources or other *Salvia* species. Table 4 summarizes the isolation distances required for PVG certification in both Utah and California. California standards are described specifically for desert chia (Schlosser 2021), while the Utah standards are general for outcrossing annual species (UCIA 2023). Nevada and Arizona do not specify these standards for Source Identified PVG seed.

Table 4: Crop years and isolation distance requirements for pre-varietal germplasm crops of desert chia. CY= crop years, or the time that must elapse between removal of a species and replanting a different germplasm entity of the same species on the same land. I= isolation distance, or the required distance (in feet) between any potential contaminating sources of pollen.

State	G1		G2		G3+	
	CY	I	CY	I	CY	I
Utah	3	900-600	2	450-300	1	330-165
California	5	60	5	30	2	15

Site Preparation.

Desert chia seeds are sown into a weed free bed. Studies from wildland settings suggest methods to break up soil compaction—specifically, soil ripping—may improve establishment of desert chia (Rowe et al. 2022).

Seed Pre-treatments.

The presence of burnt organic matter (charred wood and aqueous extracts of charred wood) has been shown to increase germination of desert chia by 43% compared to a control (Baskin and Baskin 2002). Other sources have also found high germination of desert chia seeds after exposure to charred organic matter or smoke extracts (Keeley and Fotheringham 1998, RSA 2021). Seeds can also germinate well with no pre-treatment when sown outdoors in a production field (Brooks and Gault 2023, personal communication). Germination response to temperature depends on seed source location—heat pretreatment increased germination percentages in seeds from Mojave Desert sources compared to higher elevation sources (Capon and Brecht 1970).

Seeding Techniques.

Desert chia seed is best sown in autumn. Seeds can be incorporated into the soil by lightly raking after broadcast seeding (Immel 2009). A seed drill (19 mm depth) has been effective in establishing desert chia in wildland seeding (Farrell and Fehmi 2018). Germination can be improved by sprinkling burnt organic matter over the seedbed (Emery 1988).

Establishment and Growth.

As an annual, desert chia will produce seed in the same year as it is sown (or following year if sown in fall) as long as proper growth and pollination are achieved.

Progeny of the desert chia crop may freely self-sow and establish (Immel 2009). Removing volunteer plants of uncertain generation class will help prevent having a mixed-generation crop (Brooks and Gault 2023, personal communication).

Weed Control.

Weeds can be manually removed or carefully spot-sprayed with a non-selective herbicide as they emerge. There are limited number of herbicides registered and labeled for use on native plant crops. See the Native Seed Production guide from the Tucson Plant Materials Center (USDA NRCS 2004) for further details on weed management in native seed production fields.

Pest Management.

Desert chia is generally avoided by herbivores (Gornish and Shaw 2017). No additional information on pest susceptibility or management was described in literature or through personal communication.

Pollination Management.

Growing native plants in or near their native range increases the likelihood that compatible pollinators will be able to find and pollinate the crop (Cane 2008). In general, growers can consider implementing pollinator management and stewardship practices to augment and attract existing pollinator communities. Specific practices will depend on the plant species' pollination needs, and the biology of the pollinators. For example, if a plant relies on native solitary bees, growers can create nesting opportunities adjacent to or within the field perimeter with downed woody material or crafted bee boxes (Cane 2008, MacIvor 2017). In some cases, there may be a need to supplement with managed pollinators through honeybee or bumblebee rental services to ensure pollination of wildflower crops for seed increase (Cane 2008)

No recommendations for pollinator management specific to desert chia were described in the literature or through personal communications.

Irrigation.

A desert chia field grown at Victor Valley College (VVC) in Victorville, California from Mojave Desert seed stock responded well to 7.5" of supplemental irrigation applied over 2 months. This represents a 50% increase from the upper end of summer rainfall ranges for the area (Brooks and Gault 2023, personal communication).

Seed Harvesting.

Since mature desert chia seed can remain on the plant for extended periods, harvesting can be delayed until the majority of seeds are mature across the field (Brooks and Gault 2023, personal communication). Similar to collecting from wildland populations, seeds can be collected by snapping or clipping inflorescence stems and placing them into a breathable bag. Details on mechanical techniques for harvesting from larger desert chia fields are not described in the literature or through personal communication.

Seed Yields and Stand Life.

The stand life for an annual will be one year for the target generation class. The VVC seed increase field of desert chia yielded approximately 6.8 lbs of bulk seed over a 1200 ft^2 field grown from 3 grams of starter seed (Brooks and Gault 2023, personal communication).

NURSERY PRACTICE

Nursery propagation is not commonly practiced for annual species, except in some cases for small-scale seed increase or starting seedlings from limited seed stock in preparation for agricultural seed production (Brooks and Gault 2023, personal communication). If needed, seeds can be planted in flats filled with a well-draining soil (including perlite, sand, and/or coir in the potting mix). Seeds can be sprinkled over the soil surface and lightly pressed in to improve seed-soil contact. Flats should be kept moist during the germination and seedling emergence period. After seedlings are fully emerged, watering can be reduced (Immel 2009).

REVEGETATION AND RESTORATION

As a drought tolerant annual that can thrive in disturbed and burned areas (Figure 16), desert chia can be a great addition to restoration seed mixes and plantings. Desert chia can improve pollinator resources and help stabilize a site after fire or other disturbances (Gornish and Shaw 2017, Esque et al. 2021b). Desert chia has been successfully used for trail and pipeline right-of-way reclamation (Farrell and Fehmi 2018, Rowe et al. 2022). Desert chia was listed as part of a revegetation seed mix for mine reclamation in the Mojave Desert (Kjelstrom & Associates 2015).

Figure 16: Desert chia growing among invasive grasses. Photo: BLM SOS CA690

Wildland Seeding and Planting.

Wildland Seedings.

Desert chia can be seeded at approximately 1.12 lbs per acre (Gornish and Shaw 2017). Seeds should be sown in fall, ahead of winter rains, for optimal establishment (Immel 2009, Rowe et al. 2022). In compacted soils, soil ripping (up to 17 cm) has been shown to increase establishment of desert chia from seed (Rowe et al. 2022). In unburned areas, applying charred organic matter at the time of seeding may improve germination (Emery 1988). Farrell and Fehmi (2018) saw successful establishment of desert chia in Sonoran Desert grasslands after drill seeding into 19 mm deep furrows as part of an 18 species seed mix applied at 3.5 lbs PLS per acre.

After seeding in a California coastal grassland and shrub community, desert chia became more common on south-facing slopes relative to north-facing slopes over time, but greatly declined in cover during drought years (Kimball et al. 2017). Desert chia's preference for exposed, dry sites might make it more vulnerable to drought conditions (Kimball et al. 2017). Due to desert chia seeds' appeal to granivores, methods to deter seed predation such as seed coating with deterrent compounds may improve establishment (Taylor et al. 2020), although no studies specific to desert chia and seed coating were found.

Wildland Plantings.

Annual species are generally not recommended as plug transplants and will likely perform better with direct seeding methods (Immel 2009).

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RESOURCES

BLM SEED COLLECTION MANUAL

https://www.blm.gov/sites/default/files/docs/2021-12/SOS%20Technical%20Protocol.pdf

OMERNIK LEVEL III ECOREGIONS

https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states

CLIMATE SMART RESTORATION TOOL

https://climaterestorationtool.org/csrt/

SEED ZONE MAPPER

https://www.fs.usda.gov/wwetac/threat-map/TRMSeedZoneData.php

MOJAVE SEED MENUS

https://rconnect.usgs.gov/MojaveSeedMenu/

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