BIG GALLETA

Pleuraphis rigida (Thurb.)

Poaceae - Grass Family

Casey Hensen and Ashlee Wolf |2023

ORGANIZATION

NOMENCLATURE

Big galleta (*Pleuraphis rigida* Thurb.) is a member of the Poaceae or grass family (USDA NRCS 2023). It is in the Chloridoideae subfamily and Cynodonteae tribe which are characterized by adaptations in leaf anatomy and a C_4 photosynthetic pathway especially suited for warm and arid climates (Barkworth et al. 2007).

NRCS Plant Code.

PLRI3 (USDA NRCS 2023).

Synonyms.

According to the Integrated Taxonomic Information System (ITIS) and the Flora of North America, *Hilaria rigida* (Thurb.) Benth. Ex Scribn. is the most current accepted scientific name for big galleta (Barkworth 2020, ITIS 2023). However, this document follows the United States Department of Agriculture naming convention, which classifies big galleta in the genus *Pleuraphis.*

Common Names.

Big Galleta, big galleta, and big galleta grass (SEINet 2023a, USDA NRCS 2023).

Subtaxa.

No varieties or subspecies are currently recognized by the Flora of North America or the Integrated Taxonomic Information System (Barkworth 2020, ITIS 2023).

Chromosome Number.

The chromosome number for big galleta is 2n= 18, 36, and 24 (Barkworth 2020, CCDB 2023).

Since big galleta possesses intraspecific ploidy variation (differences in chromosome numbers between populations), it may be necessary to assess the cytotypes of populations prior to mixing seed sources or starting propagation. Combining incompatible cytotypes can result in loss of fitness and fertility in plantings (Kramer et al. 2018).

Hybridization.

Cytological evidence suggests hybridization between big galleta and James' galleta (*Hilaria jamesii*) and first generation hybrids can backcross to either parent species (Reeder 1977). Other *Hilaria* species, specifically tobosa (*Hilaria mutica*) and James' galleta, have been found to hybridize with one another in areas of sympatry (Winkler and Massatti 2020).

DESCRIPTION

Big galleta is a perennial tufted grass with branching culms that reach 35-250 cm in height and arise from a hard, rhizomatous base (Barkworth 2020, Figure 1). The lower parts of the stems are felty-pubescent with leaf sheaths often also felty-pubescent, a distinguishing characteristic of big galleta compared to other *Hilaria* species (SEINet 2023a). Upper nodes are glabrous, or villous with hairs up to 1.5 mm long. The blades are between 2-10(16) cm long and 2-5 cm wide with tips coming to a rigid point. Ligules are 1-2 mm long and densely ciliate. The spike inflorescence (Figure 2) has three sessile spikelets—two lateral and one central—at each node. The three spikelets disarticulate as a unit and leave a bare, zig-zagging rachis upon dispersal (SEINet 2023a). The lateral spikelets hold two to four florets consisting of two lower staminate florets and may have one or two sterile upper florets. The glumes of lateral spikelets are membranous with seven nerves that extend to the two- to four-lobed tip of the glume. One to three glume nerves extend into awns. The central spikelets sit slightly higher than the lateral spikelets and hold one stipitate, bisexual floret. The lemmas of the central spikelets often exceed the glumes, and are two-lobed, with midveins extending into a single awn (Barkworth 2020). When mature, the papery glumes of big galleta splay out, giving it a distinctive look (SEINet 2023a).

Figure 1: A big galleta individual. Photo: Jean Pawek

Figure 2: The dry inflorescence of big galleta. Photo: Sue Carnahan

DISTRIBUTION AND HABITAT

Big galleta is common throughout the Mojave and Sonoran Deserts in southern California, Arizona, and northwestern Mexico (SEINet 2023a, Figure 3). Observations are concentrated in the Sonoran and Mojave Basin and Range ecoregions with occasional records in the Arizona/New Mexico Mountains and the Arizona/New Mexico Plateau.

Habitat and Plant Associations.

Big galleta can be found throughout deserts, plains, stabilized dunes, slopes, lower bajadas, and rocky hills (CNPS 2023, SEINet 2023a). The California Native Plant Society (CNPS) Manual of California Vegetation and NatureServe recognize two floristic alliances defined by the presence of big galleta: the big galleta desert grassland and the buckhorn cholla/big galleta grass scrub (CNPS 2023). NatureServe also defines nine Associations where big galleta is dominant or co-dominant including the following with Vulnerable (G3) or Imperiled (G2) statuses: burrobush/big galleta dwarf-shrubland (imperiled), big galleta grassland (vulnerable), Joshua tree/big galleta wooded grassland (imperiled), Mojave yucca/big galleta shrubland (vulnerable), Mormon-tea/ big galleta shrubland (vulnerable), and broom snakeweed/big galleta-desert globemallow shrub grassland (imperiled).

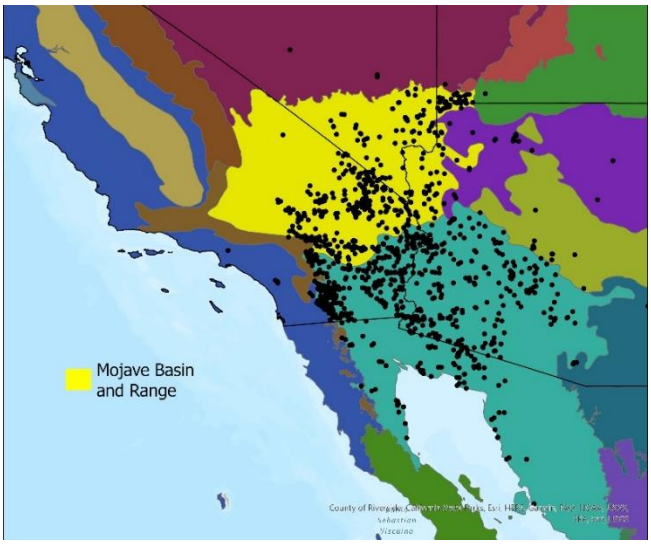

Figure 3: Distribution of big galleta based on georeferenced herbarium specimens and verified observations (black circles, SEINet 2022) with EPA Level III Ecoregions (US EPA 2015). The Mojave Basin and Range ecoregion is shown in yellow.

Big galleta is typically dominant or co-dominant in subshrub and herbaceous layers with Indian rice grass (*Achnatherum hymenoides*), bush muhly (*Muhlenbergia porteri),* black grama (*Bouteloua eriopoda*), soft prairie clover (*Dalea mollissima*), Cooper's goldenbush (*Ericameria cooperi*), snakeweed (*Gutierrezia sarotherae*), panicgrass (*Panicum urvilleanum*), Thurber's sandpaper plant (*Petalonyx thurberi*), and desert globemallow (*Sphaeralcea ambigua*). The invasive species, red brome (Bromus rubens), is also common with big galleta (CNPS 2023).

Other associated species include Joshua tree (*Yucca brevifolia*), burrobush (*Ambrosia dumosa*), cheesebush (*Hymenoclea salsola*), fourwing saltbush (*Atriplex canescens*), buckhorn cholla (*Cylindropuntia acanthocarpa*), Mormon tea (*Ephedra californica*), Nevada ephedra (*Ephedra nevadensis*), creosote (*Larrea tridentata*), water-jacket (*Lycium andersonii*), catclaw acacia (*Senegalia greggii*) and Mojave yucca (*Yucca schidigera*) (CNPS 2023).

Big galleta-dominated alliances can contain a high number of annual forbs, which comprise up to 63% of the associated flora in some locations (Felger 1980).

Figure 3: Big galleta in a Nevada desert scrub community. Photo: BLM SOS NV052

Figure 4: Big galleta growing in a Nevada Joshua-tree woodland habitat 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 big galleta occurs (Shryock et al. 2018; Table 1). According to herbarium specimen locations (SEINET 2022), big galleta has been documented in all PSZs in the Mojave Desert ecoregion but most abundantly documented in Zones 21 and 25 and least abundantly documented in Zone 22 (Table 1). The average annual precipitation in the PSZs where big galleta 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 (4.7 inches). Note, herbarium specimen locations may not represent the full distribution and abundance of big galleta due to sampling biases.

Table 1: Climate of the provisional seed zones (PSZ) where big galleta occurs within the Mojave Desert ecoregion (Shryock et al. 2018).# = the number of herbarium or verified observations of big galleta 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	112	15.6	6.2	9.4	18.8	38.4
25	90	16.5	6.2	10.3	18.9	34.6
23	67	15.8	5.4	10.4	16.1	35.9
20	62	25.5	10.5	14.9	15.3	34.5
29	57	25.5	4.2	21.4	13.8	31.7
27	54	9.6	3.3	6.3	20	36.7
26	52	14.5	2.7	11.8	16.8	34.9
24	51	10.7	2.8	7.9	18.8	38.6
28	20	7.8	2.4	5.3	22.3	41.3
22	4	36.1	13.3	22.8	10	32.4

Elevation.

Big galleta can grow at elevations from sea-level up to 5,200 ft (1,600 m). In the Mojave, it typically occurs below 4,000 ft (1,219 m) (Columbus 2012, SEINet 2023a).

Soils.

Big galleta grows in a variety of soil textures such as loam, sandy loam, sand, bedrock, and rock (Calflora 2023), but does poorly on clays (Pratt et al. 2023). It tolerates pH levels between 6.5 to 8.7 (Calflora 2023, Pratt et al. 2023). No associations with biological soil crusts were described in the literature.

ECOLOGY AND BIOLOGY

Big galleta is a fast-growing, highly drought tolerant warm season grass (Pratt et al. 2023). Big galleta is more effective at extracting moisture from soil during dry periods than any other desert plant (Pratt et al. 2023). Two major growth periods occur in big galleta in response to the regional bimodal precipitation patterns of summer monsoons and winter rains (Pratt et al. 2023). Big galleta clusters can live more than 100 years (Mackay 2013) and it is considered one of the most valuable forage grasses in the desert (Munz 2004).

Reproduction.

Breeding System.

Big galleta is capable of reproduction after one year of life. Seed production of big galleta is low and seedling establishment is rare (Heizer and Hassell 1985). Big galleta primarily relies on vegetative reproduction via rhizomes and tillers (Calscape 2023, CNPS 2023). No evidence of self-compatibility was noted in the literature.

Reproductive Phenology.

Big galleta flowers year-round from January to December in response to rainfall, but flowering herbarium specimens are most abundantly collected from March through May (SEINet 2023a). In the Mojave Desert, it mostly flowers from February to June (Pratt et al. 2023). Seed is most commonly available in April through June, although several collections have been made between August and October (BLM SOS 2022).

Pollination.

Like all grasses, big galleta is wind-pollinated (Connor 1979).

Seed and Seedling Ecology.

Big galleta seeds are dispersed by both animals and wind (CNPS 2023). Big galleta seeds are short-lived and transient in the seed bank (CNPS 2023), though no quantitative information was found in the literature regarding seed longevity.

Species Interactions.

Belowground Interactions.

Big galleta is associated with soil mycorrhizae and soil collected near the base of the grass was found to have a nearly 50% mycorrhizal inoculum potential (indicating fungal propagule density and activity) in the Mojave Desert (Titus et al. 2002).

Wildlife and Livestock Use.

Big galleta is a priority species for restoring habitat for the federally endangered Mojave desert tortoise, *Gopherus agassizii* (Esque et al. 2021). At six sites monitored in a study by Esque et al. (2014), big galleta made up 2.3% of the Mojave Desert tortoise diet (Esque et al. 2014). Big galleta was also found to be a highly preferred desert tortoise forage in the Harcuvar Mountains of western Arizona, comprising 67% of all recorded bites (Snider 1992).

Big galleta is considered highly valuable forage for domestic cattle and sheep in the Mojave Desert due to its abundance and palatability, especially during growth of new foliage (Matthews 2000, Pratt et al. 2023). Due to its rigid culms, it is somewhat resistant to trampling and heavy grazing (Pratt et al. 2023). In the Mojave Desert, cattle utilization of big galleta can range between 10-60% (average 32%) and cattle grazing was found to contribute to declines in big galleta abundance over a 10 year period in a grazing system where pastures receive one to two year rest periods (Hughes 1982).

It is also fair forage for domestic horses (Barkworth 2020). Big galleta is a large component of bighorn sheep (*Ovis canadensis*) diets in southern Nevada (Bradley 1965). Other wild species such as elk (*Cervus canadensis*) and mule deer (*Odocoileus hemionus*) consume big galleta in trace amounts (Krausman et al. 1997).

Big galleta is considered poorly palatable to waterfowl and fairly palatable for upland game birds and small nongame birds (Matthews 2000). However, the robust grass does provide cover to small mammals and birds (Dittberner and Olson 1983).

Other Notable Species Interactions.

Big galleta can act as a nurse plant for desert agave (*Agave deserti*), cholla (*Cylindropuntia* spp.), barrel cactus (*Ferocactus cylindraceous*) and other shrubs (Franco and Nobel 1988, Martin 1993). One study investigating nurse plant interactions found that seedlings of *Agave* occurred almost exclusively underneath the canopy of big galleta, primarily near the center and northern sides of the grass (Franco and Nobel 1988). Soil nitrogen under big galleta was 60% higher than soils near exposed *Agave* seedlings (Franco and Nobel 1988).

The relationship between big galleta and cholla cactus is thought to be symbiotic—the shrubby grass shades young cacti which in turn provide the grass spiny protection from herbivores (Martin 1993). However, when cacti grow larger, they eventually shade out big galleta.

Disturbance Ecology.

Big galleta can have variable responses to fire. Big galleta communities are typically too sparse to fuel fire, but swales dominated by the grass can have more contiguous fuels to support fire spread (Humphrey 1974). In a study assessing the effects of fire frequency on plant communities in the Mojave Desert, big galleta

was only found in unburned areas (among areas that burned 1 to several times) and its absence from burned areas was speculated to be due to a legacy of disturbance at the site (Brooks 2012). A study in the western Sonoran Desert found big galleta was present in the first growing season following fires (Brown and Minnich 1986).

Dry plants may be severely damaged from fire, killing above-ground foliage and live centers, while green plants receive minimal and superficial damage, allowing them to recover quickly (Jameson 1962, Humphrey 1974). Surviving burned plants may resprout from rhizomes (Jameson 1962).

Big galleta will colonize sand dunes and disturbed sandy areas in the Mojave and Sonoran deserts and serves as a soil stabilizer in open areas (Burk 1977, Nobel 1980, McAuliffe 1988).

Sahara mustard (*Brassica tournefortii*) may frequently invade big galleta stands in sandy areas (CNPS 2023), however, there is little mention of invasive species interacting with big galleta.

Ethnobotany.

No uses for big galleta were noted in the literature. However, others in the genus are used by the Hopi and Navajo tribes for basketry, brushes/brooms, and as forage for domestic horse and sheep (Barrows 1967, SEINet 2023a).

Horticulture.

Though not showy, big galleta can be a valuable addition to xeriscape gardens due to its low need for water and fast growth (Carlock 2023). It is available at some retail nurseries for use in horticulture and landscaping (Calscape 2023). Big galleta may be useful for establishing groundcover on non-playing surfaces of golf courses due to its low maintenance requirements and ability to establish in disturbed areas (Burayu and Umeda 2021).

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), evidence of local adaptation and its influence on restoration outcomes can take decades to emerge for long-lived species (Germino et al. 2019).

Further, plants have coevolved with interacting organisms, such as pollinators and herbivores, that can exhibit preferential behavior for local materials (Bucharova et al. 2016, 2022).

Empirical seed transfer zones have not been developed for big galleta. The Desert Southwest Provisional Seed Zones (PSZs) may be used to plan seed sourcing in the absence of species-specific information. 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.

Big galleta 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 big galleta, although there is currently a germplasm release under development by NRCS at Tucson Plant Materials Center.

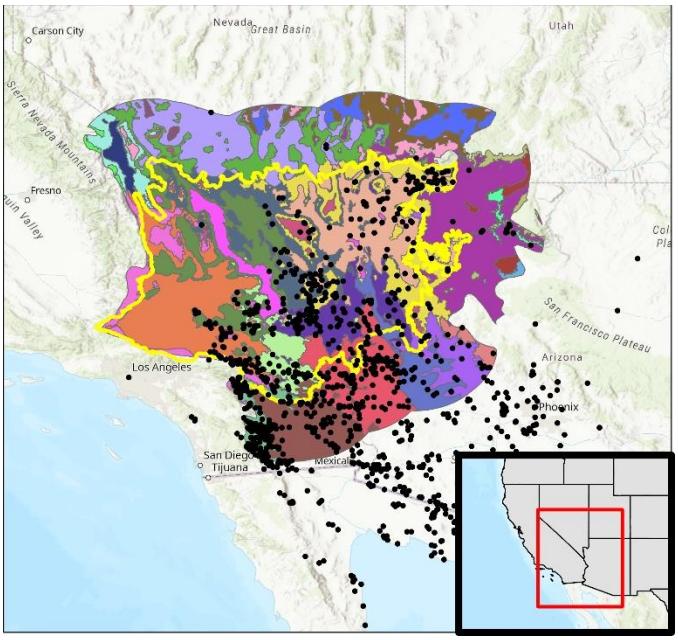

Figure 5: The distribution of big galleta across the Desert Southwest Provisional Seed Zones (Shryock et al. 2018). Occurrences (black dots) are based on georeferenced herbarium specimens and verified observations (SEINet 2023). The Mojave Basin and Range Level III ecoregion (yellow outline) is buffered 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 harvests to 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.

Big galleta is typically collected between April and November with the majority of collections occurring in May (BLM SOS 2022). Seeds may mature unevenly and drop quickly (Flory 1942).

Collection Methods.

Big galleta seeds can be collected by hand by stripping readily disarticulating spikelets from the rachis. Since this species can have low seed set, multiple florets should be assessed for presence of a caryopsis to assess if there are sufficient seed quantities for a viable collection (Wolf, personal observation).

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).

No post-collection management practices specific to big galleta were found in the literature or through personal communications.

Figure 6: Collected seed and chaff material of big galleta. Photo: BLM SOS CA930C

Figure 7: Bare seed and some chaff of big galleta. Photo: BLM MD1

Seed Cleaning.

A report from the Tucson Plant Materials Center describes cleaning big galleta seeds with a Westrup Brush Machine (#14 mantle, speed of 7) (Somerville et al. 1996). This was followed by using an air seed shucker, then hand screening (#12 round mesh), and finally running material through a seed aspirator to remove small chaffy

material. This resulted in hulled seed as the final product (Somerville et al. 1996).

Seed Storage.

Big galleta seed is orthodox (SER SID2023), but may not store well (Kay et al. 1988). In a seed lot with low initial germination (16%), germination rates declined dramatically after one year of storage under various conditions including room temperature and cold storage (Kay et al. 1988). However, big galleta was recorded to have 90% viability after drying under 15% relative humidity and freezing for 25 days at -20°C (-4°F) (SER SID2023).

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 pure seed unit – a combined unit of seed and attached structures that is classified as pure seed as opposed to inert material – for big galleta is defined by the AOSA as a "spikelet group that disarticulates as a unit, spikelet, multiple florets, or floret, with or without awn(s), provided a caryopsis with some degree of endosperm development can be detected (AOSA 2016)."

To test germination rates of big galleta, the AOSA (2016) recommends placing seeds in a moistened substrate, such as between blotter paper, in a covered petri dish with temperatures set to either 20; 25; or ranging from 20-30°C (photoperiod not specified but is typically on 16-8 light cycle). A final count for germination assessment can be conducted after 10 days (AOSA 2016).

Wildland Seed Yield and Quality.

Wild-collected big galleta seed is generally medium quality, with an average of 65.2% fill, 98.1% purity and 63.2% viability indicated by tetrazolium tests across 28 Seeds of Success collections (BLM SOS 2022, Table 2). Wild collections contain an average of over 114,000 PLS/lb (BLM SOS 2022, Table 2).

Table 2: Seed yield and quality of big galleta 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)	0.72	0.09-3.88	28
Clean weight (lbs)	0.25	0.0003-3.132	28
Purity (%)	98.10	92-98	28
Fill (%)	65.21	11-99	28
Viability (%)	63.19	26-96	21
Pure live seeds/lb	114,680	18,484-250,315	28

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

Big galleta will grow best in full sun and in moderately coarse, fast draining soils with a neutral pH (Calscape 2023, 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).

There are no species-specific certification standards for big galleta in the states where it occurs.

Isolation Distances.

Sufficient isolation distances are required to prevent cross-pollination across seed production crops of big galleta from different sources or other *Hilaria/Pleuraphis* species. Table 3 summarizes the isolation distances required for PVG certification in Utah for outcrossing perennial species (UCIA 2023). California, Nevada and Arizona do not specify these standards for Source Identified PVG seed.

Table 3: Crop years and isolation distance requirements for pre-varietal germplasm crops of big galleta. 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

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 intense 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).

No information about site preparation specific to big galleta fields was found in the literature or through personal communication.

Seed Pre-treatments.

Soaking big galleta seeds in water prior to sowing to remove germination inhibitors resulted in a germination rate of 32% (Graham 2003). Other growers report that big galleta does not require pre-treatment when seeds are sown shortly after collection (Sturwold et al. 2022, personal communication).

Warm temperatures enhance big galleta germination. In an experiment to germinate big galleta seed for revegetation trials in the Mojave Desert, germination rates reached 55% under 16 hours at 80°F (27°C) and 8 hours at 60 °F (16°C) compared to 0% germination when temperatures were cycled at 70°F (21°C) and 50°F (10°C) (Somerville et al. 1996).

Seeding Techniques.

Big galleta should be seeded in early spring at a seeding rate between 4.5-9 pure live seed pounds per acre, 4.5 PLS lbs/acre if using a drill and 9 PLS lbs/acre if broadcast (Graham 2003, Wolf 2018). Seed should be sown 1-2 inches deep. Recommended plant spacing in established fields is 36-40 inches within rows and up to 40-48 inches between rows (Graham 2003, Wolf 2018).

Establishment and Growth.

Limited information is available on how long until seed is produced from mature plants or the initial establishment rates for big galleta. Irrigated fields will produce seed starting late spring through summer (Wolf 2018).

Weed Control.

Weeds can be manually removed or carefully spot sprayed with non-selective herbicide as they emerge. Herbicide should only be applied after plants have developed 3-5 leaves (Wolf 2018). In smaller fields, hand rogueing weeds can be sufficient (Hagman 2023, personal communication).

There are a 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.

Seedlings of big galleta can be susceptible to aphids in nursery environments (Graham 2003). Harvester ants (*Pogonomyrmex* spp. and *Messor* spp.) favor big galleta seeds and can consume many of the seeds directly off the stalks (Plath 2023, personal communication). No further mention of pests or management strategies for big galleta was found in the literature or through personal communications.

Pollination Management.

Since big galleta is wind pollinated, plants should be able to readily exchange pollen within a seed production field without employing management strategies. See Isolation Distances for information on avoiding cross-pollination with crops of big galleta from different sources or other *Hilaria/Pleuraphis* species.

Irrigation.

After planting under flood irrigation, irrigation should be applied frequently enough to maintain a moist soil surface and avoid soil crusting as the plants establish. Established big galleta fields should be irrigated once every month throughout the growing season (Wolf 2018).

Many growers apply uniform watering techniques regardless of species due to their set infrastructure and labor resources. For example, at the Tucson Plant Materials Center, all fields are watered with flood irrigation (Dial 2023, personal communication). After seeding, fields are irrigated to maintain a moist soil surface and avoid soil crusting that would interfere with germination. Once plants are established, fields are flooded approximately every four weeks during the growing season. Irrigation frequency will depend on heat and precipitation levels and may be as frequent as every two weeks during the hottest part of the year to minimize plant stress which can decrease seed yield (Dial 2023, personal communication).

Other growers utilize drip irrigation and find that flood irrigation does not adequately penetrate the soil in arid growing conditions (Hagman 2023, personal communication).

Seed Harvesting.

Small-scale seed increase fields may be harvested by hand following similar methods as wildland collections (see Collection Methods). A seed stripper or combine can be used for mechanical harvest (Wolf 2018). Seed strippers allow for multiple harvests as seeds mature at different intervals throughout the season (Lochner 1997). Combines typically only allow one harvest event since stalks are cut close to the ground (Lochner 1997).

Seed Yields and Stand Life.

No information on seed yields or stand life was found in the literature or through personal communications.

NURSERY PRACTICE

Big galleta is described as "easy to grow" by nursery professionals in the Mojave Desert region (Graham 2022, personal communication; Plath 2023, personal communication). However, due to low seed fill, planting material might include limited amounts of actual seeds among floral chaff (lemmas, glumes, etc.). Therefore, it is recommended to sow extra material to increase the chances that viable seeds are included (Graham 2022, personal communication; Plath 2023, personal communication).

After germination in a greenhouse, growers at Joshua Tree National Park keep seedlings in the same conditions for four weeks (Graham 2003). Once the seedlings grow to a minimum of two true leaves, they are transplanted into newspaper cylinders (11.5 inches tall and 3 inches in diameter) wrapped with polyvinyl and are watered with drip irrigation. The soil medium consists of a 2:1:1 mix of sand, mulch, and perlite. After 8-12 weeks, plants are transplanted with the paper tube surrounding the root area into tall 2-gal PVC containers (15 inches tall and 6 inches in diameter). Plants are given slow-release Osmocote fertilizer (9 months – 13N:13P_2O_5:13K_2O) at a rate of 22 grams per container. After transplanting, plants are moved into another greenhouse that contains a higher temperature variance for four more weeks. Finally, plants are moved under a 55% shade cloth (Graham 2003). If conditions are hot and dry, an automated drip system will water up to every other day. This stage can last up to 9 months. Four to eight weeks before outplanting, plants are weaned from water and shade is removed. Hardening typically lasts up to 2 months. Overwintering can happen directly in the outdoor growing area (Graham 2003).

REVEGETATION AND RESTORATION

Due to its rhizomatous root system, tolerance of light and drought, and fast growth rates, big galleta is a good candidate for controlling soil erosion and revegetating rocky and sandy sites (Wolf 2018). It is a priority species for the Mojave Desert Native Plant Program to restore habitat for the Mojave Desert tortoise and revegetate disturbed areas.

In addition to the seeding and planting efforts described below, senesced shoots of big galleta have been used as a vertical mulch in the Sonoran Desert--dried grass shoots were collected from the area and placed vertically along the edges of a small, circular trench (10 cm wide and 10 cm deep) which was backfilled to hold the shoots in place in a ring-pattern, forming a 30 cm tall and 10 cm wide circle of dried grass shoots with an open interior (Rader et al. 2022). This low-tech abiotic treatment resulted in increased soil accumulation and increased recruitment of native shrub seedlings associated with the vertical mulch structures. In contrast, outplanting big galleta and other species in the same experiment resulted in 100% mortality attributed to an excessively dry growing season after planting (Rader et al. 2022). The vertical mulch met several restoration goals and served as a bet-hedging strategy in a year when environmental conditions were too harsh for plant establishment (Rader et al. 2022).

Wildland Seeding and Planting.

Wildland Seedings.

The difficulty of securing large amounts of viable seed of big galleta poses a challenge for wildland reseeding efforts. Seed heads can have poor fill, and the uneven maturation of the seeds make the timing of collection a challenge (Flory 1942).

Seed establishment, however, has been found to improve when ensuring seed is planted below the soil surface and includes supplemental irrigation (Winkel et al. 1995).

Big galleta was included in a seed mix in a revegetation program near Castle Mountain Gold Mine in the Mojave Desert (Walker and Powell 1999). The mix was hand-sewn at a rate of 40 lbs per acre and included 11 other desert species. The origin of the seed mix is unknown. Two years later, big galleta was not detected in the seeded area (Walker and Powell 1999).

Big galleta was experimentally seeded to restore regraded areas around golf courses (not on playing surfaces) in two Arizona municipalities: Scottsdale and Sun City West (Burayu and Umeda 2021). Seeds were supplied by the University of Arizona, but the original source was not described. To prepare the seed bed prior to sowing, topsoil was loosened, scratched, and leveled. Grasses in the study were seeded by hand and rolled over by a push lawn roller to tamp the soil. The seeding rate for big galleta was 174 pounds/acre, an unusually high seeding rate nearly twenty times higher than the rate recommended to establish a monocultural seed increase field with broadcasted seed (Wolf 2018). Plots were irrigated throughout the establishment phase (approximately 0.2 inches daily during July and August), then watering was reduced and terminated by November. Big galleta emergence rate was 90% on average, across both locations (Burayu and Umeda 2021).

Wildland Plantings.

Transplanting seed-grown or salvaged container stock of big galleta can result in variable success. Plants may benefit from inoculation with native soils to boost mycorrhizal communities (Somerville et al. 1996).

Big galleta was used in a planting experiment to determine how container size influences establishment success in a fallow field southwest of Phoenix, Arizona (Bean et al. 2004). Plants were randomly assigned to different container sizes: rose pots (2 x 2 x 3″), one-gallon pots, and paper pots (3″ diameter and 8″ height). Plants were between 6 to 9 months old before being planted at a rate of 250 plants/ha. The source of the seed was not stated in the study. Plants were provided slow drip irrigation for 12 hours once per week in the summer and twice per week in the fall. One year following transplant, the survival rate for big galleta was highest for the one-gallon pot transplants (95%) compared to rose pots (55%) and paper pots (50%) (Bean et al. 2004).

Big galleta was grown in containers from wildland-collected and locally-sourced seed in a study to test irrigation regimes and pot size effects for revegetation of disturbed areas in the Yuma Proving Ground area of the Sonoran Desert (Somerville et al. 1996). Two irrigation treatments were applied: 1) one gallon per hour, one time per week and 2) one gallon per hour once every two weeks. Outside of these two treatments, a subset of the plants was watered once at the time of planting without any follow-up irrigation. Three pot sizes were tested: SuperCells (8.25" deep and 10 in^3), Deepots (10" deep and 40 in^3), Treepots (16" deep and 555 in^3 or 2 gallons). Big galleta had 75-80% survival under both irrigation regimes (1x/week or 1x/every two weeks), and <40% survival when watered only once at the time of planting. Big galleta had the lowest survival rates when planted in Deeppots (~45%) and high survival rates when planted in Tree Pots (>70%) and Supercells (~78%). After nearly one year, the Supercell plants were the tallest. In this example, smaller pots did not hinder big galleta establishment, and growth and survival was

significantly increased with regular watering (Somerville et al. 1996).

Another study investigated the survival of salvaged native perennials (including big galleta) in the Mojave Desert in the Lake Mead National Recreation Area (Abella et al. 2015). Plants were hand-excavated from future construction sites within the park, with minimal soil retained. Plants were treated with either a rooting hormone and/or a watering treatment. After treatment, plants were placed in temporary nursery with a 1:3 mulch-to-sand mix. To prepare the field site, salvaged topsoil was added to a thickness of 5 cm. Each plant was given 1 liter of water and potting soil during planting, along with a mesh anti-herbivore cage. At planting, plants were given either DRiWATER, hand watered, or no water except at the time at planting. Survival was recorded at 27 months. Results showed that big galleta had moderate survival (41%) at the initial salvage/nursery stage. After 27 months in the field, big galleta showed only 14% survival (too low to statistically compare treatments). The researchers found that the cactus and long-lived shrubs performed best, while grasses performed poorest. This is the inverse of the typical findings found in other salvage transplant studies and therefore warrants further investigation (Abella et al. 2015).

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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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