Virgin River Brittlebush

Encelia virginensis A. Nelson

Asteraceae - Sunflower family

Ashlee Wolf and Molly Wiebush |2023

ORGANIZATION

NOMENCLATURE

Virgin River brittlebush (*Encelia virginensis* A. Nelson) is a member of the Heliantheae tribe of the Asteraceae family, and in the californica clade of the genus *Encelia* (Clark 1998, Fehlberg and Ranker 2007, Singhal et al. 2021).

NRCS Plant Code.

ENVI (USDA NRCS 2023).

Synonyms.

Encelia frutescens var. *virginensis* (A. Nelson) S. F. Blake, *Encelia virginensis* var. *virginensis* A. Nelson (ITIS 2023).

Common Names.

Virgin River brittlebush, Virgin River Encelia (ITIS 2023, USDA NRCS 2023).

Subtaxa.

There are no subtaxa recognized by the Flora of North America or the Integrated Taxonomic Information System (Clark 2020, ITIS 2023).

Chromosome Number.

The chromosome number for Virgin River brittlebush is 2n=36 (Clark 2020, CCDB 2023). Variation in chromosome number has not been documented in *Encelia* species.

Hybridization.

All *Encelia* species are obligate outcrossers, and natural hybrids are frequently documented where

species co-occur (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 all following generations or backcrosses are also fertile (Clark 1998, Fehlberg and Ranker 2007, DiVittorio et al. 2020, Singhal et al. 2021). However, hybrid offspring are rarely found in the wild and usually only 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).

Virgin River brittlebush is likely of hybrid origin, the result of a cross between *E. actoni* and *E. fructescens* subsp. *fructescens*. Virgin River brittlebush is often indistinguishable from *E. actoni* x *E. fructescens* hybrids, and measurements of several morphological characters (such as leaf hairs) from both Virgin River brittlebush and *E. actoni* x *fructescens* hybrids are very similar (Ehlringer and Clark 1987, Clark 1998). Virgin River brittlebush also has significant genetic overlap with both its suspected parent species. Evidence for Virgin River brittlebush being a species and not a named hybrid includes the presence of true-breeding populations of Virgin River brittlebush more than 100 km from the nearest populations of *E. actoni* or *E. fructescens* (Clark 1998).

DESCRIPTION

Virgin river brittlebush is a perennial shrub growing 50-150 cm tall (Figure 1). The slender stems branch at the base, develop fissured bark, and are covered in simple spreading hairs when young (Clark 2020).

Figure 1: A prolifically flowering Virgin River brittlebush individual. Photo: BLM SOS CA930A

The leaves are gray-green, folded on the midvein, and narrowly ovate to deltate in shape with sparse canescent or strigose pubescence on the leaf faces (Clark 2020, SEINet 2023). Composite flower heads are borne singly on stems with canescent peduncles (Figure 2). The ray flowers are yellow, 8-15mm long, and number 11-21. The yellow disc flowers are 5-6 mm long. All *Encelia* species in the *californica* clade have corollas that reflect ultraviolet light (Clark and Sanders 1986, Ehleringer and Cook 1987). The involucres are 9-13 mm long with narrowly ovate phyllaries. The fruit is a cypsela, 5-8 mm in length, generally lacking pappus but rarely with 1-2 bristly awns.

Figure 2: The composite head of Virgin River Brittlebush. Photo: Patrick Alexander

DISTRIBUTION AND HABITAT

Virgin River brittlebush is found most frequently in the Mojave Desert with sporadic occurrences in adjacent ecoregions including the Southern Great Basin, Arizona/New Mexico Mountains, Sonoran Desert, Madrean Archipelago and Colorado Plateau. Records from herbarium specimens and verified observations are most dense in the eastern Mojave Desert (Figure 3).

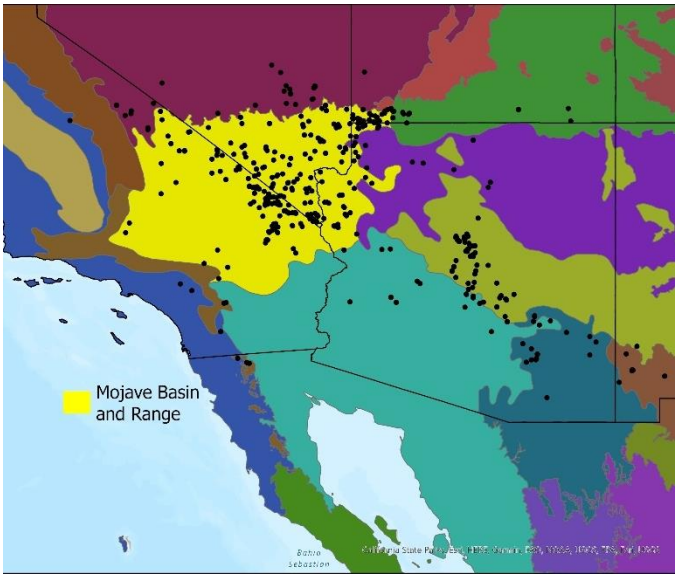

Figure 3: Distribution of Virgin River brittlebush (black circles) from georeferenced herbarium specimens and verified observations (SEINet 2022) with EPA Level III Ecoregions. The Mojave Basin and Range ecoregion is shown in yellow.

Habitat and Plant Associations.

Virgin River brittlebush grows in intermittently flooded washes, canyons, scree slopes, and washes adjacent to alluvial fans, road cuts, and other areas with regular or recent disturbance (NatureServe 2023).

NatureServe describes one Alliance (Acton's Brittlebush - Virgin River Brittlebush - Netvein Goldeneye Desert Scrub Alliance) and one Association (Virgin River Brittlebush Shrubland) defined by the presence of Virgin River Brittlebush (at least 2% absolute cover in the shrub canopy with no other species with equal or greater cover). Both the alliance and the association are classified as Vulnerable in the state of California (NatureServe 2023).

Figure 4: Virgin River brittlebush growing in open desert scrub in Utah. Photo: BLM SOS UT930

Figure 5: Virgin River brittlebush growing on gravelly slopes in a Joshua Tree and desert scrub community in Nevada. Photo: BLM SOS NV040

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). 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 Virgin River brittlebush occurs (Shryock et al. 2018; Table 1). According to herbarium specimen locations (SEINET 2022), Virgin River brittlebush has been documented in all PSZs in the Mojave Desert ecoregion except Zones 27 and 28, which have the lowest annual average precipitation. Records are most abundant in Zone 22 and 29 and least abundant in Zone 24 (Table 1). The average annual precipitation in the PSZs where Virgin River brittlebush occurs in the Mojave Desert ecoregion is 20 cm (7.9 inches), with an average of 6.4 cm (2.5 inches) falling in the summer and an average of 13.6 cm (5.4 inches) falling in the winter. Note, herbarium specimen locations may not represent the full distribution and abundance of Virgin River brittlebush due to sampling biases.

Elevation.

Virgin River brittlebush grows at elevations of 500-1500 m (1650-4921 ft).

Soils.

Virgin River brittlebush grows in a variety of soil textures ranging from sand to loam. The soils are typically calcareous alluvium but may be derived from other substrates including rhyolite and granite (SEINet 2022, NatureServe 2023).

Table 1: Climate of the provisional seed zones (PSZ) where Virgin River brittlebush occurs within the Mojave Desert ecoregion (Shryock et al. 2018), showing the number of herbarium records or verified observations 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)
21	113	15.6	6.2	9.4	18.8	38.4
23	89	15.8	5.4	10.4	16.1	35.9
20	71	25.5	10.5	14.9	15.3	34.5
25	49	16.5	6.2	10.3	18.9	34.6
24	21	10.7	2.8	7.9	18.8	38.6
26	7	14.5	2.7	11.8	16.8	34.9
29	4	25.5	4.2	21.4	13.8	31.7
22	1	36.1	13.3	22.8	10	32.4

ECOLOGY AND BIOLOGY

Encelia species bloom abundantly, and thus are potentially an important resource for pollinators (Sturwold et al. 2022, personal communication). Virgin River brittlebush can survive freezing temperatures (Singhal et al. 2021). NatureServe classifies this species as Vulnerable (G3) (NatureServe 2023).

Reproduction.

Breeding System.

Virgin River 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.

Virgin River brittlebush flowers from April to June but can flower opportunistically in response to rainfall (Clark 2020). Seeds typically mature between May and June (BLM SOS 2022).

Pollination.

Documented floral visitors include a wide variety of insects, including flies, bees, butterflies and moths, true bugs, and beetles (Simpson and Neff 1987). Hurd and Linsley (1975) reported that bees of the genera *Anthidium*, *Colletes*, and *Megandrena* visit *Encelia* species.

Seed and Seedling Ecology.

Virgin River brittlebush seeds are likely wind-dispersed, as they easily blow off the plant at maturity (Rodgers and Miller 2008). *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 Virgin River 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). Virgin River brittlebush reestablishes from seed in burned areas in the Mojave Desert (Lei 1999).

There is little information available on seed predation for Virgin River brittlebush. However, other *Encelia* species have documented seed predators. Kangaroo rats (*Dipodomys* spp.) eat brittlebush (*E. farinosa*) seeds, though they do not prefer them (Tesky 1993). Both ants and rodents have been observed removing and caching brittlebush seeds from restoration sites (DeFalco et al. 2012). While these interactions are not reported for Virgin River brittlebush, it is possible that the species has similar relationships with seed predators and dispersers.

Species Interactions.

Belowground Interactions.

Although there is no literature indicating Virgin River brittlebush's associations with arbuscular mycorrhizal fungi (AMF) or other belowground organisms, other *Encelia* species associate with AMF (Valencia 2009).

Insect Interactions.

Virgin River brittlebush is a likely larval host plant for the fatal metalmark (*Calephelis nemesis*), orange totrix moth (*Argyrotaenia franciscana*), and the dwarf tawny wave (*Cyclophoro nanaria*) (Calscape 2023).

Wildlife and Livestock Use.

Virgin River brittlebush is among several *Encelia* species used for cover by the endangered Mojave desert tortoise (*Gopherus agassizii*) (Drake et al. 2015). Although Virgin River brittlebush is not specifically noted as a food plant for tortoises, Button brittlebrush (*E.*

frutescens) was eaten by captive tortoises in trace amounts (Drake et al. 2015).

Chuckwallas (*Sauromalus obesus)* eat the leaves of Virgin River brittlebush (Sanborn 1972).

Disturbance Ecology.

Virgin River brittlebush is considered an early seral, pioneer species in post-fire vegetation communities. Other *Encelia* species in the Mojave Desert are noted to persist or quickly establish in a variety of disturbance types including flooding, fire, and soil disturbance (Brown and Minnich 1986, Prose et al. 1987, Buck-Diaz and Evens 2011). Virgin River brittlebush is associated with habitats that are defined by regular soil disturbances such as flooding in intermittent drainages or erosion on steep rocky slopes (NatureServe 2023). Several herbarium records indicate that the shrub can grow with invasive species including annual bromes (*Bromus* spp.) in post-fire habitats (SEINet 2022).

Due to the shrub's structure, with many fine branches close to the ground, Virgin River brittlebush generally burns to the ground in fires (Brown and Minnich 1986). However, it can resprout or produce seedlings fairly rapidly after fire damage (Lei 1999). In blackbrush (*Coleogyne ramosissima*) shrublands in the Mojave Desert, Virgin River brittlebush was found to have significantly higher density in burned compared to unburned sites following several different fire events (Lei 1999). Open stands of snakeweed (*Gutierrezia sarothrae*) and Virgin River brittlebush replaced blackbrush stands after fire disturbance (Lei 1999). Soil seed density of Virgin River brittlebush was significantly higher in burned areas compared to adjacent unburned areas in southern Nevada (Lei 2001).

Ethnobotany.

There are no reported ethnobotanical uses of Virgin River brittlebush, though other *Encelia* species have uses.

Horticulture.

Although Virgin River brittlebush would make a nice addition to a xeriscape pollinator garden, it does not appear to be commonly available at retail nurseries for horticultural or landscaping use (Calscape 2023).

DEVELOPING A SEED SUPPLY

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

Seed Sourcing.

Seed sourcing can influence restoration outcomes due to local adaptation (Custer et al. 2022), landscape genetic patterns (Massatti et al. 2020, Shryock et al. 2021) and differing ability to adapt to current and future climate conditions (Bucharova et al. 2019). However, there has been relatively little research evaluating seed sourcing strategies in actual restoration settings

where many additional factors influence performance (Pizza et al. 2023). While non-local sources can perform well in meeting initial restoration goals such as establishment and productivity (Pizza et al. 2023), 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 Virgin River 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 8). 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 guide seed sourcing according to current and projected climate conditions.

Commercial Seed Availability and Germplasm Releases.

Seed for this species does not appear to be commonly available commercially, and there have been no conservation plant releases for Virgin River brittlebush.

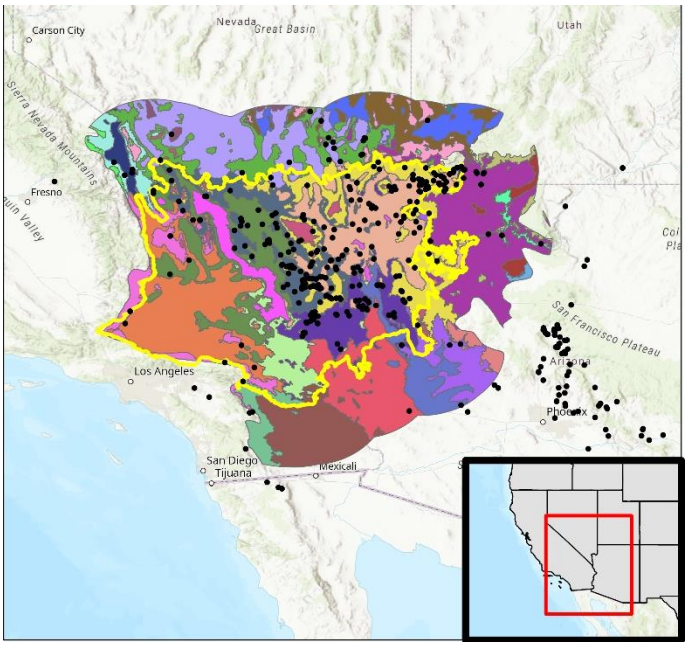

Figure 6: The distribution of documented Virgin River brittlebush (black dots) across the Desert Southwest Provisional Seed Zones (Shryock et al. 2018). Occurrences are based on georeferenced herbarium specimens and verified observations (SEINet 2022). The Mojave Basin and Range Level III ecoregion (yellow outline) is buffered up to 100km in all directions. PSZs do not always extend a full 100km beyond the Mojave ecoregion.

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.

In the Mojave Desert, Virgin River brittlebush is typically collected between April and June with the majority of collections occurring in May (BLM SOS 2022).

Figure 7: Virgin River brittlebush with a seed head ripe for collection. Photo: BLM SOS AZ010

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. Recommended hand collection methods for Virgin River 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; Devitt 2023, personal communation).

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.

Seeds from plants in the sunflower family can be difficult to process. In general, fertile seeds will separate easily from the flower head compared to infertile or parasitized seeds, which will not come free easily (Wall and MacDonald 2009; Asbell 2022, personal communication).

Virgin River brittlebush seeds should be completely dry before processing. To clean, seed material can be removed 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).

Relative difficulty of processing *Encelia* seeds may depend on collection methods. 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). 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 (Brooks and Gault 2023, personal communication).

Figure 8: Virgin River brittlebush seeds with a whole seed head, bare seeds, and some chaff, scale shown in cm. Photos: BLM SOS CA930A

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).

Virgin River brittlebush, like all *Encelia* species, has orthodox seed. It showed no reduction in viability after fourteen years of storage at -15 °C at the Kew Botanical Gardens (SER SID 2023). Seed pests and fungus were not reported as issues for *Encelia* species (Graham 2022, personal communication), and diseased seeds are generally easy to distinguish because they stick to the flower head in clumps instead of separating easily from the plant (Asbell 2022, personal communication).

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 AOSA includes *Encelia* species in its tetrazolium testing protocols for the Asteraceae family. These methods involve imbibing seeds overnight at 20-25 °C (68-77 °F), then cutting seeds longitudinally and placing them in a 0.1% tetrazolium solution for 6 hours to overnight at 30-35 °C (86-95 °F). Viability can then be

quantified by assessing the percentage of seeds with embryos that are either evenly stained or have more than half of their cotyledons stained (AOSA 2010).

Wildland Seed Yield and Quality.

Wild-collected Virgin River brittlebush seed is generally high quality, with an average of 90% fill, 90% purity and 93% viability indicated by tetrazolium tests across 20 Seeds of Success collections (BLM SOS 2022, Table 2). Wild collections contain an average of over 188,000 PLS/lb (BLM SOS 2022, Table 2).

Table 2: Virgin River 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)	0.68	0.22-1.95	20
Clean Weight (lbs)	0.14	0.013-0.385	20
Purity (%)	90	51-99	20
Fill (%)	90	72-99	20
Viability (%)	93	82-98	20
Pure live seeds/lb	188,515	99,474-426,199	20

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

Virgin River brittlebush will likely grow best in full sun and well-draining soils. This species is not commonly grown for seed increase in agricultural settings, and practices are still under development. However, techniques from the more commonly grown brittlebush may also apply.

Agricultural Seed Field Certification.

As with wildland source seed (see Wildland Seed Certification section), seed grown in an agricultural seed increase field must also be certified by an official seed certifying agency, where programs exist. Field grown seed is also certified and labeled as Source-Identified (SI), as long as it has not undergone selective breeding or testing. Seed field certification includes field inspection, seed testing for purity and germination (see Seed Testing section), and proof of certification for all source or parent seed used to start the field (AOSCA 2022). The SI-label or "yellow tag" for seed from a seed increase field denotes information about source seed, field location, and generation level (G1-Gx) indicating if there is a species-specific limitation of generations allowed to be grown from the original source (e.g., in a species with a three-generation limit, G1/G3, G2/G3, G3/3) (AOSCA 2022).

Table 3 outlines the pre-variety germplasm certification standards for Virgin River brittlebush seed in the state of California (CCIA 2022). The Nevada and Arizona Departments of Agriculture do not specify standards for PVG crops. The Utah Crop Improvement Association does not specify standards for PVG crops, but may apply standards of similar species or crop groupings (UCIA 2023).

Table 3: Pre-varietal germplasm (PVG) standards for seed analysis results of Virgin River brittlebush seed increase crops in California.

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

Isolation Distances.

Sufficient isolation distances are required to prevent cross-pollination across seed production crops. California standards are described specifically for Virgin River brittlebush, while the Utah standards are general for outcrossing perennial species (Table 4; UCIA 2023). Nevada and Arizona do not specify these standards for Source Identified PVG seed.

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

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

Site Preparation.

Fields should be as weed-free as possible prior to planting. Site preparation to reduce undesirable vegetation should be planned and implemented well in advance of field establishment (USDA NRCS 2004). If fields are uncultivated or fallow and have perennial or annual weeds, one or more years of intensive cultivation (e.g., 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). Pre-emergent herbicides may be useful if planting plugs but should not be used for direct seeding.

Seed Pre-treatments.

While there is little information on germinating Virgin River brittlebush, the more common brittlebush can germinate readily with no pre-treatments (Plath 2023, personal communication), although seed pre-treatments may improve germination. Soaking seeds in gibberellic acid, a commonly used germination stimulant, has been shown to improve germination (Padgett et al. 1999, Graham 2019). However, some growers have reported no success with gibberellic acid (Schaff 2023, personal communication). Cold stratification and seed coat removal can also increase germination rates (CalBG 2023, SER SID 2023).

Seeding Techniques.

Seeding in the fall allows for maximum root growth during the winter and early spring months (Drennan and Nobel 1996). At least one grower reported direct seeding to be unsuccessful with other *Encelia* species, and recommended planting from plugs instead (Schaff 2023, personal communication). In general, plug planting may be more effective than direct sowing when there is a limited amount of seed available, if seed has low viability, or if the seed lot has weed seed contaminants that can be more easily weeded out in a nursery (Winters 2023, personal communication).

Establishment and Growth.

No specific information on establishment and growth of Virgin River brittlebush seed increase crops was found in the literature or through personal communication.

Weed Control.

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

Pest Management.

Growers reported very little issues with pests or disease in *Encelia* species. However, Chrysanthemum lacebugs (*Corythuca marmorata*) can cause heavy damage to brittlebush in greenhouses. These insects are usually found on the underside of the leaves. 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). 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).

Pollination Management.

Growing native plants in or near their native range increases the likelihood that compatible pollinators will be able to find and pollinate the crop (Cane 2008). In general, growers can implement pollinator management and stewardship practices to augment and attract existing pollinator communities. Specific practices will depend on the plant species' pollination needs, and the biology of the pollinators. For example, if a plant relies on native solitary bees, growers can create nesting opportunities adjacent to or within the field perimeter with downed woody material or crafted bee boxes (Cane 2008, MacIvor 2017).

Irrigation.

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 flood irrigation does not adequately penetrate the soil in arid growing conditions (Hagman 2023, personal communication).

Seed Harvesting.

Seeds are typically hand-harvested and possibly up to five times per season (Brooks and Gault 2023, personal communication, Schaff 2023, personal communication). *Encelia* seeds can shatter, so if harvesting equipment is used only experienced operators should be employed (Winters 2023, personal communication). Windrowing and direct combine harvest are not recommended for Encelia species (Schaff 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 Virgin River 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). Most 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 plants with stronger root systems (Asbell 2022, personal communication).

It is important to maintain a dry soil surface in the greenhouse when starting Encelia species. If the soil surface is too damp, 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). *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).

Virgin River brittlebush was grown from Mojave Desert wild-collected seed in a nursery for a restoration project at the Beaver Dam National Conservation Area. Seed was sown in March in 4-liter pots with a soil medium of 10% compost and 90% wash sand. The pots were placed in a greenhouse and watered daily until June, when they were moved to an outdoor shade structure with 30% solar reduction. Plants were watered with a sprinkler system as needed when they showed signs of visible stress. The plants flowered in the nursery and were transplanted into a restoration site in November (Devitt et al. 2020).

REVEGETATION AND RESTORATION

Virgin River brittlebush has not been commonly used in revegetation and restoration projects (Devitt et al. 2020) and there has not been a historic demand for this species (Kleiner 2023, personal communication). However, its ability to establish after disturbance and support a variety of ecosystem functions makes Virgin River brittlebush a priority species for native plant materials development and restoration in the Mojave Desert.

Wildland Seeding and Planting.

Wildland Seedings.

No instances of wildland seedings using Virgin River brittlebush were found in the literature or through personal communication.

Wildland Plantings.

Encelia species generally do not require much water, but supplemental watering is suggested for up to two years after outplanting at restoration sites to support establishment (Graham 2022, personal communication; CNPS Calscape 2023).

Virgin River brittlebush was planted in the Beaver Dam Wash National Recreational area (southern Utah) to address poor recruitment of shrubs after a fire occurred over 10 years prior to the study (Devitt et al. 2020). Virgin River brittlebush was planted in the fall across a soil hydrological gradient, which was determined based on elevation and slope. Plants were planted on the sidewall slopes and adjacent to the central wash. To assess techniques for promoting plant establishment, plants were either caged, received hydrogel (a mixture of potassium polyacrylate polymer and water injected into the soil to reach

the root area), cages and hydrogel, or no treatments. Survival was initially high, with cage plus hydrogel treatment maintaining 100% survival by day 214. Survival declined quickly thereafter, reaching an overall rate of 24% after 30 months. However, the cage plus hydrogel treatment had 43% survival while the central wash locations had survival as low as 9%. Ninety-six percent of flowers and 72% of seeds were produced in the upper headwater locations with 89 percent of flowers produced in the fencing plus hydrogel treatment. (Devitt et al. 2020).

Virgin River brittlebush was also outplanted from container stock to revegetate a strip mine and tailings area in the Mojave Desert (Rodgers 1994). The container stock was propagated from locally collected seed. The outplanted shrubs had greater than 90% survival rate in the first several months following planting (Rodgers 1994). However, no subsequent monitoring results were reported.

ACKNOWLEDGEMENTS

Funding for *Mojave Desert Native Plants* was provided by the Bureau of Land Management, Mojave Native Plant Program. The conceptual framework and design of *Mojave Desert Native Plants* was developed by Corey Gucker and Nancy Shaw in Western Forbs: Biology, Ecology, and Use in Restoration. Cierra Dawson and Brooke Morrow developed maps and summarized data for climate, seed collection, and seed certification sections. We are grateful to Dolores Gault and Dakota Brooks (Victor Valley College); Madena Asbell (Mojave Desert Land Trust); Jean Graham (Joshua Tree National Park); Amy Johnson (Las Vegas State Tree Nursery); Ed Kleiner (Comstock Seeds); Victor Schaff; Lou Thomas, Paul Sturwold, Shanna Winters, Lexi Beaty, Mack Nash, Mark Reeder, and Jose Marfori (The Living Desert Zoo and Gardens); Heather Dial (Natural Resources Conservation Service); Steve Plath (Desert Seed Resource Center; Tren Hagman (Granite Seed); and Damon Winters (L&H Seed) for providing information on their experience working with Virgin River brittlebush and related Mojave Desert species. Scott Harris (IAE) and Dale Devitt (University of Nevada, Las Vegas) provided content review. Thank you to Judy Perkins (BLM) for coordination, content review, and initiating this project.

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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://doi.org/10.5066/P9BQ6IYJ

MOJAVE SEED MENUS

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

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Ashlee Wolf; Molly S. Wiebush. 2023. Virgin River Brittlebush (*Encelia virginensis*). In: Mojave Desert Native Plants: Biology, Ecology, Native Plant Materials Development, And Use in Restoration. Corvallis, OR: Institute for Applied Ecology. Online: https://www.blm.gov/programs/natural-resources/native-plant-communities/native-plant-and-seed-material-development/ecoregional-programs

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