DESERT PLANTAIN

Plantago ovata Forssk.

Plantaginaceae - Plantain family

Ashlee Wolf |2023

ORGANIZATION

NOMENCLATURE

Desert plantain (*Plantago ovata* Forssk.) is in the Plantaginaceae, or plantain family (USDA NRCS 2022).

NRCS Plant Code.

PLOV (USDA NRCS 2022).

Synonyms.

Plantago brunnea Morris, *Plantago gooddingii* A. Nels. & Kennedy, *Plantago insularis* Eastw., *Plantago insularis var. scariosa* (Morris) Jeps., *Plantago minima* A. Cunningham, *Plantago fastigiata* E. Morris, *Plantago insularis* var. *fastigiata* Morris Jeps. (ITIS 2023, SEINet 2023).

Common Names.

Desert plantain, desert Indianwheat, Indian wheat, woolly plantain, pastora, mumsa (USDA NRCS 2022, SEINet 2023).

Subtaxa.

Molecular evidence suggests there are two varieties of desert plantain in North America: var. *fastigiata* (E. Morris) S.C. Meyers and Liston and var. *insularis* (E. Morris) S.C. Meyers and Liston (Meyers and Liston 2008). However, the morphological characteristics to distinguish between varieties are not easily seen on many herbarium specimens. Therefore, the varieties are not recognized in the Flora of North America (Shipunov 2020).

Chromosome Number.

The chromosome number for desert plantain is 2n=8 (Rosatti 2012, Shipunov 2020).

Hybridization.

There is no evidence of hybridization between desert plantain and other *Plantago* species.

DESCRIPTION

Desert plantain is an annual forb that can reach up to 400 mm tall, with a slender taproot, and herbage often covered in dense, silky hairs (Rosatti 2012, Shipunov 2020, SEINet 2023; Figure 1). The leaves form dense basal clusters and range from 10 to 230 mm wide and 0.5 to 12 mm long. They lack a distinct petiole and can be linear to linear-lanceolate with entire or minutely toothed margins (Shipunov 2020). The inflorescence is a spike born on a leafless, ungrooved scape with spreading hairs (Rosatti 2012; Figure 2). The bisexual flowers--arranged spirally and densely packed—are subtended by green, ovate bracts (1.4 to 4 mm long) with translucent margins and tufts of white hairs in the axils (Rosatti 2012, SEINet 2023). The corolla lobes are membranous-papery, brown, and can be spreading or reflexed. The fruit is a two-seeded capsule that dehisces at or slightly below the middle around its entire circumference. The seeds are ellipsoid, reddish-brown to black, and 2 to 2.5 mm long (Rosatti 2012, SEINet 2023).

Desert plantain can be distinguished from its relative, woolly plantain (*P. patagonica*), by the size and shape of floral bracts—woolly plantain will have more linear-triangular or slender bracts that are 2 to 16 mm long (SEINet 2023).

Figure 1: A cluster of desert plantain individuals. Photo: BLM SOS NV052

Figure 2: The spike inflorescence of desert plantain. Photo: Sue Carnahan

Varieties or Subspecies.

The Jepson Manual treatment for *Plantago ovata* (Rosatti 2012) describes the following:

Var. *fastigiata* will have a green bract midrib.

Var. *insularis* will have a brown midrib and corolla lobes with a prominent red-brown midrib.

However, these characteristics are considered unreliable and many herbarium specimens cannot be assigned a variety (Rosatti 2012, Shipunov 2020).

DISTRIBUTION AND HABITAT

Desert plantain is a ubiquitous native forb in the Mojave and Sonoran desert ecoregions in California, Arizona, Nevada, Utah, and northern Mexico (SEINet 2022; Figure 4). Records become increasingly sparse in neighboring ecoregions such as the Central California Foothills and Coastal Mountains and in the eastern extent of its range in the Madrean Archipelago and Chihuahuan Desert. It is also native to northern Africa, the Mediterranean region of Europe, the Middle East, and India (Kew 2023).

Figure 3: Desert plantain in open desert habitat in Nevada. Photo: BLM SOS NV052

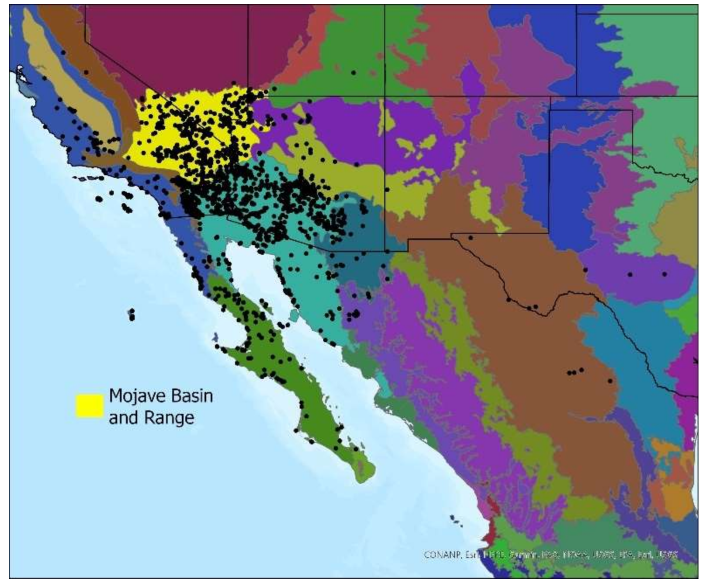

Figure 4: Distribution of desert plantain based on georeferenced herbarium specimens and verified observations (black circles, SEINet 2022) with EPA Level III Ecoregions (US EPA 2015). The Mojave Basin and Range ecoregion is shown in yellow.

Habitat and Plant Associations.

Desert plantain can be found in a wide variety of habitats within the Mojave and Sonoran deserts including desert scrub flats, gently sloping bajadas, along the bed and margins of ephemeral washes, steep rocky hillsides, and sandy dunes. It can also grow in disturbed sites such as parking lots and housing developments (SEINet 2022).

Associated species in the Mojave Desert include creosote bush (*Larrea tridentata*), burrobush (*Ambrosia dumosa*), Mojave yucca (*Yucca schidigera*), desert trumpet (*Eriogonum inflatum*), desert globemallow (*Sphaeralcea ambigua*), cheesebush (*Hymenoclea salsola*), desert marigold (*Baileya multiradiata*), beavertail cactus (*Opuntia basilaris*) and brittlebush (*Encelia* spp.).

Figure 5: Steep sloping habitat with well-developed soil crust in Nevada. Photo: BLM SOS NV052

Climate.

The Mojave Desert is characterized by low annual precipitation (5-25 cm or 2-10 inches 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 plantain occurs (Shryock et al. 2018; Table 1). According to herbarium specimen locations (SEINET 2022), desert plantain occurs in all PSZs in the Mojave Desert ecoregion but is most abundant in Zones 21 and 24 and least abundant in Zones 20, 29, and 22 (Table 1). The average annual precipitation in the PSZs where desert plantain occurs in the Mojave Desert ecoregion is 17.8 cm (7.0 inches), with an average of 5.7 cm (2.2 inches) falling in the summer and an average of 12.1 cm (4.8 inches) falling in the winter. Note, herbarium specimen locations may not represent the full distribution and abundance of desert plantain due to sampling bias towards accessible locations and ephemerality of this desert annual.

Table 1: Climate of the provisional seed zones (PSZ) where desert plantain occurs within the Mojave Desert ecoregion (Shryock et al. 2018).# = the number of herbarium or verified observations of desert plantain 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)
21	142	15.6	6.2	9.4	18.8	38.4
24	125	10.7	2.8	7.9	18.8	38.6
27	67	9.6	3.3	6.3	20	36.7
25	54	16.5	6.2	10.3	18.9	34.6
26	44	14.5	2.7	11.8	16.8	34.9
28	43	7.8	2.4	5.3	22.3	41.3
23	37	15.8	5.4	10.4	16.1	35.9
20	13	25.5	10.5	14.9	15.3	34.5
29	3	25.5	4.2	21.4	13.8	31.7
22	2	36.1	13.3	22.8	10	32.4

Elevation.

Desert plantain is found at elevations below 1981 m (6500 ft) (Shipunov 2020, SEINet 2022).

Soils.

Desert plantain grows in alluvial and colluvial deposits derived from various parent materials including limestone, dolomite, basalt, granite, gneiss, and carbonate to siliceous detrital rocks (BLM SOS 2022, SEINet 2022). Surface textures where desert plantain is found are typically sandy or gravelly. Several specimen records indicate plants growing in desert pavement, a soil surface characterized by closely packed, cemented rock fragments with no fine materials (SEINet 2022). No specific associations with biological soil crusts were noted in the literature.

ECOLOGY AND BIOLOGY

In general, winter annuals can make up at least 40% of the Mojave Desert flora (Cain and Castro 1959, as cited in 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). Desert plantain can thrive in disturbed environments and supports a wide range of ecological interactions with a variety of animals, fungi, and other plants.

Reproduction.

Breeding System.

Desert plantain is capable of both selfing and outcrossing. Self-pollination is enabled through synchronization of anther dehiscence and stigma receptivity to pollen (Sharma et al. 1993).

Reproductive Phenology.

Desert plantain typically flowers from March to May (SEINet 2023). According to seed collection data, it can produce seed from March to May in the Mojave Desert (BLM SOS 2022).

Pollination.

When desert plantain outcrosses, it is pollinated via wind and insects (Sharma et al. 1993). Although wind pollination is more typical, plants are infrequently visited by bees, including the giant honeybee (*Apis dorsata*), and dipteran flies that are attracted to its copious pollen. The relative degree of insect pollination may vary between sites and seasons (Sharma et al. 1992).

Seed and Seedling Ecology.

Desert plantain and other *Plantago* species often have a significant presence in soil seed banks across their range (Holzapfel et al. 1993, DeFalco et al. 2009). Seed can be detected using both emergence and extraction methods for seed bank analyses (Abella et al. 2013). The related species, woolly plantain, is reduced in the seed bank following fire in North American deserts, but Plantago species in general can recover in the seed bank as plants recolonize the area, especially after above-average precipitation (Cave and Patten 1984, Esque et al. 2010). No information on its longevity in the soil seed bank was found.

Desert plantain seeds will germinate between September and March in response to cool temperatures and rainfall events (Clauss and Venable 2000). Desert plantain exhibits bet-hedging germination behavior in that they will refrain from initiating germination until conditions are optimal. However, the range of conditions that trigger germination varies by population and by year. In a field study, populations from more xeric environments across the Sonoran Desert had a longer range of germination dates while populations in more mesic environments had a more restricted range of germination dates (Clauss and Venable 2000). By staggering germination across a wider time range in more xeric environments, desert plantain may reduce the likelihood of reproductive failure if an entire cohort fails to establish.

Desert plantain is commonly found in the refuse piles associated with desert seed-harvester ants (*Veromessor pergandei* or *Pogonomyrmex rugosus*) and plants growing in these piles have significantly more fruits or seeds produced per plant than nearby plants (Rissing 1986). The increase in reproductive output in the proximity of ant nests may be an adaptive strategy to encourage seed dispersal by ants (Rissing 1986). An herbarium specimen note describes an instance of seed gathering by harvester ants which were observed climbing desert plantain inflorescences, "cutting off fruit", and transporting fruits to nest (SEINet 2022).

Desert plantain seeds produce a mucilaginous, gelatin-like mass that surrounds the seeds when wet. This mucilage serves several potential functions including acting as an adhesive as it dries, binding seeds to rocks and thus anchoring them to the ground as well as deterring granivory (LoPresti et al. 2019); enhancing germination by prolonging moisture levels surrounding seeds (Kreitschitz et al. 2021); and aiding in dispersal by attaching seeds to feathers or fur on animals (Kreitschitz et al. 2021).

This gelatinous substance excreted from desert plantain seeds is produced commercially as a soil stabilizer which was demonstrated to reduce soil erodibility and promote the growth of biocrust in a field experiment in the Colorado Plateau ecoregion (Fick et al. 2020). No sources were found to indicate that the seeds have a similar effect on a meaningful scale in wildland settings.

In an incubator study that examined the germination response to temperature and light, desert plantain seeds collected from North Africa exhibited optimal germination at 15 °C (59 °F), regardless of light conditions (Hammouda and Bakr 1969).

Species Interactions.

Belowground Interactions.

Desert plantain is considered to be mycorrhizae dependent and plants have increased growth and reproductive output when inoculated with vesicular-arbuscular mycorrhiza compared to non-inoculated plants in a greenhouse setting (Bloss 1982).

Laboratory trials using fungal strains and desert plantain seeds from the Sonoran Desert suggest that germination of desert plantain seeds in wild settings may be enhanced by naturally occurring soil fungi (Li et al. 2019).

Parasites and Predation.

The fungal parasite, *Fusarium oxysporum*, is a reported pathogen of desert plantain crops grown agriculturally in North America (Russell 1975). It causes rapid wilting of seedlings. No sources were found indicating the pathogen's presence or impact in wildland settings.

Wildlife and Livestock Use.

Desert plantain is an important forage species for the endangered desert tortoise (*Gopherus agassizii*) (Esque et al. 2021b). It is among the most frequently eaten plants for juvenile tortoises, which preferentially eat the immature fruits of this species (Oftedal et al. 2002).

Desert plantain makes up the greatest proportion of species in feral burro diets in the Mojave Desert, accounting for 64% of burro diet composition in the spring (Abella 2008). It is also an important spring forage plant for desert bighorn sheep (*Ovis canadensis nelsoni*) in the Sonoran Desert (Krausman et al. 1989), and the seeds are eaten by a variety of rodents (Reichman 1975).

Cattle will reportedly eat desert plantain even after plants have matured and dried (Hall et al. 2005). However, no specific notes about its nutritional quality or livestock preference were found in the literature.

Other Notable Species Interactions.

Desert plantain is a host plant for Edith's checkerspot butterfly (*Euphydra editha*) (Robinson et al. 2010), as well as 29 additional likely lepidopteran species (Calscape 2023).

Disturbance Ecology.

Desert plantain, along with other native annuals, can colonize disturbed areas following fire and land clearing in both the Mojave and Sonoran deserts (Abella 2010). It was shown to increase in biomass and density one year after a fire in the Sonoran Desert (Cave and Patten 1984). However, one study in the Colorado Desert found fire had a negative effect on desert plantain abundance (Steers and Allen 2011). In some cases, desert plantain can be the predominant fuel source for desert wildfires since it can grow in dense stands and carry fire across the interspaces between shrubs and trees (Esque et al. 2013).

Desert plantain may be able to compete with and establish among invasive plants. Although the invasive plant Sahara mustard (*Brassica tournefortii*) releases allelopathic and fungicidal compounds from its roots, desert plantain grew larger in soil that had been treated with Sahara mustard root extract compared to non-treated soils in a greenhouse experiment. This result suggests it may be able to establish and thrive in invaded areas (Underwood 2014).

Ethnobotany.

The Akimel O'odham (also known as Pima) used the seeds for food and medicinal purposes, including creating a cold infusion of the seeds to treat diarrhea (NAEB 2022).

Desert plantain is the most popular commercial source of psyllium, a type of dietary fiber derived from the seeds. Psyllium from desert plantain has also been used as a food thickener. It is most commonly grown in India where it is called isabgol (Masood and Miraftab 2010). Psyllium has a variety of other current and potential uses including treating high cholesterol, bladder problems, high blood pressure, wound dressing, and colon cancer (Masood and Miraftab 2010). The mucilage excreted from the seeds has also been used as a food thickener and may even be useful as an additive to prevent chocolate from melting in the heat (Rubis and Massman 1967).

Horticulture.

Desert plantain does not seem to be commercially available for retail purchase for landscaping or horticultural purposes (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).

Researchers with the United States Geological Survey (USGS) developed empirical seed zones for desert plantain within the Mojave Desert ecoregion based on landscape genomic and climate threshold analyses (Figure 7; Shryock et al. 2021). These species-specific seed zones indicate areas within which desert plantain seed can be sourced and applied with reduced risk of maladaptation. Shryock et al. (2021) also modeled each seed zone's geographic area under future climate, noting that the genotypes that are adapted to higher summer maximum temperatures were modeled to experience a five-fold expansion in potential habitat area.

Referencing seed zones based on projected future climate conditions can allow for adaptive planning and plant materials sourcing.

Outside of the Mojave Desert, the Desert Southwest Provisional Seed Zones (PSZs) may be used to plan seed sourcing for desert plantain. 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 plantain 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. Because desert plantain seeds are cultivated as a commercial product for food additives or nutritional supplements, seeds available through online vendors may have been sourced from cultivated origins as far away as

India. There have been no conservation plant releases of desert plantain.

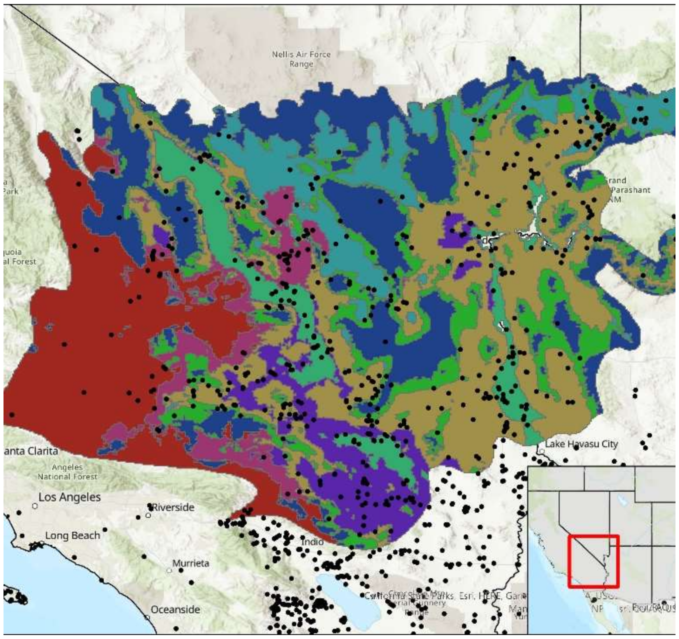

Figure 6: Distribution of desert plantain based on georeferenced herbarium specimens and verified observations (black circles, SEINet 2022) across its species-specific empirical seed zones (colored polygons) within the Mojave Desert delineated using genomic and climate analyses (Shryock et al. 2021).

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.

In the Mojave Desert, desert plantain is typically collected between March and June with the majority of collections occurring in April (BLM SOS 2022).

Collection Methods.

Whole inflorescence stalks can be collected and placed into paper bags (Esque et al. 2021b). Seed will easily dehisce out of the capsules and into the bags (Wall and MacDonald 2009).

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). 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).

Figure 7: Collected seed and chaff material of desert plantain; scale shown in cm. Photo: BLM SOS NV052B

Figure 8: Bare seed and some chaff of desert plantain. Photo: BLM SOS CA650

Seed Cleaning.

The seed will typically fall out of the capsules into the collection bag prior to cleaning. Material can be sieved using a #16 sieve followed by air separation with a blower at 1.5 speed (Wall and MacDonald 2009).

Cleaning guidelines for the related and morphologically similar species, woolly plantain, describe using a Westrup La-H brush machine with a gentle brush (0.5 mm) and a #10 mantle followed by an air separator at low speed (Saidnawey and Cain 2023).

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 plantain seed is orthodox (SER SID 2023). It has been shown to maintain up to 95% viability after drying to a standardized equilibrium at 15% relative humidity and freezing for five weeks at -20 ° C (SER SID 2023)

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 describes guidelines for testing seed viability for plants in the Plantaginaceae family (AOSA 2016). These methods involve soaking mucilaginous seeds in a beaker of water overnight at 20-25 °C to allow moisture imbibition, then cutting seeds longitudinally and placing them in a 0.1 to 0.5% tetrazolium (TZ) solution overnight at 30-35°C. Mucilaginous seed coats, such as those found in desert plantain, can interfere with TZ uptake. To avoid this, the cut surfaces of seeds can be placed on filter paper moistened with the TZ solution. Viable seeds will have their entire embryo and endosperm evenly stained while non-viable seeds will have portions of their embryo unstained, or abnormal staining that is blackened or discolored (AOSA 2010).

Wildland Seed Yield and Quality.

Wild-collected desert plantain seed is generally of high quality, with an average of 90% fill, 90% purity and 86% viability indicated by tetrazolium tests across 32 Seeds of Success collections from the Mojave Desert (BLM SOS 2022, Table 2). Wild collections contain an average of over 293,000 pure live seeds (PLS) per lb (BLM SOS 2022, Table 2).

Table 2: Seed yield and quality of desert plantain 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	0.05-3.46	32
Clean weight (lbs)	0.24	0.01-1.27	32
Purity (%)	96	73-99	32
Fill (%)	90	50-99	32
Viability (%)	86	30-98	32
Pure live seeds/lb	293,055	93,120-428,828	32

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 plantain will grow best in full sun to partial shade in fast draining soils with a neutral pH (CNPS Calscape 2023, Granite Seed 2023).

Desert plantain grows naturally in Europe and Asia, and is commercially cultivated for its seed in India and the Middle East (see Ethnobotany section for discussion on psyllium and other commercial uses). Therefore, there is a wealth of research on its seed biology and cultivation practices (e.g. Agrifarming 2016). While there may be relevant information to draw from this species' ecology and cultivation on other continents, North American seed sources and growing conditions are likely to be distinctive and require localized research and methods. Therefore, agricultural practices described in this account focus on knowledge and practices from North American sources.

Some attempts to grow desert plantain as a commercial crop for psyllium in warm desert regions of North America were unsuccessful due to frost intolerance and root rot diseases (Rubis and Massman 1967). However, desert plantain has been successfully cultivated in lower elevation valleys of Arizona where hard frosts are uncommon. Yields of experimental plantings in these cases were up to 1200 pounds of seed per acre (Rubis and Massman 1967). Some historic desert plantain crops were grown to produce a hybrid between *P. ovata* and *P. insularis* to improve frost tolerance. However, some crops seem to have been grown from *P. ovata* seeds that were potentially collected from naturally occurring populations in Arizona. In either case, growing practices may be applicable to growing native seed for restoration.

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).

Table 3 outlines the pre-varietal germplasm certification standards for desert plantain seed in the state of California with a minimum of ¼ lb sample size to be submitted for testing (CCIA 2022). 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 plantain in California.

Factor	G1	G2	G3 to G10
Pure Seed (minimum)	90%	90%	90%
Inert Matter (maximum)	90%	90%	90%
Total Other Crop Seed (maximum)	90%	90%	90%
Weed Seed (maximum)	10%	10%	10%
Noxious Weed	10%	10%	10%
Germination and Hard Seed (minimum)	10%	10%	10%

Isolation Distances.

Sufficient isolation distances are required to prevent cross-pollination across seed production crops of desert plantain from different sources or other Plantago species. Table 4 summarizes the isolation distances required for PVG certification in both Utah and California. California standards are described specifically for desert plantain (CCIA 2022), 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 plantain. 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.

	G1		G2		G3+	
State	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 planting. 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).

Desert plantain is dependent on mycorrhizal fungi (Granite Seed 2023); soil inoculation may improve plant growth in fields where soil health is depleted.

Seed Pre-treatments.

No information on seed pre-treatments to facilitate germination was found in the literature or through personal communication.

Seeding Techniques.

Growers using North American desert sources have successfully established fields of desert plantain with direct seeding (Schaff 2023, personal communication).

Seeding rates for desert plantain can range from 3 to 10 pure live seed (PLS) lbs per acre (Granite Seed 2023).

For desert plantain, approximately 3.5 PLS lbs per acre would achieve 20 to 25 seeds per square foot, a general seed density recommended by the Natural Resources Conservation Service (NRCS) for drill seeding (Dial 2023, personal communication). This rate can be doubled if seed is broadcasted or in severely disturbed areas (Dial 2023, personal communication).

Establishment and Growth.

As an annual, desert plantain 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.

Weed Control.

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 plantain crops grown for psyllium in North America are susceptible to Plantago wilt (*Fusarium oxysporum*), a fungal pathogen that causes pre-emergent damping off, or rapid wilting of 120- to 150- day old seedlings (Russell 1975). The pathogen does not typically infect first year crops but can cause crop damage in successive years with circular areas of dying plants and resulting declines in seed yield. Pathogenic *Fusarium* fungi present in the soil can be reduced by heat treatments or fungicidal fumigations. Addition of lime and nitrate nitrogen fertilizer has been effective for treating *Fusarium oxysporum* in other crops (UCANR 2020).

Seed collected from infected plants may be healthy, but seed coats contaminated with the fungus can potentially spread the pathogen. Treating seed with a fungicide before sowing for agricultural seed increase or restoration may protect emerging seedlings from infection (UCANR 2020).

Pollination Management.

Since desert plantain is primarily selfing and wind-pollinated, no pollination management is recommended for this species in agricultural seed increase settings.

Irrigation.

No information on irrigation techniques specific to desert plantain was found in the literature or through personal communication.

Seed Harvesting.

While farming practices for commercial psyllium crops are not reviewed in other sections herein, it is presumed that harvesting techniques may be applicable to crops grown for native seed increase from North American desert wildland sources. Psyllium crops are harvested close to the ground, or by uprooting entire plants in the early morning to avoid seed shattering (Parshad 2004). In arid regions of the United States, psyllium crops planted in October have been harvested in May with a combine (Russell 1975)

Seed Yields and Stand Life.

The stand life for an annual will be one year for the target generation class. Removing volunteer plants of uncertain generation class will help prevent having a mixed-generation crop (Brooks and Gault 2023, personal communication).

No information on seed yield in fields grown from wildland sourced seed was found in the literature or through 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). No specific descriptions of nursery practices for desert plantain were found in the literature or through personal communication. If needed, techniques for other desert annuals can be referenced. 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

Desert plantain is a priority species to restore habitat for the desert tortoise (Esque et al. 2021b), in addition to a variety of other wildlife species (see Wildlife and Livestock Use). Its ability to establish and thrive in disturbed environments makes it a good candidate for restoration projects aimed at improving native ground cover following wildfires and other disturbances. In general, annual plants are more likely to be restored via direct seeding and indirectly through establishing perennial plants or improving site conditions (Abella 2017).

Wildland Seeding and Planting.

Wildland Seedings.

Desert plantain was included in a study comparing techniques for establishing desert tortoise forage plants from seed in the Mojave Desert (Abella et al. 2015). Seed was locally collected and broadcasted in January as either pelletized or bare seed in fenced and unfenced treatment plots. Pelletized seeding quadrupled the density of desert plantain compared to bare seed. The combination of pelletized seeding and fencing resulted in the highest average density among all treatments (Abella et al. 2015). These results suggest that granivory and herbivore pressure may limit establishment of desert plantain in seeding applications without augmentations such as pelletizing and fencing.

Desert plantain has also been applied in revegetation seeding following pipeline construction in Sonoran semi-desert grasslands, where it represented 3.8% pure live seed (PLS) of a commercially purchased multi-species seed mix (Farrell 2016). It was confirmed to be growing in the seeded area in subsequent monitoring, but specific metrics on establishment were not described.

Wildland Plantings.

Annual species are generally not recommended as plug transplants and will likely perform better with direct seeding methods (Abella 2017).

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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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