Desert Marigold

Baileya multiradiata Harv. & A. Gray

Asteraceae – Sunflower Family

Ashlee Wolf and Molly Wiebush |2023

ORGANIZATION

NOMENCLATURE

Desert marigold (*Baileya multiradiata*) is in the Asteraceae or sunflower family (ITIS 2023). It is most frequently placed in the tribe Helenieae and subtribe Gaillardiinae. The genus *Psilostrpophe* is considered a likely closest relative of the genus *Baileya* (Turner 1993).

NRCS Plant Code.

BAMU (USDA NRCS 2022).

Synonyms.

Baileya multiradiata var. thurberi (Rydb.) Kittell, *Baileya australis* Rydb., *Baileya multiradiata* var. *nudicaulis* A. Gray, *Baileya pleniradiata* var. *multiradiata* (Harv. & A.Gray) Kearney, *Baileya pleniradiata* var. *thurberi* Rydb., *Baileya thurberi* Rydb. (ITIS 2023, SEINet 2023, Tropicos 2023).

Common Names.

Desert marigold, desert baileya, showy desert-marigold, paper daisy, wild marigold, many-flowered desert marigold, hierba amarilla (Thomas 2022, SEINet 2023).

Subtaxa.

No subtaxa of desert marigold are recognized by the Flora of North America or the Integrated Taxonomic Information System (ITIS 2023).

Chromosome Number.

Chromosome numbers are 2n=32, with one anomalous count of 2n=34 (Watson 1973) attributed to potential misinterpretation of a pair of B chromosomes (Turner 1993, CCDB 2023).

Hybridization.

There are no records of naturally occurring hybridization between desert marigold and other *Baileya* species. Barriers to gene exchange result in infertility of artificial crosses between desert marigold and its congener, woolly desert marigold (*Baileya pleniradiata*) (Brown 1974).

DESCRIPTION

Desert marigold is a biennial or short-lived perennial forb, growing 20-100 cm in height, with canescent tomentose herbage (Keil 2012; Figure 1).

Figure 1: A robust desert marigold individual. Photo: BLM SOS NV052

Its basal leaves are densely wooly, petiolate, and 1-3 times pinnately divided with lobes ranging from linear to ovate in shape (Keil 2012, SEINet 2023; Figure 2). Showy composite heads (4-5 cm wide) are held in a hemispheric involucre with linear-lanceolate phyllaries (Figure 3) and are borne singly on mostly leafless stalks rising 10-30 cm above the foliage (Keil 2012, SEINet 2023). Yellow rays (10-20 mm long) occur in greater than one series and are conspicuously three-lobed at the tip (Keil 2012; Figure 4). Yellow discs number over 100. The fruit is a cylindric or slightly angled achene, lacking pappus, and striated with even longitudinal ribs (Keil 2012).

Figure 2: The basal rosette with petiolate, pinnately lobed leaves covered in wooly hairs. Photo: Patrick Alexander

Figure 3: Desert marigold's composite flower head with linear-lanceolate phyllaries. Photo: Sue Carnahan

Distinguishing between desert marigold and the closely related woolly desert marigold (*Baileya pleniradiata*) can be challenging and requires flowers or fruits. Woolly desert marigold will generally have shorter (10 cm or less) and more leafy inflorescence stalks (Kearney et al. 1960).

The rays of woolly desert marigold are shorter (6-10 mm) and shallowly 3-lobed compared to the prominently lobed and longer rays of desert marigold. Additionally, the achenes of woolly desert marigold are angled with more prominent ribs at the angles while desert marigold is striated with even ribs (Keil 2012).

Figure 4: Desert marigold's composite flower head. Photo: Patrick Alexander

DISTRIBUTION AND HABITAT

Desert marigold is found throughout the warm desert ecoregions of the southwestern United States and northern Mexico. It commonly occurs in the Mojave, Sonoran, and Chihuahuan Deserts in addition to more restricted or sporadic occurrences in ecoregions that neighbor the warm deserts such as the Madrean Archipelago, Arizona/New Mexico Mountains, Arizona/New Mexico Plateau, and the Central Basin and Range (Figure 5). Because desert marigold is frequently used in seed mixes, it has become naturalized outside of its native range. Plants in the northeastern Sonoran Desert are apparently native, while those found in the southwestern portions of the Sonoran Desert are thought to be naturalized (Keil 2012). Plants in the southwestern Mojave Desert near Edwards Air Force Base may also be naturalized (Keil 2012).

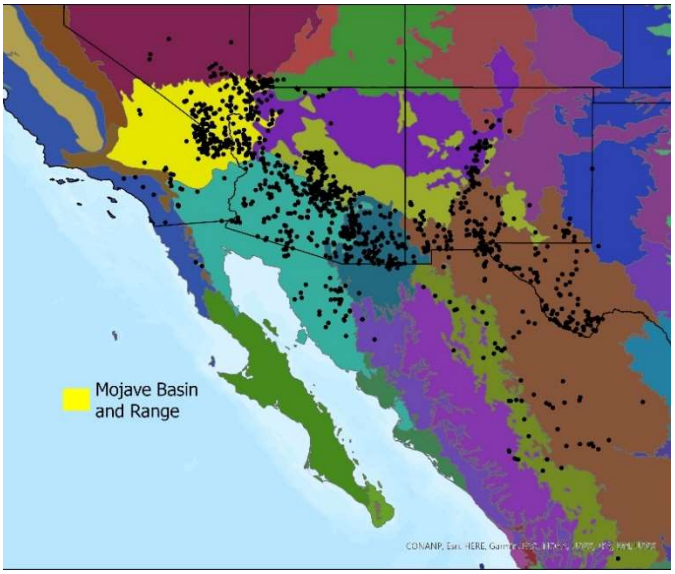

Figure 5: Distribution of desert marigold based on georeferenced herbarium specimens and verified observations (black circles, SEINet 2022) with EPA Level III Ecoregions (US EPA 2015). The Mojave Basin and Range ecoregion is shown in yellow.

Habitat and Plant Associations.

Desert marigold is generally found in full sun on wash bottoms and margins, alluvial slopes, and sandy plains (SEINet 2022). Throughout its range, it can be common along roadsides where it appears to be adapted to increased disturbance and water runoff (Thomas 2022).

Figure 6: Desert marigold in a rocky, exposed habitat in Arizona. Photo: BLM SOS AZ932

Mojave Desert.

In the Mojave Desert, desert marigold is found in desert flats, shallow washes and benches, and gentle slopes (SEINet 2022). Associated species in these habitats include Joshua tree (*Yucca brevifolia*, *Y. jaegeriana*), Mojave yucca (*Yucca schidigera*), burrobush (*Ambrosia dumosa*), catclaw acacia (*Acacia greggii*), yerba santa (*Eriodictyon angustifolium*), brittlebush (*Encelia farinosa*), big galleta (*Hilaria rigida*), and blackbrush (*Coleogyne ramosissima*) (BLM SOS 2022, SEINet 2022).

Figure 7: Desert marigold habitat on a gravelly slope in Nevada Photo: BLM SOS NV052

Figure 8: Desert marigold habitat along a roadside in Arizona. Photo: BLM SOS AZ932

Climate.

The Mojave Desert is characterized by low annual precipitation (2-10 inches or 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).

Climate information is derived from the climate-based provisional seed transfer zones (PSZs) where desert marigold occurs (Shryock et al. 2018; Table 1). According to herbarium specimen locations (SEINet 2022), desert marigold occurs in all PSZs in the Mojave Desert ecoregion except Zone 27. It appears to be most abundant in Zones 20 and 21 and very infrequently collected in the PSZs in the western and southwestern portions of the Mojave that generally have lower precipitation amounts (Zones 22, 24, 26, 28, and 29) (Table 1). The average annual precipitation in the PSZs where desert marigold occurs in the Mojave Desert ecoregion is 18.7 cm (7.4 inches), with an average of 6 cm (2.4 inches) falling in the summer and an average of 12.7 cm (5 inches) falling in the winter. Note, herbarium specimen locations may not represent the full distribution and abundance of desert marigold due to sampling bias towards accessible locations.

Table 1: Climate of the provisional seed zones (PSZ) where desert marigold occurs within the Mojave Desert ecoregion (Shryock et al. 2018).# = the number of herbarium or verified observations of desert marigold 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)
20	148	25.5	10.5	14.9	15.3	34.5
21	126	15.6	6.2	9.4	18.8	38.4
23	69	15.8	5.4	10.4	16.1	35.9
25	69	16.5	6.2	10.3	18.9	34.6
26	6	14.5	2.7	11.8	16.8	34.9
29	5	25.5	4.2	21.4	13.8	31.7
22	4	36.1	13.3	22.8	10.0	32.4
24	3	10.7	2.8	7.9	18.8	38.6
28	1	7.8	2.4	5.3	22.3	41.3

Elevation.

Desert marigold is most commonly found at elevations below 5000 ft (1524 m) (Keil 2012, SEINet 2023) but can occur up to 6500 ft (1981 m) (Thomas 2022).

Soils.

Desert marigold typically occurs in alkaline, coarse soils with sandy and gravelly texture, often associated with alluvial deposits (BLM SOS 2022, Thomas 2022). It can also thrive in caliche, clay, and loamy soils as long as there is decent drainage (Thomas 2022).

No associations with biological soil crusts were noted in the literature.

Desert marigold is a drought- and disturbance-tolerant species that is attractive to a variety of pollinators and wildlife (Esque et al. 2021).

ECOLOGY AND BIOLOGY

Reproduction.

Breeding System.

The Asteraceae family to which desert marigold belongs is primarily insect-pollinated with few self-compatible species (Vogel 2015). Its rich floral nectar and frequent insect visitation further suggest desert marigold is an outcrossing species. However, no sources specifically describe reproductive biology of desert marigold.

Reproductive Phenology.

Desert marigold typically flowers from March to October (SEINet 2023), although it can opportunistically bloom in response to rainfall throughout the year. Wildland seed collection data indicate seeds typically mature April to June in the Mojave desert (BLM SOS 2022), and May to October in the Chihuahuan desert where monsoonal influences are more prominent (SWSP 2023).

Pollination.

Desert marigold flowers are nectar-rich and abundant, attracting a variety of floral visitors, including several groups of bees and butterflies (Esque et al. 2021, Thomas 2022). Bee visitors to desert marigold include those in the genera *Colletes, Andrena, Caliopsis, Perdita, Megachile, Ashmeadiella,* and *Dufourea*, among others (Pickering 2022). Leanira Checkerspot (*Chlosyne leanira*) and orangetip (*Anthocheris* spp.) butterflies are also noted visitors (Thomas 2022).

Seed and Seedling Ecology.

Desert marigold seedlings seem to best germinate under spring and fall conditions in desert ecosystems and can rapidly emerge after disturbances such as fire (Bauer et al. 2009). In a multi-year study conducted 1948-1956 in Joshua Tree National Park, researchers examined the relationship between climate (temperature and precipitation) and germination of several Mojave desert plants in the field (Juhren et al. 1956). They found that desert marigold consistently germinated when daytime temperatures were between 16 °C (61° F) and 29 °C (84 °F), and nighttime temperatures were between 5 °C (41 °F) and 9 °C (48 °F). They speculate that desert marigold could likely germinate with higher daytime temperatures not recorded in their study timeframe. Interestingly, they observed that the highest germination rates did not correlate with the highest rainfall and that 7 mm of rainfall was sufficient for germination. However, they note that desert marigold was shown to have optimal germination in a laboratory setting when given 50 mm of artificial rainfall.

Desert marigold seeds have a variety of potential dispersal mechanisms. Its seeds are eaten by small mammals, insects, and birds, including the black-throated sparrow (Williams 2023). These granivores may inadvertently disperse viable seeds. Viable desert marigold seeds have been found in cactus wren (*Campylorhynchus brunneicapillus*) nests in the southern Chihuahuan Desert, indicating potential for bird dispersal during nest material gathering and construction (Milton et al. 1998). Desert marigold seeds also disperse overland via wind and gravity. A study on seed movement in the Chihuahuan Desert found that desert marigold seeds were among the most frequently found species in structures called connectivity modifiers (ConMods) which capture seed and sediment to improve passive establishment and assess seed movement on the landscape (Turk 2021).

According to a study on the effects of granivore removal on plant abundance in the Chihuahuan Desert, desert marigold significantly decreased in density in areas where granivores (rodents and ants) were removed (Samson et al. 1992). The authors speculate that the cases where their study species decreased in response to granivore removal may be driven by complex interactions between how different granivores select for varying seed sizes across seasons that may influence competitive interactions between plants (Samson et al. 1992).

Species Interactions.

Belowground Interactions.

Desert marigold is associated with arbuscular mycorrhizal fungi. Roots show increased colonization by arbuscular mycorrhizal structures during flowering, potentially due to high phosphorous demand (Titus et al. 2002).

Insect Herbivory.

Desert marigold is a larval host for the desert marigold moth (*Schinia minniana*) which use the flower heads to deposit a single larvae per head and seal a cocoon by webbing the ray flowers closed around it (Myles and Binder 1990). The

larvae—protected from predators and solar radiation—feed on developing achenes within the flower head (Myles and Binder 1990).

Wildlife and Livestock Use.

Desert marigold foliage is a minor diet component for the endangered desert tortoise (*Gopherus agassizii*), making up less than 1% of tortoise diets in the eastern Mojave Desert (Esque 1994). The high mineral and other nutritional content of its foliage may contribute to its forage potential for the desert tortoise and small mammals (Esque et al. 1990, as cited in Thomas 2022).

Desert marigold is toxic to sheep and goats due to the chemical hymenoxon. Horses and cattle are likely unaffected by this compound and no cases of poisoning have been reported (Turner 2020). However, livestock will typically avoid eating desert marigold unless other forage is lacking (Thomas 2022).

Other Notable Species Interactions.

In addition to the desert marigold moth, desert marigold is a likely host plant for the white-lined sphinx moth (*Hyles lineata*) (CNPS Calscape 2023).

Disturbance Ecology.

Desert marigold is considered an "increaser" and early-seral species in response to disturbance in the Mojave and Sonoran deserts (Abella 2010). Herbarium records note associations with a variety of disturbances including horse trails, invasive plant dominance, and burned areas (SEINet 2022).

Desert marigold exhibits rapid seedling emergence and establishment in burned areas in the Mojave and Sonoran deserts, where it can become the dominant ground cover following wildfires (Wilson et al. 1994, Bauer et al. 2009, Abella et al. 2009).

Ethnobotany.

Desert marigold has been used as building material and dermatological aid (NAEB 2022). The Jemez Puebloan people have used it to mix with clay in adobe buildings (Cook 1930). The Acoma and Laguna tribes rubbed it under their arms as a deodorant (Swank 1932).

Desert marigold contains compounds with anticancer properties including an ester called baileyolin which is known to be antibiotic and inhibit tumor formation (X.A. Dominguez et al. 1977, as cited by Turner 2020).

Horticulture.

Desert marigold is a common addition to xeriscaping and urban pollinator gardens due to its drought tolerance and attractiveness to a variety of pollinators (CNPS Calscape 2023). It attracts a diversity of bees, even in degraded urban landscapes (Lowe and Foltz Sweat 2017). It is recommended to grow desert marigold in full sun and well-drained, rocky soils where it can re-seed itself (CNPS Calscape 2023). It is commonly available from retail nurseries as a container plant or in seed packets (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.

Seed sourcing can influence restoration outcomes due to local adaptation (Custer et al. 2022), landscape genetic patterns (Massatti et al. 2020, Shryock et al. 2021) and differing ability to adapt to current and future climate conditions (Bucharova et al. 2019). However, there has been relatively little research evaluating seed sourcing strategies in actual restoration settings where many additional factors influence performance (Pizza et al. 2023). While non-local sources can perform well in meeting initial restoration goals such as establishment and productivity (Pizza et al. 2023), plants have coevolved with interacting organisms, such as pollinators and herbivores, that can exhibit preferential behavior for local materials (Bucharova et al. 2016, 2022). Further, evidence of local adaptation and its influence on restoration outcomes can take decades to emerge for long-lived species (Germino et al. 2019).

Empirical seed transfer zones have not been developed for desert marigold. The Desert Southwest Provisional Seed Zones (PSZs) may be used to plan seed sourcing in absence of species-specific information (Figure 9). The Desert Southwest PSZs use twelve climatic variables that are known to drive local adaptation in contrasting native species 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 extant 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 (2010-2040 and 2040-2070 futures, and moderate and high emissions scenarios).

Commercial Seed Availability and Germplasm Releases.

Desert marigold is often 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 are no conservation plant releases of desert marigold.

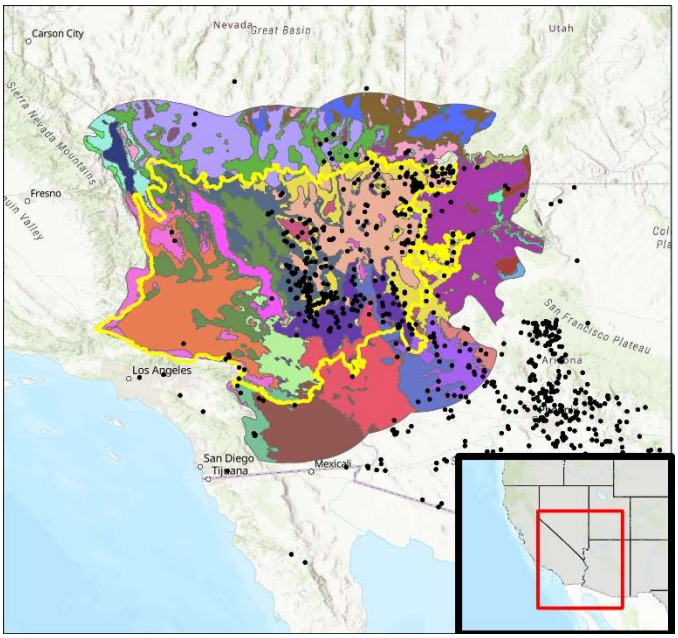

Figure 9: The distribution of desert marigold across the Desert Southwest Provisional Seed Zones (Shryock et al. 2018). Occurrences (black dots) are based on georeferenced herbarium specimens and verified observations (SEINet 2023). The Mojave Basin and Range Level III ecoregion (yellow outline) is buffered up to 100 km in all directions. PSZs do not always extend a full 100 km beyond the Mojave ecoregion.

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 under 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 (CPC 2023). 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 marigold is typically collected between mid-April to mid-June with the majority of collections occurring in May in the Mojave Desert. However, flowering and seeding is responsive to rainfall and a collection has been made in December in the Mojave Desert (BLM SOS 2022). In the Chihuahuan Desert, desert marigold is collected from May to December, with most collections occurring in October (SWSP 2023).

Figure 10: A composite head of desert marigold holding ripe achenes. Photo: Patrick Alexander

Collection Methods.

Desert marigold seed can be collected by hand when the majority of achenes are ripe by rubbing floral heads to release achenes into paper bags. Alternatively, whole heads can be snapped or clipped just below the base, though material collected this way would require more processing during seed cleaning.

Post-Collection Management.

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.

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). Desert marigold seeds should be dried for 4 to 6 weeks in paper bags in a warm, dry room prior to processing (Graham 2003). 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 marigold seeds may have attached chaff that needs to be removed and separated during seed cleaning. To accomplish this, small lots of desert marigold seed can be rubbed through sieves (#14 and #25) to remove the finer chaff, followed by a winnowing with a blower set at 1.5 speed. Increasing the blower speed can further winnow out lighter sterile fruits, leaving only the fertile achenes (Wall and MacDonald 2009).

Woolly desert marigold seed, which has a very similar structure to desert marigold, was cleaned at the Bend Seed Extractory using the following method: The seed was run through a Westrup Model LA-H brush machine with a #10 mantel at medium speed. Then the seeds were air-screened through an office Clipper with a 1/16 round top screen and a 30 x 20 wire bottom screen at medium speed with low to medium air. This process resulted in a lot with 99% purity (Barner 2009).

A similar method is recommended for larger lots of desert marigold seed harvested from agricultural seed production fields which can be cleaned by processing with a brush machine or hammer mill, followed by air screening equipment (Thomas 2022). In all cases, the sieve, brush machine, or hammermill serves to separate the chaff from the achenes. This step is essential if putting the seed through an air separator which can get clogged with the chaffy material (Saidnawey and Cain 2023).

Figure 11: Collected material of desert marigold before seed cleaning, scale shown in inches. Photo: BLM SOS NV052

Seed Storage.

Desert marigold seed is orthodox (SER SID2023). No species-specific storage protocols or information on seed longevity were found in the literature or through personal communication.

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).

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 the 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 includes *Baileya* species in the tetrazolium testing protocols for the Asteraceae family to assess seed viability. These methods involve imbibing seeds overnight at 20-25 °C, then cutting seeds longitudinally and placing them in a 0.1% tetrazolium chloride solution for 6 hours to 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).

To test germination rates of desert marigold, AOSA (1996) recommends placing seeds in a moistened substrate in a covered petri dish at 20-30 °C under cool white florescent lighting for 8 hours per 24-hour period. A final count for germination assessment can be conducted after 14 days (AOSA 1996).

Wildland Seed Yield and Quality.

Wild-collected desert marigold seed is of fairly high quality, with an average of 88% fill, 96% purity and 86% viability indicated by tetrazolium tests across 11 Seeds of Success collections (BLM SOS 2022; Table 2). Wild collections contain an average of over 489,700 pure live seeds (PLS) per lb (BLM SOS 2022; Table 2).

Table 2: Seed yield and quality of desert marigold 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)	0.75	0.24-1.64	11
Clean weight (lbs)	0.13	0.04-0.26	11
Purity (%)	96	94-99	11
Fill (%)	88	70-99	11
Viability (%)	86	62-97	11
Pure live seeds/lb	489,748	375,239-632,169	11

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

In general, desert marigold will do best planted in full sun and in moderately coarse to coarse soils with a neutral pH (Granite Seed 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 marigold seed in the state of California with a minimum of 5-ounce sample size required for testing (Schlosser 2020). 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).

Isolation Distances.

Sufficient isolation distances are required to prevent cross-pollination of desert marigold from different conspecific sources or other *Baileya* species. Table 4 summarizes the isolation distances required for PVG certification in both Utah and California. California standards are described specifically for desert marigold (Schlosser 2020), while the Utah standards are general for outcrossing perennial species (UCIA 2023). Nevada and Arizona do not specify these standards for Source Identified PVG seed. The distances recommended by California (15-60 feet) may be insufficient to prevent pollinator-facilitated gene flow between different Source Identified desert marigold crops and related species.

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

Factor	G1	G2	G3 to G10
Pure Seed (minimum)	70%	70%	70%
Inert Matter (maximum)	30%	30%	30%
Total Other Crop Seed (maximum)	0.20%	0.30%	0.50%
Weed Seed (maximum)	0.20%	0.30%	0.50%
Noxious Weed	None	None	None
Germination and Hard Seed (minimum)	60%	60%	60%

Table 4: Crop years and isolation distance requirements for pre-varietal germplasm crops of desert marigold. 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.

Fields should be as weed-free as possible prior to sowing or transplanting desert marigold seeds or plugs. Site preparation to reduce undesirable vegetation should be planned and implemented well in advance of field establishment (USDA NRCS 2004). If fields are uncultivated or fallow and have perennial or annual weeds, one or more years of intensive cultivation (i.e. cover cropping) and herbicide treatment may be necessary (USDA NRCS 2004). After managing undesirable species, final seedbed preparation can include shallow tilling followed by packing to promote a finely granulated, yet firm seedbed that allows soil to seed contact, as well as facilitation of capillary movement of soil moisture to support seedling development (USDA NRCS 2004).

Because desert marigold has associations with mycorrhizal fungi, soil inoculation may improve plant growth where soil health is depleted; however, this approach remains untested in disturbed desert sites.

Seed Pre-treatments.

Desert marigold seeds can germinate without pre-treatment. Growers in the Mojave did not describe seed pre-treatments specific to desert marigold and some find that it germinates sufficiently without any treatment (Johnson 2023, personal communication).

Using seed from central New Mexico, researchers found that desert marigold had greater than 50% germination across all treatments, but germination was highest (72%) after a 3-week warm-moist (30 °C) pre-treatment (Pendleton and Pendleton 2014).

Seeding Techniques.

Desert marigold seed can be planted no more than 1/4 inch deep in the fall or early winter, at a rate of 0.5 to 2 lbs PLS per acre if using a seed drill, or 1 to 4 lbs PLS if broadcasted (Thomas 2022). Researchers in the Sonoran desert found that sowing in mid-October had the highest rate of establishment compared to later fall seeding (Sullivan 1988). In regions with more severe winters, planting in the spring will reduce risk of frost damage (Thomas 2022).

In general, direct sowing may be more effective than plug planting for desert marigold (Plath

2023, personal communication). However, plug planting may be preferrable when there is a limited amount of seed available, if seed has low viability, or if the seed lot has weed seed contaminants that can be more easily weeded out in a nursery (Winters 2023, personal communication). If planting containerized plugs, transplant into the field in the fall for best establishment (Thomas 2022). See Nursery Practice for propagation guidance.

Establishment and Growth.

Time until seed production for desert marigold depends on sowing time. Seedling rosettes may require a period of cold dormancy before setting buds (TWC 2023). Therefore, fall sowing is ideal and spring sowing may not result in blooms and seed production until the following spring (Hagman 2023, personal communication). However, later plantings in June or July are also possible and plants can bloom and produce seed as early as late summer and fall of the same year (Thomas 2022).

In a study on the effects of nitrogen addition in a Chihuahuan Desert wildland setting, desert marigold did not benefit from nutrient addition—it showed decreased density likely due to self-thinning and no change in biomass with fertilization—potentially due to its association with nutrient-fixing mycorrhizae (Gutierrez et al. 1988). This may suggest that supplemental fertilization of desert marigold crops would not be beneficial.

Weed Control.

Generally, 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. In smaller fields, hand rogueing weeds can be sufficient (Hagman 2023, personal communication).

Pest Management.

No specific information on desert marigold's 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 marigold were described in the literature or through personal communications.

Irrigation.

No metrics were found relating irrigation methods and regimes to plant performance or seed yield of desert marigold. However, it is subject to crown rot if soil is consistently saturated (TWC 2023).

In a study on the effects of supplemental watering in a Chihuahuan Desert wildland

setting, desert marigold had the highest density and biomass when given weekly watering of 6 mm compared to a single event of watering with 25 mm, or no supplemental water (Gutierrez et al. 1988). This may suggest that regular drip irrigation could be preferrable to intermittent flood irrigation.

Other growers have had success with drip irrigation for native desert plants and found flood irrigation did not adequately penetrate into soil, resulting in significant evaporation in an aridland farm setting (Hagman 2023, personal communication).

Seed Harvesting.

Desert marigold has been described as both having very indeterminate ripening with seeds maturing across a wide time range, (Kleiner 2023, personal communication), and being fairly uniform in timing of seed ripening (Hagman 2023, personal communication). It is unclear if this variation is due to seed source and local adaptation, growing practices, or field location and climate. Regardless, since the seeds do not immediately shatter upon ripening, harvest can be delayed until a larger percentage of seed is ripe and ready for harvest (Kleiner 2023, personal communication; Hagman 2023, personal communication).

Seeds can generally be harvested in late spring to early summer. As with most species, the first harvest will typically be lighter compared to subsequent years (Hagman 2023, personal communication).

Seeds can be collected by hand, using techniques similar to descriptions in Collection Methods. In larger fields, mechanical seed collection can be completed using a seed stripper or combine (Thomas 2022).

Seed Yields and Stand Life.

Since desert marigold is short lived, the stand life is no more than two to three years after which the field should be rotated to another crop (Hagman 2023, personal communication). Since desert marigold volunteers from seed inevitably present in the field, the next crop should have a different seed size that can easily be separated from desert marigold during seed cleaning to avoid contamination (Hagman 2023, personal communication). Although it is short lived, desert marigold crops can produce abundant seed (Thomas 2022), though no data on yield amounts was reported in the literature or in personal communications.

NURSERY PRACTICE

Nursery growers in the Mojave Desert have had mixed success in propagating desert marigold in containers. Some growers working with both Mojave-sourced or commercially-purchased seed have had little to no success sowing desert marigold in nurseries (Sturwold et al. 2022, personal communication; Plath 2023, personal communication), while others have found the species to be easy to propagate (Johnson 2023, personal communication). Growers working with Chihuahuan Desert sources have been unsuccessful in propagating desert marigold plugs for outplanting in agricultural seed increase fields. Even though plants germinated in the greenhouse, they subsequently failed to establish (Mullins 2023, personal communication).

Desert marigold seed can be sowed in the spring in nursery containers (Thomas et al. 2022, personal communication) by sprinkling in seeds and then covering with a shallow layer of soil (Johnson 2023, personal communication). Germination may be erratic with seedlings emerging over 7 to 45 days from planting

(Thomas 2022). Pruning damaged leaves and stems in the fall or winter can stimulate growth (Thomas 2022).

In general, growers at the Joshua Tree National Park nursery soak all species' seeds overnight to encourage imbibition prior to sowing them into flats (Graham 2022, personal communication). They find that sowing in flats and then transplanting successful individuals into larger containers saves space in the nursery and prevents the soil from becoming crusted over when getting misted daily to provide surface moisture for seeds (Graham 2022, personal communication). At the Lake Mead National Recreation Area native plant nursery, growers prefer to sow directly into 8" conetainers and allow plants to grow more robustly before transplanting into larger pots or restoration sites (Wallace 2023, personal communication).

Based on nursery propagation and restoration outcomes in mine reclamation in the Mojave Desert, seed germination of desert marigold in containers can be low compared to direct seeding at the project site (Plath 2023, personal communication). Therefore, direct seeding may be preferrable to nursery propagation for this species (Plath 2023, personal communication). See Wildland Seedings for more information.

REVEGETATION AND RESTORATION

Desert marigold is frequently used in revegetation and restoration efforts throughout its range. Its drought and disturbance tolerances, and attractiveness to wildlife and pollinators, make it desirable for a variety of applications including in roadside and utility right-of-way revegetation (Walker and Powell 1999, Farrell and Fehmi 2018), post-fire recovery (Bauer et al. 2009, DeFalco et al. 2009), mine reclamation (Plath 2023, personal communication), and to compete with invasive annual grasses in the Mojave Desert (Abella et al. 2012a). Additionally, it has been favorably evaluated as a phytoremediation candidate for its potential to uptake arsenic in mine tailing reclamation (Harvey 2021). Establishment techniques for desert marigold include direct seeding, outplanting nursery stock, and extant plant salvage and relocation. It is generally considered to have high performance as a restoration species (Esque et al. 2021).

Wildland Seeding and Planting.

Wildland Seedings.

Desert marigold can successfully establish in Mojave Desert sites from direct seeding as part of a seed mix using a variety of techniques including hydroseeding, seed balls, and dry seed (Plath 2023, personal communication). The Natural Resource Conservation Service (NRCS) recommends seeding desert marigold in the fall at a rate of 0.5 to 2 PLS lbs per acre if planted with a drill and 1 to 4 PLS lbs per acre if broadcasted. The United States Geological Survey applies desert marigold at a rate of 2 PLS lbs per acre in restoration research plots across the species' range (Laushman et al. 2021).

Desert marigold has been used in roadside and utility right-of-way seeding in the Mojave Desert and is listed in state transportation department seed mixes or planting specifications in California (Caltrans 2023) and Arizona (AZDOT 2023). In a study of roadside revegetation via direct seeding in the Mojave Desert, desert marigold was included in a 12-species seed mix collected from local populations and broadcasted at a rate of 40 lbs per acre, with desert marigold included at a rate of 3 lbs per acre (Walker and Powell 1999). Desert marigold was among two species that established and persisted, forming a "dense

sward" four years after the seeding (Walker and Powell 1999). Based on anecdotal observations, desert marigold can be the only species that establishes in hydroseed applications with a multi-seed mix on compacted soils that are not ripped or roughened in any way (Plath 2023, personal communication).

Farrell and Fehmi (2018) saw successful establishment of desert marigold in a pipeline right-of-way 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.

In the Chihuahuan Desert, commercially and wildland-sourced desert marigold seed was included in a research project to establish vegetation cover in harsh playa soils to reduce hazardous dust generation near a major interstate corridor (Turk et al. 2023). Desert marigold was seeded in research plots as part of four-species mix applied at 10.28 PLS lb per acre and as a single species monoculture at 10.28 PLS lbs per acre. Treatments included soil scarification, hydro-seeding, and broadcast seeding followed by soil crimping. All treatments were covered with hydro-mulch and tackifier. Two years after seeding, desert marigold was one of the only species to establish from the seed mix, despite exceptional drought that took hold immediately after seeding (Turk et al. 2023).

In an assessment of post-fire seeding in the Mojave Desert in Clark County, Nevada, DeFalco et al. (2009) examined results of seeding in burned areas where desert marigold was included in a multispecies mix broadcasted by hand, with or without herbicide application to treat invasive annual grasses. Heavy seeding rates combined with herbicide application, especially those with the active ingredient imazapic, reduced invasive annual grasses and increased perennial plant establishment from the seed mix, including desert marigold (DeFalco et al. 2009). Table 5 summarizes the results for desert marigold across different seeding methods and seeding rates.

Table 5: A summary of methods and results for post-fire seeding of desert marigold in Clark County, NV (DeFalco et al. 2009). Seedling frequency measurements were recorded in 1 m^2 plots in 2011, five years after seeding. Seedling frequency was not reported for the Southern Nevada Fire Complex, but desert marigold was said to comprise 81% of the total plant cover in treated areas.

Method/ Location	Seeding Rate (PLS lbs/acre)	Results[2] (Seeded: Unseeded)
Hand broadcast/ Bonnie Springs Fire	0.7	1
Hand broadcast/ S. NV Fire Complex[1]	1.1	20
Hand broadcast with herbicide/ S. NV Fire Complex	6.0	6

[1] Seed broadcast in same areas over two periods: 0.5 PLS lbs/acre in 2005 and 0.6 PLS lbs/acre in 2006.

[2] Reported as ratio between seeded and unseeded controls for plant frequency (Bonnie Springs) and plant density (S. NV Fire Complex.

DeFalco et al. (2009) also examined soil seed bank composition after seeding and found that desert marigold consistently increased in the seed bank in seeded areas both two and five years post-fire. They note that the species occurred in the seed bank and established plants at rates lower than the seeding rate, suggesting that some seed was lost to unknown fates (DeFalco et al. 2009).

In a trail reclamation project in the Sonoran Desert, desert marigold seed was purchased from a commercial vendor and included in a seed mix with nine other native species, each applied

at 100 seeds per species per 1.5 x 1 m plot (Rowe et al. 2022). Seeds were broadcast by hand within plots and rolled with a Garden Weasel to press them into the soil. Some plots underwent soil ripping to reduce compaction prior to seeding, while others were seeded with no soil ripping. Desert marigold emerged the first year, but did not persist and was not detected in the following three years of monitoring, potentially due to severe drought conditions (Rowe et al. 2022).

Wildland Plantings.

Considering inconsistent outcomes in nursery propagation, and its high performance when directly seeded, planting nursery stock of desert marigold may not be favorable. In a study comparing seeding versus outplanting in the Mojave Desert, desert marigold had zero establishment from either method, while other species in the study exhibited much higher establishment with outplanting (Abella et al. 2012b). Another study where desert marigold was outplanted from container stock had zero establishment six years after planting (Abella 2017). However, salvaging and transplanting extant plants may have slightly better outcomes. In a project at Lake Mead National Recreation Area in the Mojave Desert, salvaged adult plants of desert marigold had 38% survival after 12 months of care in the nursery and 30% survival of transplanted individuals at a disturbed roadside site (Abella et al. 2015). This amounts to roughly 11 of every 100 salvaged plants establishing in the transplant site.

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RESOURCES

AOSCA NATIVE PLANT CONNECTION

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

BLM SEED COLLECTION MANUAL

https://www.blm.gov/sites/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/

MOJAVE SEED TRANSFER ZONES

https://www.sciencebase.gov/catalog/item/5ea88c8482cefae35a1faf16

MOJAVE SEED MENUS

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

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