YELLOW CUPS

Chylismia brevipes (A. Gray) Small

Onagraceae- Evening Primrose Family

Ashlee Wolf |2023

ORGANIZATION

NOMENCLATURE

Yellow cups (*Chylismia brevipes* (A. Gray) Small) is in the evening primrose family, or Onagraceae (USDA NRCS 2023).

According to taxonomic revisions based on molecular analyses within the Onagraceae family, yellow cups is best classified in the genus *Chylismia* (Wagner et al. 2007). However, the U.S. Department of Agriculture uses *Camissonia brevipes* (A. Gray) P.H. Raven as the nomenclature for yellow cups (USDA NRCS 2023). Flora of North America (FNA) and the Integrated Taxonomic Information System (ITIS) list *Chylismia brevipes* as the currently accepted name for yellow cups (Wagner 2022, ITIS 2023). This account uses the FNA classification.

NRCS Plant Code.

CABR23 (USDA NRCS 2023).

Synonyms.

Oenothera brevipes, Oenothera divaricata, Oenothera pallidula, Oenothera brevipes var. *pallidula, Oenothera brevipes* subsp. *pallidula, Oenothera brevipes* subsp. *arizonica, Camissonia brevipes, Camissonia brevipes* subsp. *arizonica, Camissonia brevipes* subsp. *pallidula* (Tropicos 2023).

Common Names.

Golden beeblossom, yellow cups, sun cups, golden suncup (SEINet 2023).

Subtaxa.

The FNA and the ITIS recognize three subspecies in the *Chylismia brevipes* classification:

- *C. brevipes* subsp. *arizonica*
- *C. brevipes* subsp. *brevipes*
- *C. brevipes* subsp. *pallidula*

Chromosome Number.

The chromosome number for yellow cups is 2n=14 (Wagner 2012).

Hybridization.

There may be a limited amount of natural hybridization between yellow cups and co-occurring subspecies of the related *Chylismia claviformis* (Raven 1962). Generally, the *Chylismia* genus is thought to be a hybrid complex that diverged via rapid evolutionary radiation resulting from uplift of the Sierra Nevada and increasing aridity in the Great Basin Region (Raven and Cleland 1963).

DESCRIPTION

Yellow cups is an annual forb comprised of basal leaves and branching flowering stalks rising to 3-75 cm in height (Wagner 2022). Plants are covered in strigose (stiff, adpressed) or spreading hairs (SEINet 2023). The leaves are mostly basal and can be simple or pinnately lobed, with mixed leaf shapes occurring within individual plants (Wagner 2022). The flowers, which open at dawn, occur on racemes with nodding pedicels. The sepals are 5-9 mm long and the bright yellow petals are 3-18 mm long. The petals can sometimes have red dots at the base and fade to orange or reddish (Wagner 2012). The oblong-cylindrical capsules (18-92 mm in length) are ascending or spreading and contain tan seeds (1-1.5 mm in length).

Figure 1: A yellow cups individual. Photo: BLM SOS CA930A

Figure 2: The raceme inflorescence of yellow cups. Photo: BLM SOS CA690

Varieties or Subspecies.

According to the FNA treatment (Wagner 2022), the yellow cups subspecies are described as follows:

C. brevipes subsp*. arizonica* is distinguished by having flower buds that are individually reflexed and petals that fade to a reddish color. The other two subspecies, described below, have flower buds that are not individually reflexed and have petals that fade to yellow or orange.

C. brevipes subsp. *brevipes* is stout in stature, villous, and with flower buds with subapical free tips (1-2 mm).

C. brevipes subsp. *pallidula* is slender, usually with stiff, slender bristles on herbage, flower buds with subapical free tips (0-1 mm), and petals often with red dots near the base.

DISTRIBUTION AND HABITAT

Yellow cups primarily occurs in the Mojave and western Sonoran Deserts in California, Nevada, Utah, and Arizona (Figure 3). Sporadic occurrences extend to adjacent ecoregions including the Arizona-New Mexico Mountains, Colorado Plateau, Arizona-New Mexico Plateau, and Central Basin and Range (Great Basin).

Habitat and Plant Associations.

Yellow cups grows in dry desert washes, plains, and slopes in creosote bush (*Larrea tridentata*) scrub and Joshua tree (*Yucca brevifolia*) woodlands (SEINet 2022, Wagner 2022).

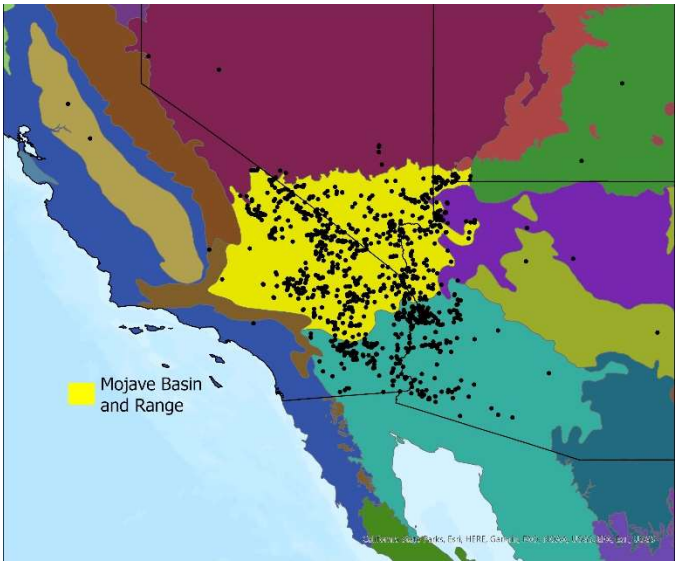

Figure 3: Distribution of yellow cups based on georeferenced herbarium specimens and verified observations (black circles, SEINet 2022) with EPA Level III Ecoregions (US EPA 2015). The Mojave Basin and Range ecoregion is shown in yellow.

Common associated species in the Mojave Desert include creosote bush (*Larrea tridentata*), (*Ambrosia dumosa*), brittlebush (*Encelia farinosa*), Mexican bladdersage (*Salazaria mexicana*), Mojave yucca (*Yucca schidigera*), blackbrush (*Coleogyne ramosissima*), and littleleaf ratany (*Krameria erecta*). It is often recorded with other co-blooming annual species including bristly fiddleneck (*Amsinckia tesselata*), desert chia (Salvia columbariae), cryptantha (*Cryptantha* spp.), pincushion flower (*Chaenactis fremontii*), and smooth desert dandelion (*Malacothrix glabrata*) (SEINet 2022).

Figure 4: Yellow cups in a sandy wash in California. Photo: BLM SOS CA930A

Figure 5: Yellow cups growing on a gravelly slope in California. Photo: BLM SOS CA930A

Climate.

The Mojave Desert is characterized by low annual precipitation (5-25 cm or 2-10 inches in valley areas), with most rainfall occurring in the winter and a smaller amount during summer thunderstorms (Randall et al. 2010). Heterogenous climate patterns across the region are influenced by large-scale patterns and regional topography and are important drivers of local adaptation and intraspecific variation (Shryock et al. 2018, Baughman et al. 2019) and phenological events (Beatley 1974). Specifically, the reproductive phenology of many desert plant species is highly responsive to pulses in rainfall over short time scales (Bowers and Dimmitt 1994, Zachmann et al. 2021).

Climate information is derived from the climate-based provisional seed transfer zones (PSZs) where yellow cups occurs (Shryock et al. 2018; Table 1). According to herbarium specimen locations (SEINET 2022), yellow cups occurs in all PSZs in the Mojave Desert ecoregion but is most abundant in Zones 21 and 24 and least abundant in Zone 22 (Table 1). The average annual precipitation in the PSZs where yellow cups occurs in the Mojave Desert ecoregion is 17.8 cm (7.0 inches), with an average of 5.7 cm (2.2 inches) falling in the summer and an average of 12 cm (4.7 inches) falling in the winter. Note, herbarium specimen locations may not represent the full distribution and abundance of yellow cups due to sampling biases and ephemerality of this desert annual which often does not emerge in dry years.

Table 1: Climate of the provisional seed zones (PSZ) where yellow cups occurs within the Mojave Desert ecoregion (Shryock et al. 2018).# = the number of herbarium or verified observations of yellow cups within the PSZ (SEINet 2022); MAP=mean annual precipitation; SP=summer precipitation, or the mean precipitation that falls in the summer (May-October); WP= winter precipitation, or the mean precipitation that falls in the winter (November-April); MAT=monthly average temperature; Range= Average of the monthly temperature ranges (monthly maximum minus monthly minimum).

PSZ	#	MAP (cm)	SP (cm)	WP (cm)	MAT (C)	Range (C)
24	221	10.7	2.8	7.9	18.8	38.6
21	220	15.6	6.2	9.4	18.8	38.4
26	114	14.5	2.7	11.8	16.8	34.9
23	97	15.8	5.4	10.4	16.1	35.9
25	96	16.5	6.2	10.3	18.9	34.6
27	86	9.6	3.3	6.3	20	36.7
28	72	7.8	2.4	5.3	22.3	41.3
20	41	25.5	10.5	14.9	15.3	34.5
29	28	25.5	4.2	21.4	13.8	31.7
22	1	36.1	13.3	22.8	10	32.4

Elevation.

Yellow cups is generally found at elevations below 4,500 ft (1371 m) (SEINet 2023).

Soils.

Yellow cups grows in well-draining soils (Calscape 2023), generally with gravelly, sandy, or rocky surface textures derived from a variety of parent materials. Limestone is a frequently recorded parent rock but volcanic formations are also noted with herbarium specimens (SEINet 2022). No associations with biological soil crusts were noted in the literature.

ECOLOGY AND BIOLOGY

In general, winter annuals are estimated to make up at least 40% of the Mojave Desert flora (Johnson et al. 1978) and fill an important niche by providing pollinator and wildlife forage, ground cover, and potential competition for invasive annual grasses (Brooks 2000, Esque et al. 2021). While yellow cups typically makes up a small portion of the annual plant community, it serves as a nectar source for a unique subgenus of pollinators and as a diet plant for the endangered desert tortoise (*Gopherus agassizii*). Yellow cups was included as an indicator species to objectively define and analyze patterns of "good wildflower years" in the Mojave and Sonoran Deserts (Bowers 2005). NatureServe classifies yellow cups as Apparently Secure (G4) on a global level, but it is considered Critically Imperiled (S1) in Utah and Vulnerable (S3) in Arizona (NatureServe 2023). NatureServe ranks each subspecies as follows:

- ssp. *brevipes* is ranked as Apparently Secure (T4) globally and Vulnerable (S3) in Arizona. It is not ranked in California, Nevada, or Utah.
- ssp. *arizonica* is ranked as Imperiled globally and Critically Imperiled (S1) in Arizona. It is not ranked in California.
- ssp. *pallidula* is ranked as Apparently Secure (T4) globally. It is ranked as Critically Imperiled (S1) in Utah and Imperiled (S2) in Arizona. It is not ranked in California or Nevada.

Reproduction.

Breeding System.

Yellow cups is self-incompatible and relies on insect pollination to reproduce (Raven 1962).

Reproductive Phenology.

Yellow cups flowers February to May (SEINet 2023). Flowers typically open about two hours before sunrise (Raven 1962) and stay open for more than four days when not fertilized (Gerst 2011). Fruits mature from May to June. Fruits that mature later in the season can have higher numbers of seeds per fruit compared to those that mature early in the season (Gerst 2011).

Pollination.

Yellow cups is pollinated by a wide variety of bees including those in the genus *Andrena*, subgenus *Onagrandrena*, which are active in the hours immediately before and after sunrise (Raven 1962).

Seed and Seedling Ecology.

As a winter annual in the Mojave Desert, yellow cups germinates after winter rains and completes its life cycle by the following spring (Gerst 2011). No information on seed bank longevity, germination patterns and conditions, granivory, seedling hardiness, or other aspects of this species seed and seedling ecology was found in the literature or through personal communication.

Species Interactions.

Belowground Interactions.

No literature about the relationship between yellow cups and belowground organisms was found.

Parasites and Predation.

Yellow cups is a likely larval host plant for the Pacific green sphinx moth (*Proserpinus lucidus*) and the phaeton primrose sphinx moth (*Euproserpinus phaeton*) (Calscape 2023). White-lined sphinx moth (*Hyles lineata*) larvae consume leaf, stem, flower and fruit tissues, sometimes consuming entire plants (Gerst 2011).

Wildlife and Livestock Use.

Yellow cups has been recorded in the diets of the endangered Mojave desert tortoise in the northeastern Mojave Desert (Esque 1994). In a diet experiment for captive desert tortoises, juveniles fed a mix of native forbs that included the related species, *Chylismia claviformis*, thrived compared to juvenile tortoises fed exotic or native grass diets (Drake et al. 2016).

Other Notable Species Interactions.

Yellow cups, along with other annual species, can preferentially grow in fertile islands, the nutrient-rich areas beneath perennial shrubs, compared to open desert interspaces (Traylor 2019), although there is no evidence it is restricted to these areas.

Disturbance Ecology.

Chylismia species can increase in density after soil disturbance compared to undisturbed sites (Suazo et al. 2012). No information detailing the disturbance ecology of yellow cups in response fire, invasive species, or other disturbances was found in the literature or through personal communication.

Ethnobotany.

The Mohave people likely used yellow cups seeds for food (NAEB 2022).

Horticulture.

Yellow cups is not widely cultivated for horticultural or landscaping use.

DEVELOPING A SEED SUPPLY

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

Seed Sourcing.

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

Researchers with the U.S. Geological Survey (USGS) are currently developing empirical seed transfer zones for yellow cups in the Mojave Desert ecoregion (Shryock 2023, personal communication). When complete, data will be available on the Science Base catalog webpage.

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

Outside of the Mojave Desert, the Desert Southwest Provisional Seed Zones (PSZs) may be used to plan seed sourcing for yellow cups. 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.

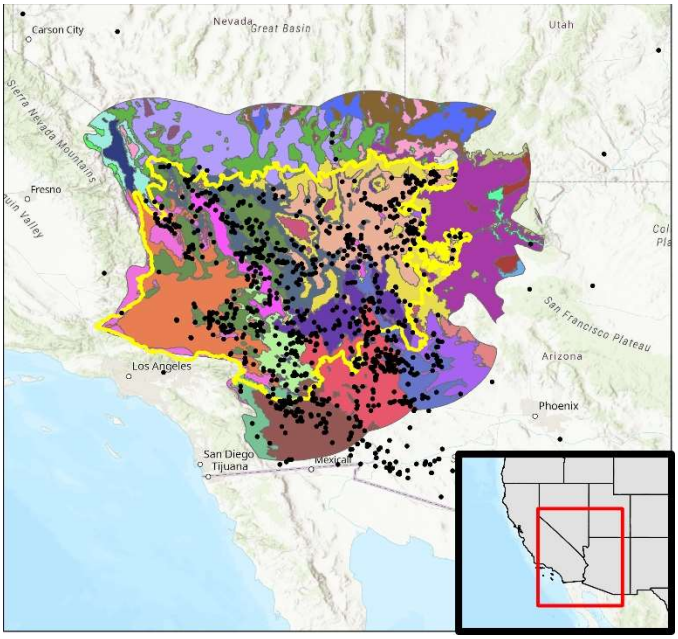

Figure 6: The distribution of yellow cups across the Desert Southwest Provisional Seed Zones (Shryock et al. 2018). Occurrences (black dots) are based on georeferenced herbarium specimens and verified observations (SEINet 2023). The Mojave Basin and Range Level III ecoregion (yellow outline) is buffered up to 100 km in all directions. PSZs do not always extend a full 100 km beyond the Mojave ecoregion.

The USGS Climate Distance Mapper Tool incorporates the Southwest Deserts Seed Transfer Zones with climate models and can serve to guide seed sourcing according to current and projected climate conditions.

Commercial Seed Availability and Germplasm Releases.

Yellow cups is not widely available for purchase from large-scale commercial seed vendors. There have been no conservation plant releases of yellow cups.

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 harvesting no more than 20% of available seed (BLM 2021). However, in arid regions and in drought conditions, it may be best to adapt this guidance to collect no more than 10% of available seed due to limited regeneration and low-density populations (Asbell 2022, personal communication). Several practices are in place to ensure proper genetic diversity is captured from the source population. These include collecting from the entire population uniformly, sampling a diversity of phenotypes and microclimates, and collecting in various time windows to capture phenological and temporal diversity (BLM 2021).

Seed Collection Timing.

In the Mojave and Sonoran Deserts, yellow cups is typically collected between April and June with the majority of collections occurring in April (BLM SOS 2022).

Collection Methods.

Whole, ripe capsules can be collected. However, seed can quickly disperse out of capsules, making wildland collection difficult to time. Mesh or organza bags can be placed around unripe fruits to catch seeds as they disperse (Asbell 2023, personal communication).

Figure 7: Yellow cups plants growing in a nursery at the Mojave Desert Land Trust. Note the organza bags placed around unripe pods to collect seed when pods open. Photo: Ashlee Wolf

Post-Collection Management.

Immediately following collection, seeds should be properly managed to avoid damage or declines in viability during transport and temporary storage. Seed should be dried and ventilated to prevent molding (Pedrini and Dixon 2020). Ventilation can be achieved by collecting and storing seed in breathable containers, such as paper or cloth bags.

To dry material before storage or processing, spread it in a single layer on trays or newspaper indoors in a well-ventilated room, or outdoors in a shaded area (BLM 2021). Collected material should be visually inspected for seed-predating insects (Pedrini and Dixon 2020). If seed predation is observed, consider fumigation with No-Pest Strips. After collection, prevent exposure to excessively hot or cold temperatures during transportation and temporary storage by keeping seed in a dry, insulated container (e.g., a cooler) in a shaded area while in the field (BLM 2021).

Figure 8: Collected seed and chaff material of yellow cups; scale shown in cm. Photo: BLM SOS CA930A

Figure 9: Bare seed of yellow cups. Photo: Bend Seed Extractory

Seed Cleaning.

If whole capsules are collected, seed can be cleaned by rubbing material over a small screen to break up the fruits and release the seeds. The material can then be run through #18 and #30 sieves followed by running it through a blower at 1.0 to 1.25 speed (Wall and MacDonald 2009).

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).

Seed Testing.

After collection, a representative sample of each seed lot must be tested in an appropriate seed lab to ensure purity and germination meet minimum standards defined by the Association of Official Seed Analysts (AOSA 2016) and species standards from state-level certification programs as available. A set of "principles and standards for native seeds in ecological restoration" (Pedrini and Dixon 2020) outlines further guidelines specific to native plants, including procedures for obtaining representative samples of seed lots and incorporation of dormancy measures into seed testing and labels.

The pure seed unit-- a combined unit of seed and attached structures that is classified as pure seed as opposed to inert material —for the *Chylismia* genus is defined by the AOSA as a "a seed with or without the seed coat" (AOSA 2016).

Wildland Seed Yield and Quality.

Wild-collected yellow cups seed is generally high quality, with an average of 95% fill, 98% purity and 94% viability indicated by tetrazolium tests across 48 Seeds of Success collections (BLM SOS 2022, Table 2). Wild collections contain an average of over 1,500,00 pure live seeds per pound (BLM SOS 2022, Table 2).

Table 2: Seed yield and quality of yellow cups seeds collected in the Mojave Basin and Range Ecoregion, cleaned by the Bend Seed Extractory and tested by the Oregon State Seed Laboratory or the USFS National Seed Laboratory (BLM SOS 2022). Fill (%) was measured using a 100 seed X-ray test. Viability (%) was measured using a tetrazolium chloride test.

	Mean	Range	Samples
Bulk weight (lbs)	0.51	0.03-5.57	52
Clean weight (lbs)	0.13	0.003-1.65	52
Purity (%)	98	92-99	52
Fill (%)	95	81-99	52
Viability (%)	94	81-98	48
Pure live seeds/lb	1,507,796	673,581-5,455,571	52

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

Yellow cups has not been produced in large scale agricultural seed increase fields. It will likely grow best in full sun to partial shade and in well drained soils (Calscape 2023).

Agricultural Seed Field Certification.

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

Table 3 outlines the pre-varietal germplasm certification standards for yellow cups seed in the state of California with a minimum of ¼ lb sample size to be submitted for testing (CCIA 2022). The Nevada and Arizona Departments of Agriculture do not specify standards for PVG crops. The Utah Crop Improvement Association does not specify standards for PVG crops, but may apply standards of similar species or crop groupings (UCIA 2023)

Table 3: Pre-varietal Germplasm (PVG) standards for seed analysis results of yellow cups in California.

Factor	G1	G2	G3 to G10
Pure Seed (minimum)	90%	90%	90%
Inert Matter (maximum)	10%	10%	10%
Total Other Crop Seed (maximum)	0.20%	0.30%	0.50%
Weed Seed (maximum)	None	None	None
Noxious Weed	None	None	None
Germination and Hard Seed (minimum)	65%	65%	65%

Isolation Distances.

Sufficient isolation distances are required to prevent cross-pollination across seed production crops of yellow cups from different sources or other *Chylismia* species. Table 4 summarizes the isolation distances required for PVG certification in both Utah and California. California standards

are described specifically for yellow cups (CCIA 2022), while the Utah standards are general for outcrossing annual species (UCIA 2023). Nevada and Arizona do not specify these standards for Source Identified PVG seed.

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

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

Site Preparation.

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

Seed Pre-treatments.

Most attempts to germinate yellow cups seed have been unsuccessful (0.3-4% germination rates), even with a variety of germination conditions and pre-treatments methods (Sandoval and Birker 2023; Asbell 2023, personal communication). However, a recent trial to assess various pre-treatments showed that cold stratification of four-year-old seed had the highest germination rate: 48%, significantly higher than previous attempts (Sandoval and Birker 2023). This trial used two seed lots: one collected in the same year of the trial and the other collected four years prior. Each seed lot was divided into six treatments, administered prior to sowing in agar germination plates and maintaining in a growth chamber with an 11-hour light cycle at 20 °C and a 13-hour dark cycle at 12 °C. The six pre-treatments tested were:

1) gibberellic acid: 24 hours in 500 ppm GA-3.
2) cold moist stratification: 14 days at 5 °C in the dark.
3) water soak: 24 hours in deionized water
4) leach: 3 days in deionized water with the water changed out 3 times per day.
5) wet dry 1: 24 hours in deionized water, followed by 48-hour drying period on a paper towel.
6) wet dry 2: 24 hours in deionized water, followed by 1-week drying period on a paper towel.

All treatments, excluding the water soak, resulted in increased germination compared to any previous attempts. Further trials are planned to learn more about pre-treatment methods for optimal germination of yellow cups (Sandoval and Birker 2023).

Seeding Techniques.

In experimental seed increase plots at Victor Valley College in Victorville, California, yellow cups seed was mixed with sterile horticultural sand and broadcasted by hand in the spring at a rate of 0.5 gram per 10x20m plot (Brooks and Gault 2023, personal communication).

Establishment rates were reported to be low (<20 individuals per plot) due to competition with weeds in the field.

Establishment and Growth.

As an annual, yellow cups will produce seed in the same year as it is sown (or following year if sown in fall), as long as proper growth and pollination are achieved.

Progeny of the yellow cups crop will freely self-sow and establish. Removing volunteer plants of uncertain generation class will help prevent a mixed-generation crop, or the crop can continue to be propagated from the volunteers (Brooks and Gault 2023, personal communication).

Weed Control.

There are a limited number of herbicides registered and labeled for use on native plant crops. See the Native Seed Production guide from the Tucson Plant Materials Center (USDA NRCS 2004) for further details on weed management in native seed production fields.

Pest Management.

No pests have been observed on yellow cups in experimental agricultural seed increase settings (Brooks and Gault 2023, personal communication).

No recommendations for pest management specific to yellow cups were described in the literature or through personal communications.

Pollination Management.

Growing native plants in or near their native range increases the likelihood that compatible pollinators will be able to find and pollinate the crop (Cane 2008). In general, growers can consider implementing pollinator management and stewardship practices to augment and attract existing pollinator communities. Specific practices will depend on the plant species' pollination needs, and the biology of the pollinators. For example, if a plant relies on native solitary bees, growers can create nesting opportunities adjacent to or within the field perimeter with downed woody material or crafted bee boxes (Cane 2008, MacIvor 2017). In some cases, there may be a need to supplement with managed pollinators through honeybee or bumblebee rental services to ensure pollination of wildflower crops for seed increase (Cane 2008).

No recommendations for pollinator management specific to yellow cups were described in the literature or through personal communications.

Irrigation.

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

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), though yellow cups has not specifically been grown there. 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 avoid stressing plants and lowering seed yield (Dial 2023, personal communication).

Other growers administer water via drip irrigation and find flood irrigation does not adequately penetrate into soil, resulting in significant evaporation in aridland farm settings (Hagman 2023, personal communication).

Seed Harvesting.

Growers at Victor Valley College (VVC) reported yellow cups to be fairly uniform in phenology, with plants setting seed around the same time. Plants grown from plots seeded in the spring had ripe fruits in the following July (Brooks and Gault 2023, personal communication). Seeds can be harvested by hand. However, seeds can quickly disperse as the capsules ripen. Mesh or organza bags can be wrapped around immature, green capsules so that seeds are not lost to the wind when the capsules dehisce (Asbell 2023, personal communication). Some growers do not find that seed quickly disperses and do not use methods to prevent seed dispersal prior to harvest (Brooks and Gault 2023, personal communication).

Seed Yields and Stand Life.

Growers at VVC collected 130.7 grams of seed from two 10x20 m plots (originally sown with 1 gram of seed per plot) (Brooks and Gault 2023, personal communication).

NURSERY PRACTICE

Yellow cups seed sourced from wild collections in the Mojave Desert has been grown in a nursery setting to produce seed for a common garden research project (DeFalco 2023, personal communication). In two different years, untreated seeds were sown into 4" containers and covered with a fine layer of soil and vermiculite. There was steady emergence of seedlings over a 4-week period following seeding, during which the containers were outdoors in winter conditions in December and January. Germination was not quantified, but reported to be adequate. These results were consistent across both years of propagation. The soil was kept moist throughout the propagation period. Aphids were an occasional pest and were treated with a dilute insecticidal soap (DeFalco 2023, personal communication).

Due to the species' slender taproot, it likely would not do well with transplanting from containers into the ground (DeFalco 2023, personal communication).

See Seed Pre-Treatment for a discussion of germination practices.

REVEGETATION AND RESTORATION

Yellow cups is considered a high priority species to restore desert tortoise and pollinator habitat in the Mojave Desert (Esque et al. 2021). However, there are few documented examples of its use in restoration projects.

Wildland Seeding and Planting.

Wildland Seedings.

Yellow cups was included in a multi-species seed mix to restore areas where invasive saltcedar (*Tamarix* spp.) was removed in western Arizona (Lair 2023). Yellow cups made up 3% of the seed mix and was drill seeded at a rate of 0.03 pure live seed pounds per acre and broadcast seeded at a rate of 0.07 pure live seed pounds per acre. No information on establishment rates was reported.

Wildland Plantings.

Annual species are generally not recommended as plug transplants and will likely perform better with direct seeding methods (Immel 2009).

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RESOURCES

AOSCA NATIVE PLANT CONNECTION

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

BLM SEED COLLECTION MANUAL

https://www.blm.gov/sites/default/files/docs/2021-12/SOS%20Technical%20Protocol.pdf

OMERNIK LEVEL III ECOREGIONS

https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states

CLIMATE SMART RESTORATION TOOL

https://climaterestorationtool.org/csrt/

MOJAVE SEED TRANSFER ZONES

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

MOJAVE SEED MENUS

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

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