Acton's brittlebush

Encelia actoni Elmer

Asteraceae - Sunflower family

Molly Wiebush and Ashlee Wolf |2023

ORGANIZATION

NOMENCLATURE

Encelia actoni Elmer (Acton's brittlebush) was first described in 1905. Acton's brittlebush is a member of the Heliantheae tribe of the Asteraceae family, and in the *frutescens* clade of the genus *Encelia* (Clark 1998, Fehlberg and Ranker 2007, Singhal et al. 2021). The scientific name is sometimes spelled *Encelia actonii* (including in the USDA Plants Database), but Acton's brittlebush is named after a place (Acton, Los Angeles County, California) so *actoni* is correct (Clark 2006).

NRCS Plant Code.

ENAC (USDA NRCS 2022).

Synonyms.

Encelia frutescens fo. *actoni* (Elmer) H.M. Hall, *Encelia frutescens* var. *actoni* (Elmer) S.F. Blake, *Encelia virginensis* subsp. *actoni* (Elmer) D.D. Keck, *Encelia virginensis* var. *actoni* (Elmer) B.L. Turner (Clark 2006, Keil and Clark 2012, Tropicos 2023).

Common Names.

Acton's brittlebush (USDA NRCS 2022), Acton brittlebush, Acton encelia (CNPS Calscape 2023) Acton's encelia (Berry et al. 2014).

Subtaxa.

No varieties or subspecies are currently recognized by the Flora of North America or the Jepson eFlora (Clark 2006, Keil and Clark 2012).

Chromosome Number.

Chromosome number is 2n = 36 (Kyhos et al. 1981, Clark 1998). Variation in chromosome number has not been documented in *Encelia* species.

Hybridization.

All *Encelia* species are obligate outcrossers, and natural hybrids between them are frequently documented where two different *Encelia* species occur sympatrically (Kyhos et al. 1981, Clark 1998, Fehlberg and Ranker 2007, Singhal et al. 2021). In cultivation, all *Encelia* species can produce fertile offspring when crossed with one another, and any following generations or backcrosses are all also fertile (Clark 1998, Fehlberg and Ranker 2007, DiVittorio et al. 2020, Singhal et al. 2021). However, despite *Encelia* hybrids' fertility, offspring of hybrids are rarely found in the wild and F1 hybrids are usually only found in the ecotones between their two parent species, suggesting that strong selective pressures maintain species boundaries in this genus (Kyhos et al. 1981, Clark 1998, Fehlberg and Ranker 2007, DiVittorio et al. 2020, Singhal et al. 2021).

Several hybrids of Acton's brittlebush with button brittlebush (*Encelia frutescens*) have been documented in the wild (Clark 1998). Hybrids between Acton's brittlebush and brittlebush (*Encelia farinosa*) were noted in one paper (Clark and Sanders 1986) but were not otherwise discussed in the literature. Two species of *Encelia*, Virgin River brittlebush (*Encelia virginensis*) and sticky brittlebush (*Encelia resinosa*) are likely of hybrid origin from crosses of Acton's brittlebush and button brittlebush (*E. frutescens*) (Clark 1998, Singhal et al. 2021). Sterile hybrids of *Encelia* species with its sister genus *Geraea* (desert sunflower) have also been found in the Sonoran Desert (Kyhos 1967).

DESCRIPTION

Acton's brittlebush is a short-lived (less than 30 years) desert shrub (DiVittorio et al. 2020) that grows between 50–150 cm tall (Clark 2006, Keil and Clark 2012). Stems are soft wood, branched from the plant's base. Young stems are green and hairy, but the plant develops fissured or shredded bark with age (Elmer 1905). The silvery-green leaves are 2.5–4 cm long, ovate to deltate, with acute tips, and attach to the stem with short (6–12 mm) petioles (Clark 2006, Keil and Clark 2012). The silvery or grey-white color of the leaves (Figure 2) comes from canescent hairs that likely reflect solar radiation, providing the plants with protection from hot and dry desert conditions (Ehleringer and Cook 1987).

Figure 1: Acton's brittlebush in San Bernardino County, California. Photo: Michelle Cloud-Hughes

Leaf characteristics such as shape and hairiness have a great amount of plasticity and diversity in form in *Encelia* species, and they may vary based on habitat (Singhal et al. 2021) so should be used with caution as identifying characteristics. Flowerheads consist of both ray and disk flowers, all yellow (Figure 3, Figure 4), and are born on single stems (Clark 2006). This characteristic is useful in telling Acton's brittlebush from the co-occurring brittlebush (*Encelia farinosa*), which has multiple flower heads per stem. Acton's brittlebush (and all species in the *fructescens* clade of *Encelia*) has corollas that absorb ultraviolet light (Clark and Sanders 1986, Ehleringer and Cook 1987). Fruits are 5–7 mm long, narrowly obovate or cuneate, with dense ciliate hairs on their edges, generally without pappus though occasionally with one or two bristle-like awns (Clark 2006, Keil and Clark 2012; Figure 5). Ray flowers bear smaller sterile fruits (Elmer 1905).

Figure 2: Acton's brittlebush leaves, showing the silvery, reflective hairs. Photo: Steve Matson

Figure 3: Acton's brittlebush in flower. Photo: ©Neal Kramer 2011

Figure 4: Disc flowers and developing seeds in Acton's brittlebush. Photo: Steve Matson

Figure 5: Acton's brittlebush in seed. Photo: ©Neal Kramer 2010

DISTRIBUTION AND HABITAT

Acton's brittlebush is found in the United States in California, Nevada, and Arizona, and in Mexico in Baja California (Figure 6). Most Acton's brittlebush records occur in the Southern California Mountains (Transverse Ranges) and the western half of the Mojave Basin and Range ecoregions. This species' range also extends into the Central Basin and Range (Great Basin), Sierra Nevada, Central California Foothills and Coastal Mountains, Central California Valley, Southern California/Northern Baja Coast, and Sonoran Basin and Range ecoregions (Omernik 1987, CCH2 Portal 2022, SEINet 2022, USDI EPA 2022).

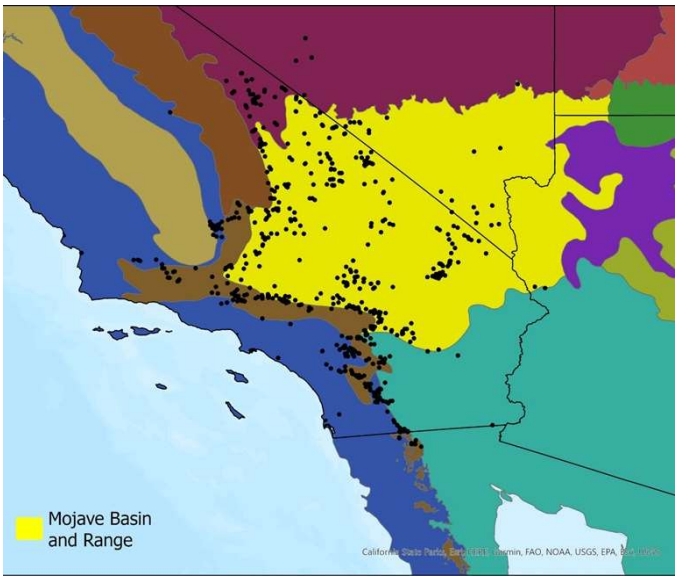

Figure 6: Distribution of Acton's brittlebush (black circles) from georeferenced herbarium specimens and verified observations. (CCH2 Portal 2022, SEINet 2022) with Omernik Level III Ecoregions (Omernik 1987). The Mojave Basin and Range ecoregion is shown in yellow.

Habitat and Plant Associations.

Encelia species tend to be habitat specific, with species boundaries defined by soil and climate conditions (Clark 1998, Fehlberg and Ranker 2007, DiVittorio et al. 2020, Singhal et al. 2021). NatureServe recognizes one habitat alliance (Acton's Brittlebush—Virgin River Brittlebush—Netvein Goldeneye Desert Scrub, ranked as vulnerable in CA) and one habitat association (Acton's Brittlebush Desert Scrubland) defined by the presence of Acton's brittlebush (Evens 2015, Schulz 2016). The California Native Plant Society describes both types as alluvial scrub habitat (Buck-Diaz and Evens 2011; Figure 7). Both are defined by shrub covers of 7–48% and least 2% cover of Acton's brittlebush (Evens 2015, Schulz 2016).

Acton's brittlebush is also documented in other chaparral and shrubland habitats, particularly blackbrush (*Coleogyne ramosissima*) and creosote bush (*Larrea tridentata*) shrublands. In the Transverse Ranges and California coast, it is found in coastal sagebrush habitats (Evens 2015,

Schulz 2016). Acton's brittlebush is one of the defining plant species of mid-elevation Mojave scrub at the transition between Mojave and Sonoran Desert ecoregions in Joshua Tree National Park (Barrows et al. 2014). This species has also been documented in Joshua tree, pinyon-juniper, and occasionally oak woodlands (CCH2 Portal 2022, SEINet 2022).

Acton's brittlebush communities are generally found on substrates with recent disturbance, like intermittently flooded arroyos, canyon bottoms, washes, alluvial fans, and road cuts (Evens 2015, Schulz 2016, SEINet 2022). Slope and aspect where Acton's brittlebush communities are found is variable, with coarse, rocky, sandy, or loamy soil that is frequently covered in gravel or cobble (Figure 8). Disturbance in these habitats is generally by flood, but a few herbarium records also document finding Acton's brittlebush recolonizing areas as soon as six months post-fire (Evens 2015, Schulz 2016, SEINet 2022).

Frequently associated plant species include the shrubs cheesebush (*Ambrosia salsola*), white bursage (*A. dumosa*), creosote bush, Virgin River brittlebush (*Encelia virgenensis*), netvein goldeneye (*Viguiera reticulata*), buck-horn cholla (*Cylindropuntia acanthocarpa*), Engelmann's hedgehog cactus (*Echinocereus engelmannii*), Nevada jointfir (*Ephedra nevadensis*), Eastern Mojave buckwheat (*Eriogonum fasciculatum*), threadleaf snakeweed (*Gutierrezia microcephala*), water jacket (*Lycium andersonii*), Mexican bladdersage (*Scutellaria mexicana*), and purple sage (*Salvia dorrii*); native forbs brownplume wirelettuce (*Stephanomeria pauciflora*), desert trumpet (*Eriogonum inflatum*) and desert globemallow (*Sphaeralcea ambigua*); and invasive annuals red brome (*Bromus rubens*) and redstem stork's bill (*Erodium cicutarium*) (Evens 2015, Schulz 2016).

Figure 7: Acton's brittlebush growing in canyon bottom habitat near the Kern River in Kern County, California. Photo: Jean Pawek

Figure 8: Acton's brittlebush growing on a slope in California. Photo: BLM SOS CA930A-970

Climate.

The Mojave Desert is characterized by low annual precipitation (2–9.8 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). heterogeneous 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 Acton's brittlebush occurs according to herbarium specimen locations (Table 1). Herbarium specimen locations may not represent the full distribution and abundance of Acton's brittlebush due to sampling bias towards accessible locations. Average annual rainfall in the PSZs where Acton's brittlebush occurs in the Mojave Desert is 3–10 inches (7.7–25.5 cm) (Shryock et al. 2018). Historically, most precipitation in the western Mojave Desert falls in the winter (Barrows et al. 2014, Charlton and Rundel 2017) and where this species occurs in the Mojave, winter rainfall ranges on average from 2.1–8.4 inches (5.3–21.3 cm). Average high temperatures in the warmest months range from 87–111 degrees F (31–44 degrees C), and lows in the coldest months average 32–37 degrees Fahrenheit (0–3 degrees C) (Shryock et al. 2018). In the southern Sierra Nevada Mountains, Acton's brittlebush can occur above the frost line (Singhal et al. 2021).

Climate change.

Southern California, western Arizona, and southern Nevada (the Mojave and Sonoran Desert ecoregions) may experience the largest shift in climate in temperate North America. (Diffenbaugh et al. 2008). Climate change predictions for the Mojave Desert include increases in mean summer and winter temperatures, decreases in precipitation leading to more frequent and intense droughts, more variability in precipitation patterns, and an increase in frequency and intensity of wildfire due to these changes (Barrows et al. 2014).

Table 1: Climate of the provisional seed zones (PSZ) where Acton's brittlebush occurs within the Mojave Desert ecoregion (Shryock et al. 2018), showing the number of herbarium records or verified observations of Acton's brittlebush that occur within the PSZ. Mean annual precipitation (MAP) is the mean of yearly rainfall. Summer precipitation (SP) is the mean precipitation that falls in the summer (May-October). Winter precipitation (WP) is the mean precipitation that falls in the winter (November-April). Monthly average temperature (MAT) is the average of the monthly temperatures. Range is the average of the monthly temperature ranges (monthly maximum minus monthly minimum).

PSZ	#	MAP (cm)	SP (cm)	WP (cm)	MAT (C)	Range (C)
26	100	14.5	2.7	11.8	16.8	34.9
29	79	25.5	4.1	21.4	13.8	31.7
23	61	15.8	5.4	10.4	16.1	35.9
24	55	10.7	2.8	7.9	18.8	38.6
25	35	16.5	6.2	10.3	18.9	34.6
20	15	25.5	10.5	14.9	15.3	34.5
28	5	7.8	2.4	5.3	22.3	41.3
21	3	15.6	6.2	9.4	18.8	38.4
27	3	9.6	3.3	6.3	20.0	36.7

A study conducted in Joshua Tree National Park predicted how several species, including Acton's brittlebush, would respond to a three degree rise in average temperature. This study used two different techniques: vulnerability assessments, which involved extensive literature review by species experts; and habitat suitability modeling, which used available data to develop predictive models of habitat loss and climate refugia. The

vulnerability assessments for Acton's brittlebush reported neutral or unknown effects of climate change on this species in Joshua Tree National Park. However, the habitat suitability model suggested that Acton's brittlebush is vulnerable to local extinction in the park and surrounding areas (Barrows et al. 2014).

Elevation.

Herbarium specimens of Acton's brittlebush have been collected between 40–6,930 feet (12–2112 m) in elevation, but experts describe the average elevation range for this species as 650–6,900 ft (200–2100 m) (Keil and Clark 2012, CCH2 Portal 2022, SEINet 2022).

Soils.

Acton's brittlebush prefers coarse textured sandy or loamy soils, with high surface cover of gravel or cobble. Soils are derived from alluvium, rhyolite, and sandstone, and are frequently calcareous (Evens 2015, Schulz 2016). No associations with biological crusts are documented in the literature.

ECOLOGY AND BIOLOGY

Acton's brittlebush is an early colonizer of disturbed areas, including burns, in the Mojave Desert. Its main benefit to other species appears to be as cover or nurse plants, including for the desert tortoise (*Gopherus agassizii*) and the federally endangered plant species Lane Mountain milk-vetch (*Astragalus jaegerianus*) (Gibson et al. 1998, Esque et al. 2021). Acton's brittlebush, like many other species of *Encelia*, produces secondary compounds for defense against insect herbivory. *Encelia* species bloom abundantly and thus are likely an important resource for pollinators (Sturwold et al. 2022, personal communication). While there is little information on how wildlife use Acton's brittlebush, birds, rodents, and ants are known to eat and cache the seeds of other *Encelia* species (Tesky 1993, DeFalco et al. 2012). While livestock are reported to find some *Encelia* species unpalatable, wild ungulates have been observed browsing on *Encelia* species (Tesky 1993).

Reproduction.

While hybridization in *Encelia* species is well-studied, little information appears to be available on the reproductive ecology of Acton's brittlebush. Studies on pollination, seed dispersal, and other reproductive ecology of this species are also limited.

Breeding System.

Acton's brittlebush is an obligate outcrosser and cannot self-pollinate (Kyhos et al. 1981, Clark 1998, Fehlberg and Ranker 2007, Singhal et al. 2021).

Reproductive Phenology.

Acton's brittlebush generally flowers from February to July (Clark 2006, Keil and Clark 2012) with herbarium specimens documenting peak flowering April to July, and individuals blooming as late as December (CCH2 Portal 2022, SEINet 2022). Flowering events can be triggered by rainfall throughout the year (Brooks and Gault 2023, personal communication).

Pollination.

No pollination studies appear to have been done with *Encelia* actoni. However, Acton's brittlebush likely relies on generalist pollinators (e.g. bees, butterflies, beetles, flies) (Kyhos et al. 1981, Clark 1998, Pickering 2022; Figure 9). Butterflies, including monarchs, queens, and sulfurs have been observed visiting this species (Graham 2022, personal communication; Sturwold et al. 2022, personal communication), as well as bees, though honeybees were noted as more common

than native bees by some observers (Sturwold et al. 2022, personal communication). Hurd and Linsley (1975) reported that bees of genera *Anthidium*, *Colletes*, and *Megandrena* visited *Encelia* species, although they only discussed these sightings in reference to the genus and did not address pollinator effectiveness, abundance or specialization for any of these genera as related to *Encelia* species.

Figure 9: A syrphid fly visiting Acton's brittlebush. Photo: John Doyen

Seed and Seedling Ecology.

Acton's brittlebush seeds are wind dispersed. Acton's brittlebush is an early colonizer of disturbed areas, and likely revegetates these areas almost entirely by seed dispersal from nearby populations (Brown and Minnich 1986, Esser 1993, Tesky 1993). *Encelia* species germinate relatively easily and after a wet winter many *Encelia* seedlings can be observed (Sturwold et al. 2022, personal communication). While there is little information on Acton's brittlebush seedling survival in the wild, brittlebush (*E. farinosa*) exhibits intraspecific competition, possibly for water, with seedling survival reduced by proximity to adult plants (Tesky 1993).

Species Interactions.

Belowground Interactions.

No research was available on belowground interactions in Acton's brittlebush. However, a study of mycorrhizal interactions in California brittlebush (*Encelia californica*) found increases in growth and less leaching of nitrogen and phosphorus in plants inoculated with arbuscular mycorrhizae (Corkidi et al. 2011).

Parasites and Predation.

Studies have documented secondary compounds that appear to function as defenses against herbivory in several species of *Encelia*, including Acton's brittlebush (Proksch and Rodriguez 1984, Srivastava et al. 1990, Kunze et al. 1996, Redak et al. 1997). In brittlebush (*E. farinosa*) and California brittlebush, these compounds were found in all parts of the plants, including roots, flowers, and seeds, though they were most concentrated in new leaves and flowers (Proksch and Rodriguez 1984, Kunze et al. 1996). Chemicals that deter pathogens as well as herbivores have been documented in at least some species of *Encelia* (Proksch and Rodriguez 1984).

In lab experiments, encelin, one of the secondary chemicals found in Acton's brittlebush, was shown to have a negative effect on both growth and survival of armyworm moth larvae (*Spodptera littoralis*) even at the lowest concentrations found in the plant's leaves. These generalist herbivores also ate less when fed medium that contained encelin (Srivastava et al. 1990). No specialist herbivores are apparently documented for Acton's brittlebush, though another species in this genus, brittlebush (*E. farinosa*) is associated with the *Encelia* leaf beetle (*Trirhabda geminata*), which feeds on it almost exclusively (Proksch and Rodriguez 1984, Kunze et al. 1996, Redak et al. 1997). The

defensive compounds found in brittlebush (*E. farinosa*) are not the same as the ones found in Acton's brittlebush (Srivastava et al. 1990), so it is likely resistant to infestations of the *Encelia* leaf beetle. However, Acton's brittlebush is still subject to insect herbivory (Figure 10).

Figure 10: This Acton's brittlebush shows evidence of insect herbivory. Photo: W. Juergen Schrenk 2021

Wildlife and Livestock Use.

Acton's brittlebush is noted as common in areas protected as desert tortoise habitat. The desert tortoise is listed as threatened both federally and by the state of California. Maintaining and restoring habitat is a priority for protecting this species (Berry et al. 2014, Esque et al. 2021). Desert tortoises use Acton's brittlebush and other *Encelia* species as cover (Esque et al. 2021, Shryock et al. 2022). Shrub cover, particularly from long-lived perennial species, protects desert tortoises from thermal stress and predation. Regeneration of long-lived shrub species can take up to 50 years after a disturbance. Short-lived shrub species such as Acton's brittlebush can provide cover for tortoises immediately after fire (Esque et al. 2021), and could be important for maintaining tortoise habitat by bridging the gap between disturbance events and recovery of long-lived shrubs. While button brittlebush (*Encelia frutescens*) has been noted as forage for desert tortoise in times of drought (Esser 1993), no sources mentioned desert tortoise browsing Acton's brittlebush.

Woody vegetation like Acton's brittlebush may also be important cover for invertebrate pollinators. While no specific relationships between any insects is documented for Acton's brittlebush, a review of studies done in the Mojave Desert found that almost all woody taxa were hosts for Lepidoptera species (Esque et al. 2021). Harvester ants have also been observed collecting Acton's brittlebush seeds after they have fallen from the ground (Asbell 2023, personal communication). Providing habitat for insects also maintains an important food source for breeding birds (Esque et al. 2021). Small seed-eating birds like the lesser goldfinch and verdin are often seen eating Acton's brittlebush seeds when the plants are fruiting (Sturwold et al. 2022, personal communication), and it is possible that birds also disperse Acton's brittlebush seeds, though this is not reported in the literature. The related species brittlebush (*Encelia farinosa*) provides habitat for several bird species, and it seems likely that Acton's brittlebush also serves this function. While little information is available on seed predation for Acton's brittlebush, other *Encelia* species do have documented seed predators. Kangaroo rats (*Dipodomys* spp.) eat brittlebush (*E. farinosa*) seeds, though they do not prefer them (Tesky 1993) and both ants and rodents have been observed removing and caching brittlebush (*E. farinosa*) seeds from restoration sites (DeFalco et

al. 2012). While these interactions are not reported for Acton's brittlebush, it is possible that they have similar relationships with seed predators and dispersers.

No information was available for the value of Acton's brittlebush as wildlife or livestock forage, but brittlebush (*Encelia farinosa*) is browsed by mule deer (*Odocoileus hemionus*) and desert bighorn sheep (*Ovis canadensis* subsp. *nelsoni*). Livestock generally do not eat brittlebush (*E. farinosa*), prompting some efforts to study how to remove it from rangelands (Tesky 1993).

Other Notable Species Interactions.

Acton's brittlebush is one of the shrub species noted as a nurse plant for Lane Mountain milk-vetch (Gibson et al. 1998). Lane Mountain milk-vetch is listed as federally endangered and is ranked by the California Native Plant Society as a 1B.1 species (1B.1 species are rare, often with small ranges, and highly threatened throughout their range) (RPI 2022). This species is only known from Fort Irwin and surrounding areas and uses nurse shrubs as a trellis for support and protection from herbivory (Gibson et al. 1998).

Disturbance Ecology.

Acton's brittlebush is associated with disturbance, particularly in drainages and other areas that experience flooding (Buck-Diaz and Evens 2011), and is frequently observed as an early colonizer of these areas (CCH2 Portal 2022, SEINet 2022). While fire has historically been rare in the Mojave Desert (Esque et al. 2010, Vamstad and Rotenberry 2010), Acton's brittlebush was also frequently documented recolonizing burned areas, with several observations of this species in burn scars one or two years post burn, and at least one herbarium record from six months post fire. Another record, approximately 14 years post-fire, reported "good recovery" for this species (CCH2 Portal 2022, SEINet 2022). This response to disturbance suggests Acton's brittlebush could have some resilience to increases in fire frequency and size in the Mojave Desert (Esque et al. 2010, Vamstad and Rotenberry 2010). Little information on how Acton's brittlebush recolonizes burned areas is available in the literature. Extrapolation from herbarium records and information on other *Encelia* species suggests that Acton's brittlebush recolonizes disturbed areas via seed dispersal. Resprouting from burned individuals is rarely seen in *Encelia* species (Esser 1993).

Ethnobotany.

The Tübatulabal people of the Kern River Valley used the roots of Acton's brittlebush to make a wash for treating rheumatism. The neighboring Kawaiisu people used leaves and flowers of Acton's brittlebush for the same treatment, and also to treat cuts and bruises on horses (NAEB 2022).

Horticulture.

Acton's brittlebush is grown and sold in nurseries as an ornamental plant, where it is used for drought-tolerant landscaping and for wildlife gardens. This species is available in several retail nurseries in California and is also currently in use in some restoration projects (Sturwold et al. 2022, personal communication; CNPS Calscape 2023; Wallace 2023, personal communication). In cultivation, *Encelia* species often maintain old, withered leaves, which may make them less attractive for purchase (Sturwold et al. 2022, personal communication).

DEVELOPING A SEED SUPPLY

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

Seed Sourcing.

Empirical seed transfer zones have not been developed for Acton's brittlebush. The Desert Southwest Provisional Seed Zones (PSZs) may be used to plan seed sourcing in absence of species-specific information (USDA NRCS 2022; Figure 11). 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.

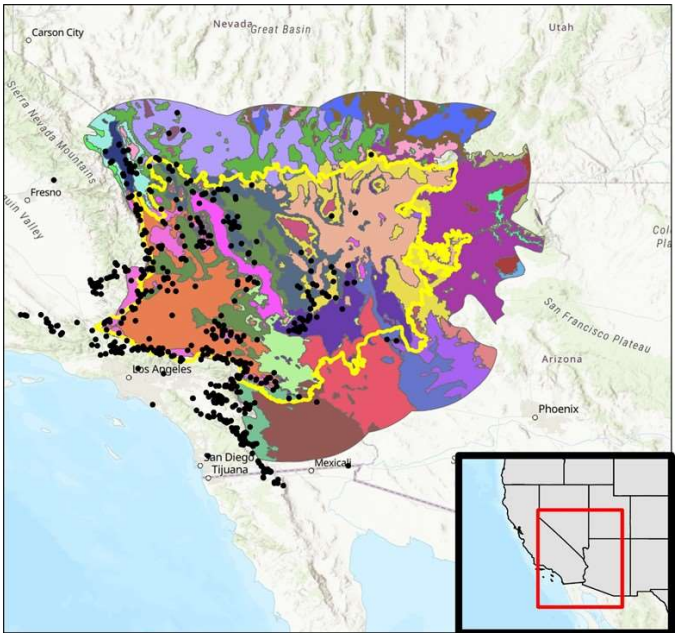

Figure 11: The distribution of documented Acton's brittlebush (black dots) across the Desert Southwest Provisional Seed Zones (Shryock et al. 2018). Occurrences are based on georeferenced herbarium specimens and verified observations (CCH2 Portal 2022, SEINet 2022). The Mojave Basin and Range Level III ecoregion (yellow outline) is buffered up to 100km in all directions. PSZs do not always extend a full 100km beyond the Mojave ecoregion.

Commercial Seed Availability and Germplasm Releases.

As of January 2023, there were no germplasm releases of Acton's brittlebush (USDA NRCS 2023). Seed for this species does not appear to be readily available commercially, and there have been no conservation plant releases of Acton's brittlebush.

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.

Seeds from *Encelia* species may be collected year-round, especially in wetter areas, and seed collections for Acton's brittlebush have been documented from April to December (RSA 2021; BLM SOS 2022; Thomas et al. 2022, personal communication). Collectors often harvest Acton's brittlebush seeds in May and June (Mirov and Kraebel 1937, BLM SOS 2022), though growers at Joshua Tree National Park are considering collecting seeds for this species earlier in the year to match phenological shifts (Graham 2022, personal communication). Growers with the Living Desert Zoo and Gardens collected Acton's brittlebush seeds in August and September, but recommended timing collecting by tracking the phenology of target populations. Summer heat can potentially damage the viability of seeds, and their suggested collection window for wild populations is in the 2–3 weeks before seeds have dispersed (Thomas et al. 2022, personal communication).

Collection Methods.

Due to the ruggedness of the terrain *Encelia* species occur in, hand-collection is usually the most effective way to harvest seeds from wild populations (Esque et al. 2021, Shryock et al. 2022). Recommended hand collection methods for Acton's brittlebush include clipping seed heads (particularly mid-season or mid-ripeness), or using tools such as tennis racquets, brooms, or vacuums to shake ripe seeds from plants into a collection vessel. The second method also can reduce the number of non-viable or unripe seeds collected in Aster species (Kleiner 2023, personal communication). While plants may occasionally have aborted inflorescences, *Encelia* species usually produce abundant viable seed (Sturwold et al. 2022, personal communication).

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).

Growers reported pests, such as seed parasites and fungal infections, are rarely a problem with *Encelia* species (Graham 2022, personal

communication; Sturwold et al. 2022, personal communication).

Seed Cleaning.

Some sources report that seeds from plants in the aster family can be difficult to process. In general, fertile seeds will separate easily from the flower head (as compared to infertile or parasitized seeds which will not come free easily) (Wall and MacDonald 2009; Asbell 2022, personal communication). The pappus and other chaff can be removed by gently rubbing them against a rubber mat with a wooden block (Wall and MacDonald 2009).

While there are no protocols published for processing Acton's brittlebush seeds, other *Encelia* species do have seed cleaning protocols. California brittlebush and brittlebush (*Encelia farinosa*) seeds both need to be processed when very dry. First, remove seeds from receptacles by hand. Receptacle chaff can then be removed from seeds with a blower set at 1.0 speed. A blower set at 1.5 speed can then be used to separate good seeds from parasitized seeds, and a setting of 1.15 will remove hollow fruits and chaff. Fertile seeds can be separated from the rest of their chaff by gently rubbing them over a #20 sieve or rubber mat and then separating the resulting broken off chaff with a seed blower while increasing speed to 1.2 (Wall and MacDonald 2009). One source rated processing *Encelia* seeds as relatively difficult, and suggested a significant amount of time should be planned for cleaning seed collections (Wall and MacDonald 2009), but growers at Victor Valley College, who are currently working on developing growing practices for Acton's brittlebush describe the seeds as easy to clean with relatively little chaff to process off (Brooks and Gault 2023, personal communication; Figure 12). Differences in clean difficulty could be related to collection methods.

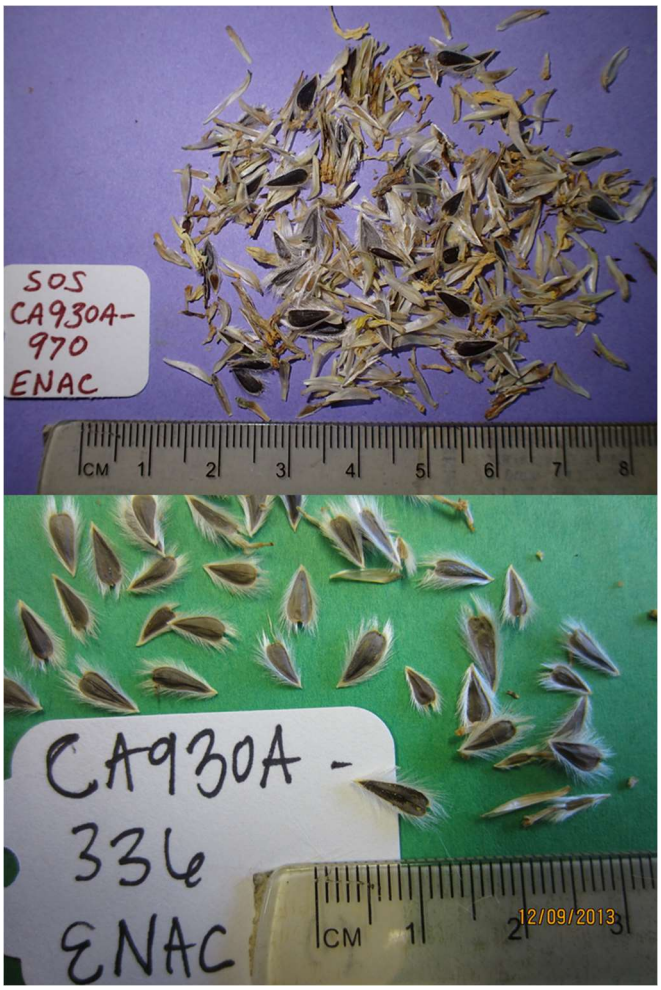

Figure 12: Acton's brittlebush seeds with chaff (top) and without chaff (bottom). Photos: BLM SOS CA930A-970 (top) and BLM SOS CA930A-336 (bottom)

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).

Acton's brittlebush, like all *Encelia* species, has orthodox seed (SER SID 2023). The California Botanic Garden reported a 52% germination rate for fresh year-old seeds (from one test), and an average germination rate of 28% from frozen seed (three tests on seed from 13–17 years old).

However, germination rate varied widely in the frozen seed, from 4% to 55% germination (RSA 2021).

Acton's brittlebush is one of the species included in a 360-year test of seed longevity for 100 species of California native plants (Went and Munz 1949, Wall 2009). Germination rates were tested before and after seeds were dried for storage, and then stored in vacuum seed glass vials at the Rancho Santa Ana Botanic Gardens (now the California Botanic Gardens). Drying seeds for storage did not appear to affect germination rates for most species tested, including Acton's brittlebush. The Acton's brittlebush seeds used in this experiment were collected 12 years earlier (1935) and stored indoors in a glass jar and then discarded and left in full sun for a summer before they were added to this experiment. In 1947, these seeds germinated in lab conditions (13% germination rate), but not in the greenhouse (Went and Munz 1949). After 10 years of vacuum storage, Acton's brittlebush was reported to have a 12% germination rate. After 20 years of vacuum storage, germination rates for Acton's brittlebush had dropped to 1% (Went 1969). In the 50-year germination tests, Acton's brittlebush seeds had no germination (Christensen 2000 as cited by (Wall 2009).

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 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 Association of Official Seed Analysts (AOSA) includes *Encelia* species in its tetrazolium testing protocols to assess seed viability for the Asteraceae family. These methods involve imbibing seeds overnight at 20-25 degrees C, then cutting seeds longitudinally and placing them in a 0.1% tetrazolium solution (TZ) for 6 hours to overnight at 30-35 degrees C. Viability can then be quantified by assessing the percentage of sees with embryos that are either evenly stained or have more than half of their cotyledons stained (AOSA 2010).

Wildland Seed Yield and Quality.

Wild-collected Acton's brittlebush from the Mojave Desert has an average of 93% fill and 91% purity, based on five Seeds of Success collections, and 96% viability as indicated by tetrazolium tests based on four Seeds of Success collections (BLM SOS 2022). One source reported 327,000 seeds/lb for Acton's brittlebush (Mirov and Kraebel 1937), but Seeds of Success collections averaged 214,300 seeds/lb across four samples, with an average pure live seed (PLS)/lb of 189,600 (BLM SOS 2022; Table 2).

Table 2: Acton's brittlebush seed yield and quality from Mojave Basin and Range collections, cleaned by the Bend Seed Extractory and tested by the Oregon State Seed Lab or the USFS National Seed Lab (BLM SOS 2022). Fill (%) was measured using a 100 seed X-ray test. Viability (%) was measured using a tetrazolium chloride test.

Seed lot characteristics	Mean	Range	Samples (no.)
Bulk weight (lbs)	0.97	0.57-2.19	5
Clean Weight (lbs)	0.35	0.036-1.19	5
Purity (%)	91	83-97	5
Fill (%)	93	92-97	5
Viability (%)	96	92-98	4
Pure live seeds/lb	189,647	148,452-251,772	4

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

Acton's brittlebush grows best in sandy or decomposed granite soils in full sun and requires little to no watering after the first year of establishment in landscaping (CNPS Calscape 2023). Maximizing seed yields may require more water than landscaping or restoration plantings.

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).

No pre-variety germplasm (PVG) certification standards currently exist for Acton's brittlebush, but the state of California does have PVG standards set for the closely related Virgin River brittlebush (Table 3) which may be a good starting point for standards for agricultural production of Acton's brittlebush. 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 (UTCIA 2015).

Table 3: Pre-varietal germplasm (PVG) standards for seed analysis results of Virgin River brittlebush seed increase crops in California. Virgin River brittlebush is closely related to Acton's brittlebush, which does not have existing PVG standards.

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%

Isolation Distances.

Sufficient isolation distances are required to prevent cross-pollination across seed production crops. California does not have isolation distance standards for Acton's brittlebush, but it does have standards documented for the closely related Virgin River brittlebush (CCIA 2022). Utah standards are general for outcrossing perennial species (UTCIA 2015; Table 4). Nevada and Arizona do not specify standards for Source Identified PVG seed.

Site Preparation.

Acton's brittlebush should be grown in a weed free bed. Pre-emergent herbicides may be useful if planting Acton's brittlebush as plugs but should not be used for direct seeding.

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

Seed Pre-treatments.

No seed treatments are required to germinate Acton's brittlebush seed. In some of their germination tests, the California Botanic Garden pre-treated Acton's brittlebush seeds with warm stratification, and growers at the Mojave Desert Land Trust also suggested this strategy for improving germination rates, (RSA 2021; Asbell 2022, personal communication). Germination rates from the California Botanic Garden's trials did not appear to be correlated with pre-treatment (RSA 2021).

Seeding Techniques.

No field seeding techniques appear to have been developed for Acton's brittlebush. At least one grower reported direct seeding to be unsuccessful with other *Encelia* species, and recommended planting from plugs instead (Schaff 2023, personal communication). For low viability seed, small seed lots, or highly contaminated seed, starting plugs instead of direct seeding can be more cost effective and result in higher quality plants (Winters 2023, personal communication).

Establishment and Growth.

Most growing information available for Acton's brittlebush is focused on wildland plantings for restoration. Researchers at Victor Valley College

are currently researching agricultural production protocols for this species (Brooks and Gault 2023, personal communication; Figure 13, Figure 14), but the information provided here is extrapolated from growing for restoration projects.

When starting *Encelia* species, including Acton's brittlebush, in the greenhouse, keeping the soil surface dry is important. If the soil surface is too damp, *Encelia* seedlings may snap off at the root collar. One recommended technique is to cover soil with a thin layer of perlite to keep soil surface dry (Johnson 2023, personal communication). At Joshua Tree National Park Native Plant Nursery, the average time to transplant Acton's brittlebush after sowing is five weeks, with the shortest time at two weeks after sowing. The shortest time for transferring plants from the greenhouse to outdoors is ten weeks after sowing, with the average time at 17 weeks after sowing (Graham 2019, personal communication). Mortality rates or rates of transplant success have not been reported for Acton's brittlebush, but at least one grower familiar with this species reported that transplanting was generally unsuccessful and resulted in mortality (Wallace 2023, personal communication).

Reported germination rates for Acton's brittlebush vary widely. A greenhouse study from 1937 reported a 32% germination rate for this species (Mirov and Kraebel 1937), which is similar to the 35% germination rate reported in a nursery setting by Joshua Tree National Park (Graham 2019, personal communication). Growers at the Mojave Desert Land Trust found that timing of sowing affected germination rate and reported a 78% germination rate for seeds sown in June but found germination rates reduced to 50% for seeds sown in October, and 40% for seeds sown in November. Based on these observations, they recommend sowing Acton's brittlebush seeds in the warmer months (Asbell 2022, personal communication). *Encelia* species exhibit quick germination, usually within four days to three weeks of planting, and are relatively easy to grow (Graham 2022, personal communication; Sturwold et al. 2022, personal communication).

Acton's brittlebush's high germination rate makes germination of G2 seeds in agricultural fields likely. Seeds from this species should be harvested quickly to prevent the establishment of a mixed generation crop (Brooks and Gault 2023, personal communication). Harvesting all seeds produced by a plant is not practical, so regular weeding of volunteer plants is probably necessary to prevent mixed generation fields. Preventing mixed generation fields is important to maintain the seed crop's suitability for seed certification and restoration use.

Figure 13: Acton's brittlebush seedlings in greenhouse production at Victor Valley College. Photo: Dolores Gault and Dakota Brooks

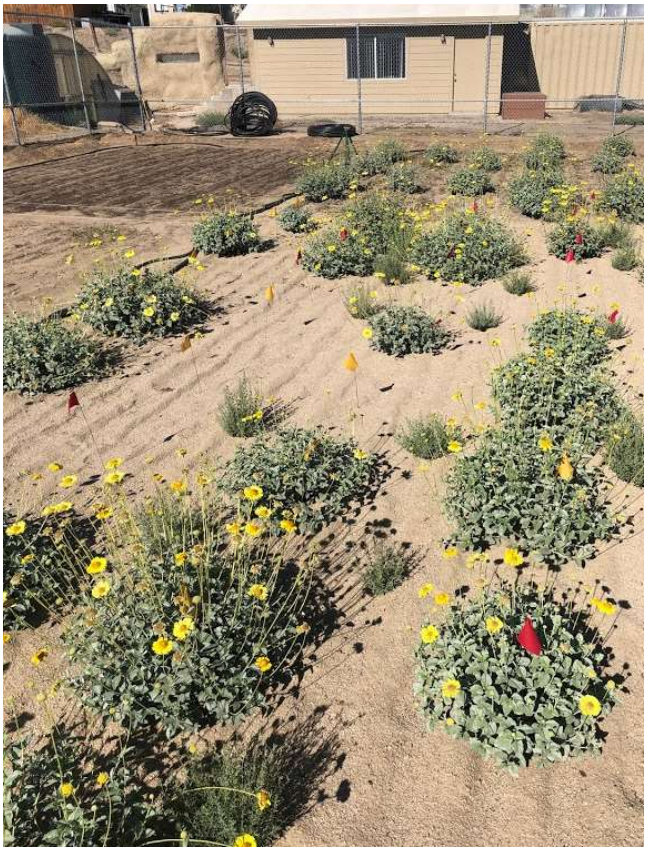

Figure 14: Acton's brittlebush in an experimental production field at Victor Valley College. Photo: Dolores Gault and Dakota Brooks

Weed Control.

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

Pest Management.

Growers reported very few issues with pests or disease in Acton's brittlebush. Chrysanthemum lacebugs (*Corythuca marmorata*) can cause heavy damage to Acton's brittlebush in the greenhouse (Figure 15). Lacebugs are usually found on the underside of the leaves (Figure 16). The initial infestation can be treated with pyrethrin, followed up with manual removal of any survivors as they are found (Asbell 2022, personal communication; Dial 2023, personal communication). Aphids and whiteflies are occasional problems in greenhouses but aren't reported to cause significant damage (Asbell 2022, personal communication; Thomas et al. 2022, personal communication; Graham 2022, personal communication; Sturwold et al. 2022, personal communication). Non-chemical treatments such as hand removal and rinsing insects from plants with water can be effective for controlling greenhouse pests at small scales (Thomas et al. 2022, personal communication). Chain link or chicken wire fences extending below ground can be used to keep burrowing animals out of fields (Brooks and Gault 2023, personal communication). Pest issues in agricultural fields are unknown, but research on defensive chemicals in Acton's brittlebush (see Parasites and Predation) suggests that this species has natural resistance to invertebrate herbivores (Srivastava et al. 1990).

Figure 15. Lacebug damage on an Acton's brittlebush leaf. Photo: Madena Asbell.

Figure 16. An adult lacebug (top) and lacebug eggs (bottom) on Acton's brittlebush. Photo: Madena Asbell

Pollination Management.

Growers did not describe specific pollinator management techniques for this species but given *Encelia* species ability to hybridize, it seems prudent to establish any Acton's brittlebush seed production beds far enough from other *Encelia* species to prevent cross pollination. California and Utah offer recommended isolation distances for growing *Encelia* species, but the distances recommended by California (60 feet) may be insufficient to prevent pollinator-facilitated gene flow between different source-identified Acton's brittlebush crops or related species. At least one grower reported using companion planting as a general technique to encourage pollinator visitation (Kleiner 2023, personal communication).

Irrigation.

Irrigation can help control phenological timing (Schaff 2023, personal communication). *Encelia* species generally do not require very much water, but supplemental watering is suggested for up to two years after outplanting at restoration sites or for landscaping (Graham 2022, personal communication; CNPS Calscape 2023). At Victor Valley College, fields of Acton's brittlebush are irrigated with microsprayers. This type of irrigation is more difficult to manage with perennial species like Acton's brittlebush and needs to be adjusted to the size of the plants. As plants get larger, water from microsprayers may not penetrate deep enough into the soil or spray the plant directly. In a small field watering can be monitored closely, but in larger fields, water sprayed on plants instead of the soil could result in seed damage among other concerns (Brooks and Gault 2023, personal communication).

Seed Harvesting.

Shrubs are often hand-harvested (Brooks and Gault 2023, personal communication; Schaff 2023, personal communication). Acton's brittlebush starts flowering in early spring and can produce seed throughout the year (Brooks and Gault 2023, personal communication). *Encelia* species may need to be harvested three to five times during the seeding period (Schaff 2023, personal communication). Cutting seedheads from Acton's brittlebush can stimulate the plants to reflower, and additional watering can also trigger flowering and seed production in this species (Brooks and Gault 2023, personal communication). The last harvest of the season can be mechanical, but this will result in collecting more immature seeds than hand-harvesting (Schaff 2023, personal communication). Operators of harvesting equipment should have experience with the target native plant species, as the plants can shatter and lose seed (Winters 2023, personal

communication). For species with wind dispersed seeds, wind conditions should also be monitored during the collection season to prevent interference with harvesting (Asbell 2023, personal communication). With hand harvesting methods, only 10-15% of available seed can typically be harvested (Schaff 2023, personal communication).

Seed Yields and Stand Life.

As with most perennials, seed production from Acton's brittlebush should not be expected in the first year. However, *Encelia* species produce seed relatively quickly for perennial shrubs (Sturwold et al. 2022, personal communication) and can be mature enough for good seed yield and production in two years (Schaff 2023, personal communication). While field longevity was not reported for *Encelia* species, they generally do not live longer than 30 years.

NURSERY PRACTICE

Encelia species have sturdy seedlings that propagate easily in a nursery setting (Graham 2022, personal communication; Figure 17). Acton's brittlebush is grown in nurseries for use in landscaping and restoration projects. Growing practices vary by grower and by planned end use of the plants.

Several growers recommended sowing seeds in the fall into flats or pots for later transplanting (Thomas et al. 2022, personal communication; Graham 2022, personal communication), but at least one grower recommended planting during the warmer months for higher germination rates (Asbell 2022, personal communication). If plants are being grown for restoration projects, seed can also be sown directly into the final container instead of transplanting seedlings from flats or small pots. Sowing plants in their final container helps grow healthier plants with stronger root systems for outplanting at a restoration site (Asbell 2022, personal communication). Acton's brittlebush seeds take between three days to three weeks to germinate and should be thinned after germination to reduce seedling competition if needed. Some growers reported better success when growing Acton's brittlebush outside in full sun instead of keeping them in a greenhouse (Thomas et al. 2022, personal communication). Growers all reported using their standard soil mix when growing Acton's brittlebush. Recommended standard soil mixes included two parts peat to one part perlite (Sturwold et al. 2022, personal communication), or for starting seeds in flats, three parts perlite to one part vermiculite and ¼ cup of slow-release fertilizer (Asbell 2022, personal communication).

Encelia species can be sensitive to overwatering. Watering recommendations vary from "as needed" to watering twice a month in the summer and once every three weeks in the winter and spring (Asbell 2022, personal communication; Graham 2022, personal communication). Growers used a combination of hand watering and drip irrigation (Graham 2022, personal communication; Sturwold et al. 2022, personal communication). However, for larger production fields, irrigation methods may need to be determined by available equipment (Winters 2023, personal communication).

Fall was recommended as the ideal time for outplanting because it allows the plants sufficient time to establish before the hot summer months (Graham 2022, personal communication; Sturwold et al. 2022, personal communication). However, timing of outplanting is often constrained by personnel needs and is frequently done in the spring when volunteers are more readily available (Graham 2022, personal communication).

Acton's brittlebush does not require any seed pre-treatments for germination but see Seed Pre-treatments for further details, and Establishment and Growth for ages for transplanting and outplanting.

Figure 17: Acton's brittlebush seedlings in cultivation. Photo: Dr. Mark S. Brunell

REVEGETATION AND RESTORATION

Acton's brittlebush has a variety of applications in revegetation and restoration. *Encelia* species are showy, so often sought after for projects like roadside revegetation. CalTrans currently uses Acton's brittlebush in revegetation projects at higher elevations in the Mojave Desert, where it is better suited than the more commonly used brittlebush (*Encelia farinosa*) (Kleiner 2023, personal communication). One rangeland study found that brittlebush (*E. farinosa*) could outcompete the introduced invasive species buffelgrass (*Pennisetum ciliare*) in the Sonoran Desert (Tesky 1993), so testing if Acton's brittlebush could also compete against introduced species may be fruitful.

Wildland Seeding and Planting.

Wildland Seedings.

There is no information on direct seeding Acton's brittlebush for wildland restoration. However, *Encelia* species, including Acton's brittlebush, appear to mainly recolonize disturbed areas by seed (Disturbance Ecology) and therefore could potentially be established by direct seeding.

Wildland Plantings.

Plants are on average released for outplanting at restoration sites 16 months after sowing but have been outplanted for restoration as early as ten months after sowing (Graham 2019, personal communication).

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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/

AUTHORS

Molly S. Wiebush, Conservation Research Ecologist, Institute for Applied Ecology, Corvallis, OR| mollywiebush@appliedeco.org

Ashlee Wolf, Ecologist, Institute for Applied Ecology, Tucson, AZ | ashleewolf@appliedeco.org

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