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Nakedstem sunray (*Enceliopsis nudicaulis*)

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Nomenclature

Nakedstem sunray (*Enceliopsis nudicaulis*) (A. Gray) A. Nelson belongs to the Ecliptinae subtribe and Heliantheae tribe within the Asteraceae family. Nomenclature follows Welsh et al. (2016).

Family

Asteraceae ☞ Aster family

Genus

Enceliopsis

Species

nudicaulis

NRCS Plant Code

ENNU (USDA NRCS 2019).

Subtaxa

Some systematists (Cronquist 1972; Welsh et al. 2016) recognize nakedstem sunray varieties: *corrugata* and *bairdii*, although others do not support varietal distinctions (Sanders and Clark 1987; Curtis 2006).

Synonyms

Encelia nudicaulis A. Gray

Common Names

Nakedstem sunray, Ash Meadows sunray, nakedstem, naked-stemmed daisy, sunray (USFWS 1983; Curtis 2006; Welsh et al. 2016; USDA NRCS 2019)

Chromosome Number

Reported chromosome numbers include: $2n = 32$, 34 , and 36 ; but most consistently reported are $2n = 34$ and 36 (Reveal and Styer 1974; Hickman 1993; Curtis 2006; Welsh et al. 2016).

Hybridization

The possibility of hybrids within the *Enceliopsis* genus have been suggested based on DNA evidence. Sequencing of two nuclear and two chloroplast regions suggests that a single plant collected from co-occurrences of nakedstem sunray and Panamint daisy (*E. covillei*) in California may represent a hybrid or backcrossed individual (Fehlberg and Ranker 2007). Hybrids of nakedstem sunray, Panamint daisy, and silverleaf sunray (*E. argophylla*) were created artificially under cultivation but did not survive long enough to evaluate fertility (Clark 1998).

Distribution

Nakedstem sunray occurs in Idaho, Utah, Nevada, Arizona, and California (Curtis 2006). It is widespread throughout the Great Basin (Clark 1998) and occurs as restricted populations in southwestern and central Idaho, northern Arizona's Mohave and Coconino counties, and southeastern California's Inyo and San Bernardino counties (Cronquist et al. 1994).

Variety *corrugata* occurs only in the Ash Meadows area of Nye County, Nevada, where soils are strongly alkaline and

poorly drained (Cronquist 1972). Variety *bairdii* occurs in Washington County, Utah, and Mojave County, Arizona. It is especially common on limestone and dolomite substrates in the southern Beaver Dam Mountains in Utah and the Moenkopi sandstone formation and southeast of St. George, Utah, and adjacent Mohave County, Arizona (Welsh et al. 2016). Variety *corrugata* is federally listed as a Threatened species (USFWS 2020).

Habitat And Plant Associations

Nakedstem sunray occurs in dry, open (Fig. 1) desert shrubland communities. In the Intermountain West, it occupies well-drained slopes, often with sagebrush (*Artemisia* spp.), juniper (*Juniperus* spp.), and sometimes with saltbush (*Atriplex* spp.) (Cronquist et al. 1994). At its northern most distribution in central Idaho, nakedstem sunray occurs on dry rocky bluffs in sagebrush communities above the Salmon River (Blake 1913). In the arid rain shadow of the White Cloud and Salmon River mountains it is found in association with shadscale saltbush (*A. confertifolia*), Indian ricegrass (*Achnatherum hymenoides*), Douglas' dustymaiden (*Chaenactis douglasii*), and, Challis milkvetch (*Astragalus amblytropis*, a rare endemic), on south- and west-facing, xerophytic slopes along the Salmon River (Rittenhouse and Rosentreter 1994).



Figure 1. Nakedstem sunray growing in a mixed desert shrubland in Utah. Photo: USDI Bureau of Land Management BLM UT 020D5 Seeds of Success (SOS).

In Utah, nakedstem sunray occurs with blackbrush (*Coleogyne ramosissima*), rabbitbrush (*Chrysothamnus* spp.), mormon tea (*Ephedra viridis*), shadscale saltbush, spiny hopsage (*Grayia spinosa*), and pinyon (*Pinus* spp.)-juniper communities (Fig. 2) (Welsh et al. 2016). On the San Rafael Swell in south-central Utah, nakedstem sunray is common in salt desert shrub communities dominated by shadscale saltbush and mixed desert shrub communities dominated by one or several of the following species: big sagebrush (*Artemisia tridentata*), Bigelow sage (*A. bigelovii*), bud sagebrush (*Picrothamnus desertorum*), broom snakeweed (*Gutierrezia sarothrae*), or yellow rabbitbrush (*Chrysothamnus viscidiflorus*) (Harris 1983).



Figure 2. Nakedstem sunray growing at the edge of a pinyon-juniper woodland in Utah. Photo: Provo Shrub Sciences Laboratory, USFS, Rocky Mountain Research Station.

In more southern and western areas in Nevada, nakedstem sunray occurs with creosote bush (*Larrea tridentata*) (Munz and Keck 1973; Cronquist et al. 1994). Additional local populations of nakedstem sunray are associated with limestone outcrops at the Nevada Test Site and in central-southern Nevada where it occurs with saltbush and black sagebrush (*Artemisia nova*) (Beatley 1976). In the Clark Mountains in trans-montane southern California, nakedstem sunray occurs in gypsum-rich soils with shadscale saltbush, cottontop cactus (*Echinocactus polycephalus*), Schott's pygmycedar (*Peucephyllum schottii*), and Fremont's dalea (*Psoralea fremontii*) (Thorne 1982). Northwest of Las Vegas, in Ash Meadows valley, nakedstem sunray (variety *corrugata*) occurs in dry washes with saline soils in association with shadscale saltbush, alkali goldenbush (*Isocoma acradenia* var. *acradenia*), desert bearpoppy (*Arctostaphylos merriamii*), and basin yellow cryptantha (*Cryptantha confertiflora*) (Mozingo and Williams 1980). In the southern and eastern parts of Ash Meadows where soils are arid and alkaline it occurs with burrobrush (*Ambrosia dumosa*) (Sada 1990).

In southern California's Clark Mountains, nakedstem sunray populations are found in gypsum-rich soils associated with shadscale saltbush, cottontop cactus (*Echinocactus polycephalus*), Schott's pygmycedar (*Peucephyllum schottii*), and Fremont's dalea (*Psoralea fremontii*) (Thorne 1982).

Elevation

Nakedstem sunray occupies habitats from 2,300 to 7,600 ft (700–2,320 m) (Cronquist et al. 1994; Curtis 2006; Welsh et al. 2016). Its elevation range is slightly narrower in Utah, 3,400 to 7,600 ft (1,040–2,320 m) (Welsh et al. 2016), and in California from 3,200 to 6,600 ft (950–2,000 m) (Hickman 1993).

Soils

Throughout its range, nakedstem sunray populations are found on deep, well-drained, dry soils (Harris 1983; Cronquist et al. 1994; Rittenhouse and Rosentreter 1994), rocky or hard compacted clays (Blake 1913; Munz and Keck 1973) with high levels of carbonates (Welsh et al. 2016), salinity (USFWS 1983), or gypsum (Thorne 1982). In east-central Idaho, nakedstem sunray occurs on xerophytic, south- and west-facing slopes where soils exceed 3 ft (> 1 m) (Rittenhouse and Rosentreter 1994). In Utah, it is common on gypsiferous or calciferous semi-barren knolls and in limestone or dolomite soils (Welsh et al. 2016). On the San Rafael Swell formation in south-central Utah, nakedstem sunray occurs in salt desert shrublands with alkaline clay soils and mixed-desert shrublands on deep, well-drained soils (Harris 1983). On the Grand Canyon rim west of Cathedral Monument in Arizona, nakedstem sunray is associated with red sandstone formations (Brian et al. 1999). In the Ash Meadows valley in Nevada, it grows in dry washes on saline clays (USFWS 1983). In other parts of California, it grows in sandy to rocky clays, compacted arid soils, and in the xerophytic Death Valley region (Munz and Keck 1973).

Description

Nakedstem sunray is a tufted perennial with erect stems developing from a stout multibranched caudex and thick woody taproot (Fig. 3) (Munz and Keck 1973; Cronquist et al. 1994; Curtis 2006; Welsh et al. 2016). Scapose stems typically grow 4 to 16 in (10–40 cm) tall, though some plants reach 24 in (60 cm) (Welsh et al. 2016). Stems are woody, densely leafy at the base, and leafless above. Both leaves and stems are covered in short white hairs which give the herbage a dull gray appearance (Hickman 1993; Cronquist et al. 1994; Curtis 2006; Welsh et al. 2016). Leaf axils often have tufts of woolly hairs (Munz and Keck 1973). Basal leaves are alternate and petiolate (Curtis 2006). Petioles can be one to three times as long as the leaf blades. Leaf blades are three-nerved, 0.8 to 3.5 in (2–9 cm) long, and vary greatly in width (0.4 to 4 in [2–10 cm]) (Munz and Keck 1973; Cronquist et al. 1994; Curtis 2006; Welsh et al. 2016). Blades are ovate to elliptic or orbicular to spatulate, cuneate to subcordate basally, and obtuse to rounded apically (Welsh et al. 2016).



Figure 3. Nakedstem sunray plant with woody taproot nearly as long as the aboveground stems are tall. Photo: USDI, Bureau of Land Management, ID 330, Seeds of Success.

Nakedstem sunray flower heads are 1.6 to 3.5 in (4.1 to 9.1 cm) in diameter and occur singly at the top of stems (Fig. 4). Flower heads are comprised of 200 to 500 or more yellow disk florets and 11 to 28 yellow ray florets, most commonly 21 (Hickman 1993; Cronquist et al. 1994; Curtis 2006). Ray florets are pistillate but sterile, and disk florets are bisexual and fertile (Curtis 2006; Welsh et al. 2016). Involucre is 0.5 to 0.9 in (1.3 to 2.2 cm) tall, 1.2 to 2.2 in (3.0 to 5.6 cm) wide, densely gray tomentose with short hairs, and has 30 to 65 or more persistent phyllaries in 3 to 5 series (Cronquist et al. 1994; Curtis 2006). Fruits are one-seeded achenes that are wedge shaped, dark brown to black, 0.4 to 0.5 in (9 to 12 mm) long, 0.1 in (3.5 mm) wide, and silky hairy (Blake 1913; Cronquist et al. 1994; Welsh et al. 2016). Achenes have two stout awl-shaped appendages that may or may not surpass the length of the long hairs covering the achene (Figs. 6 and 7) (Cronquist et al. 1994; Curtis 2006).



Figure 4. Small nakedstem sunray plant growing in rocky soils in Idaho. Photo: BLM ID 330 SOS.

Varietal descriptions. Nakedstem sunray varieties: *corrugata* and *bairdii* are distinguished morphologically by limited leaf and flowerhead characteristics but occupy restricted and unique locations and habitats (See [Distribution](#) section). Variety *corrugata* has small leaves, 0.4 to 0.8 in (1–2 cm long), that are strongly ruffled-corrugate, especially toward the margins (Cronquist 1972). Variety *bairdii* plants are large, 12 to 24 in (30–60 cm) tall, and those growing in Washington County, Utah, have larger than average flower heads (Welsh et al. 2016). In a comparative morphological study of the capitulum produced by sunrays (*Enceliopsis* spp.), researchers found no morphological differences supporting varietal descriptions (Sanders and Clark 1987).

Reproduction

Nakedstem sunray produces flower heads with pistillate but sterile ray florets and bisexual disk florets (Curtis 2006; Welsh et al. 2016). Clark (1998) suggests nakedstem sunray is self-incompatible (Clark 1998). Flowering is common in the spring but can occur as late as August (Beatley 1976; Brian et al. 1999; Curtis 2006). Abundance or variability in seed production and seedling recruitment were not reported in the literature. Germination was variable in controlled conditions, see [Germination Biology](#) section.

Ecology

Ecological and disturbance studies were lacking in the literature. Nakedstem sunray tolerates very dry conditions (Munz and Keck 1973), has a woody taproot, and is considered long-lived (Welsh et al. 2016). Given these traits, long-term persistence could be expected once plants are established.

Wildlife And Livestock Use

Adult and young (<85 days old) pronghorn (*Antilocapra americana*) utilized nakedstem sunray most in the summer on the Desert Experimental Range (DER) in western Millard County, Utah. Diet composition was evaluated from rumen and feces samples collected in spring and summer and maximum use was 13% (Smith and Beale 1980). When pronghorn were tracked for 2 years, nakedstem sunray forage was removed in the spring and early summer evaluation periods. Nakedstem sunray made up a high of 13% of pronghorn diets in 1 of the 2 years (Smith and Malechek 1974). In earlier studies (Beale and Smith 1970) reported that preference for nakedstem sunray was low on the DER. Herbage production of nakedstem sunray on the DER averaged 0.2 lb/ac (0.2 kg/ha) and was a low volume of spring and moderate volume of summer pronghorn diets.

Ethnobotany

Shoshone Indians in Nevada used a tea from boiled nakedstem sunray roots to treat bloody diarrhea, venereal diseases and a tea from boiled leaves to treat coughs. Tribal members would travel long distances to collect the plant (Train et al. 1941).

Horticulture

Although not currently grown for horticulture, large yellow flower heads extending above tufts of gray green leaves, suggest this species may be considered useful for xeriscaping (LBJWC 2020).

Revegetation Use

Although no studies reported use of nakedstem sunray in restoration, the species has been grown in test plots and farms for seed production (Shock et al. 2018; Jensen, USFS RMRS, personal communication, Jan 2020). Its tolerance of dry conditions and compacted clay soils as well as its long-lived nature suggests it may be useful in revegetation of degraded or disturbed sites receiving little precipitation (Munz and Keck 1973; Welsh et al. 2016).

Developing A Seed Supply

For restoration to be successful, the right seed needs to be planted in the right place at the right time. Coordinated planning and cooperation is required among partners to first select appropriate species and seed sources and then properly collect, grow, certify, clean, store, and distribute seed for restoration (PCA 2015).

Developing a seed supply begins with seed collection from native stands. Collection sites are determined by current or projected revegetation requirements and goals. Production of nursery stock requires less seed than large-scale seeding operations, which may require establishment of agricultural seed production fields. Regardless of the size and complexity of any revegetation effort, seed certification is essential for tracking seed origin from collection through use (UCIA 2015).

Seed Sourcing

Because empirical seed zones are not currently available for nakedstem sunray, generalized provisional seed zones developed by Bower et al. (2014), may be used to select and deploy seed sources. These provisional seed zones identify areas of climatic similarity with comparable winter minimum temperature and aridity (annual heat:moisture

index). Omernik Level III Ecoregions (Fig. 5; Omernik 1987) overlay the provisional seeds zones to identify climatically similar but ecologically different areas. For site-specific disturbance regimes and restoration objectives, seed collection locations within a seed zone and ecoregion may be further limited by elevation, soil type, or other factors.

The Western Wildland Environmental Threat Assessment Center's (USFS WWETAC 2017) Threat and Resource Mapping (TRM) Seed Zone application provides links to interactive mapping features useful for seed collection and deployment planning. The Seedlot Selection Tool (Howe et al. 2017) can also guide restoration planning, seed collection, and seed deployment, particularly when addressing climate change considerations.

Map

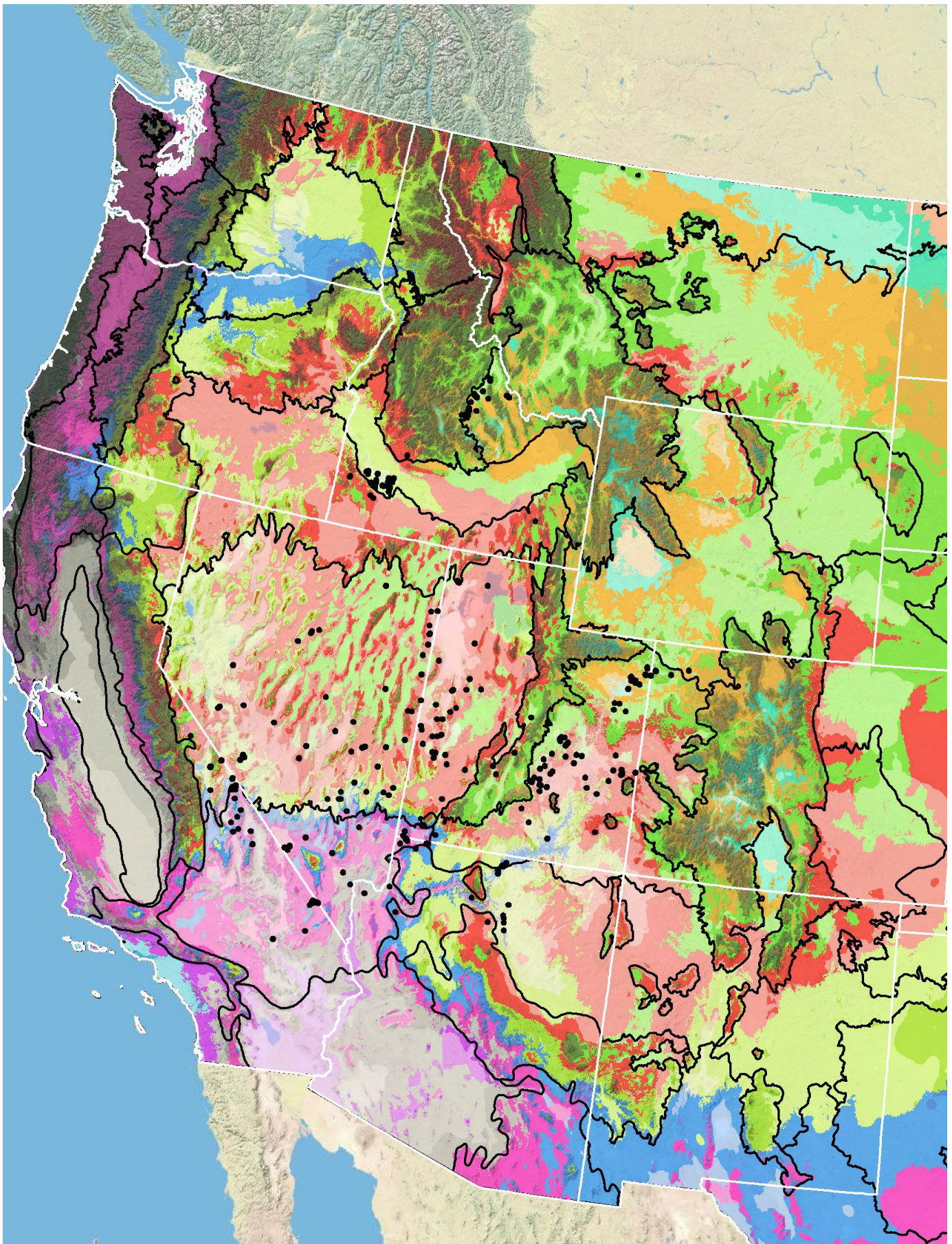


Figure 5. Distribution of nakedstem sunray (black circles) based on geo-referenced herbarium specimens and observational data from 1881-2016 (CPNWH 2017; SEINet 2017; USDI USGS 2017). Generalized provisional seed zones (colored regions) (Bower et al. 2014) are overlain by Omernik Level III Ecoregions (black outlines) (Omernik

1987; USDI EPA 2018). Interactive maps, legends, and a mobile app are available (USFS WWETAC 2017; www.fs.fed.us/wwetac/threat-map/TRMSeedZoneMapper2.php?). Map prepared by M. Fisk, USDI USGS.

Releases

As of 2020, there were no nakedstem sunray germplasm releases.

Wildland Seed Collection

Nakedstem sunray occurs in small stands and produces seed indeterminately, which suggests successful harvesting of wildland seed requires planning, scouting, and flexibility in timing of seed collection efforts. In Utah, native stands of nakedstem sunray were typically small but ranged to about 5 ac (2 ha) in size. Insect damage was severe at only one of many wildland collection sites (Jensen, USFS RMRS, personal communication, Jan 2020).

Wildland Seed Certification

Verification of species and tracking of geographic source is necessary whether wildland seed is collected for immediate project use or as stock seed for cultivated increase. This official Source Identification process can be accomplished by following procedures established by the Association of Official Seed Certifying Agencies (AOSCA) Pre-Variety Germplasm Program (Young et al. 2020; UCIA 2015). Wildland seed collectors should become acquainted with state certification agency procedures, regulations, and deadlines in the states where they collect.

If wildland-collected seed is to be sold for direct use in ecological restoration projects, collectors must apply for Source-Identified certification prior to making collections. Pre-collection applications, site inspections, and species and seed amount verification are handled by the AOSCA member state agency where seed collections will be made (see listings at AOSCA.org).

If wildland seed collected by a grower or private collector is to be used as stock seed for planting cultivated seed fields or for nursery propagation (See [Agricultural Seed Field Certification](#) section), detailed information regarding collection site and collecting procedures must be provided when applying for certification. Photos and herbarium specimens may be required. Germplasm accessions acquired within established protocols of recognized public agencies, however, are normally eligible to enter the certification process as stock seed without routine certification agency site inspections. For contract grow-outs, however, this collection site information must be provided to the grower to enable certification.

Collection Timing

Reported wildland seed collection (Fig. 6) dates for nakedstem sunray range from late May to early July in Idaho, Utah, and Nevada, but most were made in June (Table 1). The Bureau of Land Management’s Seeds of Success collection crews collected nakedstem sunray seed in late June and early July in Idaho, Utah, and Nevada. The latest of four collections was made from the highest elevation site (USDI BLM SOS 2017). Wildland seed collection dates in Utah made by Provo Shrub Lab personnel for establishment of common garden studies were made from May 25 to July 7 for sites ranging from 5,128 to 7,203 ft (1,563Ð2,195 m) (Jensen, USFS RMRS, personal communication, Jan 2020).

Table 1. Dates and locations of seed collections made by the USDI, BLM Seeds of Success collection crews.

Date	Location	Elevation (ft)	Site
June 24, 2010	Millard Co, UT	5697	South slope, desert scrub
June 29, 2010	Millard Co, UT	6102	East slope, juniper, sand desert
July 7, 2010	White Pine Co, NV	7203	East slope, pinyonÐjuniper
June 27, 2016	Custer Co, ID	6250	East to south slopes, dry rolling hills in the Salmon River uplands



Figure 6. Collection of less than 100 individual nakedstem sunray seeds. Photo: Provo Shrub Sciences Laboratory, USFS, Rocky Mountain Research Station.

Collection Methods

Seed is collected by hand. Seed disperses quickly when ripe, the presence of seed on the ground indicates seed maturity. Full seed heads can be clipped, but to collect only ripe seed, collectors can swat the seed heads over a collection hopper using a racquet. Ripe seed is dislodged, leaving remaining immature seed to continue to mature. Swatting results in a harvest that is easier and faster to clean than a collection of clipped seed heads. (Jensen, USFS RMRS, personal communication, Jan 2020).

Several collection guidelines and methods should be followed to maximize the genetic diversity of wildland collections: 1) collect seed from a minimum of 50 randomly selected plants; 2) collect from widely separated individuals throughout a population without favoring the most robust or avoiding small stature plants; and 3) collect from all microsites including habitat edges (Basey et al. 2015). General collecting recommendations and guidelines are provided in online manuals (e.g., ENSCONET 2009; USDI BLM SOS 2021).

It is critical that wildland seed collection does not impact the sustainability of native plant populations. Collectors should take no more than 20% of the viable seed available at the time of harvest (USDI BLM SOS 2021). Additionally, care must be taken to avoid the inadvertent collection of weedy species, particularly those that produce seeds similar in shape and size to those of nakedstem sunray.

Post-Collection Management

Any vegetative material (e.g. stems, large leaves) should be removed from collected seed to reduce the moisture content and thus the potential for mold growth. Keep collections in dry, shaded locations, and do not allow seed to overheat. Seed should be loosely packed in well aerated collection bags to provide good air circulation. Seed can be

dried by laying it out in thin layers on screens in a well-ventilated, rodent-free area. Potential seed insects should be controlled using appropriate chemicals or by freezing the seed collection for 48 hours once thoroughly dried. Temporary storage prior to delivery at the seed extractory should be in a cool (< 50 °F [10 °C]), dry (< 35% relative humidity) location.

Seed Cleaning

The USFS Bend Seed Extractory used the following procedure to clean wild-collected nakedstem sunray seed (Fig. 7): 1) Sieve off loose seed from stems and flower heads. 2) Process one time through a Missoula De-winger to reduce the amount of hairs on the seed using a black liner with a feed of 20, speed of 4, and tilt of 12 to 15. 3) Sieve seed again to remove more chaff from the seed heads. Large seed lots were processed using an office clipper with a 17 round screen to remove stems and air of 1 to remove empty seed. Smaller lots required less processing and were put directly through the Continuous Seed Blower (Mater CSB, Corvallis, OR) with a feed of 6 to 9 and an air setting of 250 to 300 (K. Herriman, USFS Bend Seed Extractory, personal communication, Jan 2020).

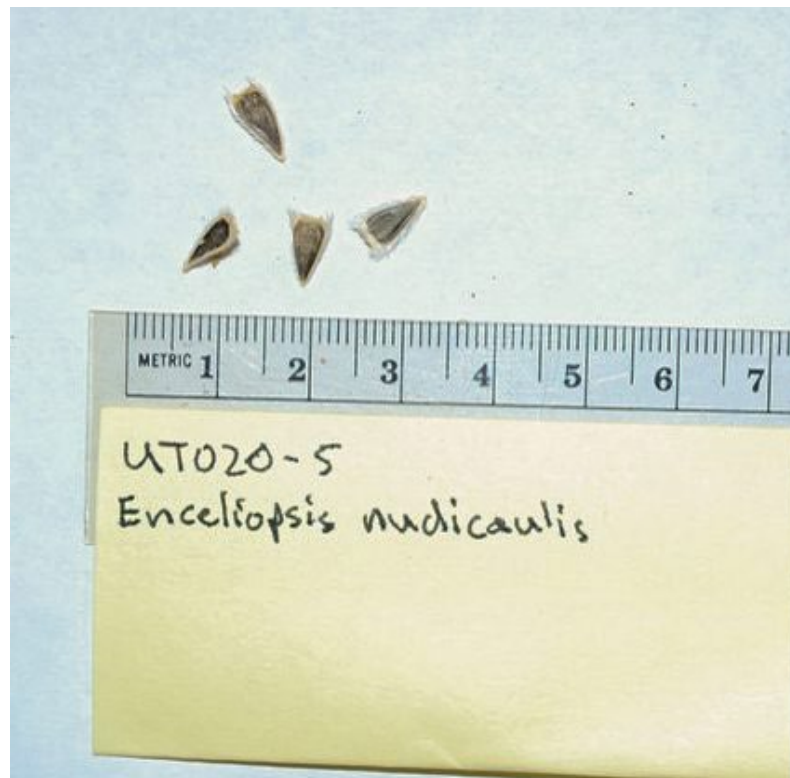


Figure 7. Four individual nakedstem sunray seeds measuring about 1 cm long and 5 mm wide. Photo: BLM UT 020 SOS.

Seed Storage

Dry seed should be stored where conditions are cool and dry.

Seed Testing

Seed purity is evaluated using standard procedures (AOSA 2016). There are no AOSA procedures for testing germination of nakedstem sunray seed. Tetrazolium chloride testing (TZ) should follow that suggested for other Asteraceae species, which includes cutting seeds longitudinally leaving the distal end intact, soaking for 6 to 12 hours in 0.1% TZ concentration at (86–95 °F [30–35 °C]). The embryos of viable seed will be entirely stained (AOSA 2010).

Germination Biology

Studies report low (10-30%; Rawlins et al. 2012) to high (75-100%; Kildisheva et al. 2018; Love and Akins 2019) germinability of nakedstem sunray seed. Love and Akins (2019) reported that nakedstem sunray seed germinated well at 40 jF (4 jC) and 70 jF (21 jC). After 2 to 4 weeks at 70 jF (21 jC), 75% of seed germinated and after 3 to 6 weeks at 40 jF (4 jC), 100% of seed germinated. No seed pretreatments were noted and no other study details were provided (Love and Akins 2019). In preliminary germination studies, Karrfalt and Vankus (2012) reported germination of nakedstem sunray was best after 4 weeks of moist pre-chilling and incubation at 59 jF (15 jC) or 68 jF (20 jC). Seed was not scarified.

Kildisheva et al. (2018) found that a cultivated population of nakedstem sunray grown in Utah was non-dormant with germination ranging between 55 and 100% after up to 4 weeks at temperatures from 41 to 77 jF (5Ð25 jC). Germination was nearly 100% and occurred most readily at temperatures of 59 jF (15 jC) and 68 jF (20 jC) suggesting temperature was most influential on germination timing. Seed germination was also improved with karrikinolide at 77 jF (25 jC) and 1mM gibberellic acid at all temperatures. Generally, nakedstem sunray was quick to germinate relative to the other Great Basin species tested, requiring only 11 days for 50% of the seeds in the tested population to germinate. Seeds were dried for 4 weeks and kept in sealed bags at (-18 jC) for 3 months prior to conducting experiments. Seeds were incubated at constant temperatures with alternating 12 hr light-12 hr dark cycles (Kildisheva et al. 2018).

In laboratory experiments, germination of nakedstem sunray seed collected in Blind Valley, Utah, was less than 30% at constant and simulated diurnal spring temperatures, and germination was much more rapid at warm than cool or cold diurnal temperatures. Seed was first dusted with fungicide then germinated (in groups of 30 seeds) on moist blotter paper in petri dishes in an incubation chamber. Incubation occurred at constant temperatures ranging from 41 to 95 jF (5Ð35 jC) and diurnal simulated soil temperatures on a cold March, cool April, and warm May day in a big sagebrush community in the Shoshone Mountains of Nevada (Rawlins et al. 2012). Germination was 10% or less at constant cold and warm to hot temeratures of 41, 68, 77, 86, and 95 jF (5, 20, 25, 30, and 35 jC). Germination was 24.2% at 50 jF (10 jC) and 29.2% at 59 jF (15 jC). Germination was 19.2% at cold, 25.8% at cool, and 24.2% at warm diurnal Great Basin temperatures. Days to 10% germination was 13.5 at cold, 17.7 at cool, and 0.92 at warm diurnal temperature incubation (Rawlins et al. 2012).

Wildland Seed Yield And Quality

PostDcleaning seed yield and quality of seed lots collected in the Intermountain region are provided in Table 1 (USFS BSE 2017). The results indicate that nakedstem sunray seed can generally be cleaned to high levels of purity and seed fill and that the viability of fresh seed is generally high. Seed weight and viability reported by others (57,607Ð77,098 seeds/lb [127,000Ð170,000 seeds/kg], >90% TZ viability (USFS GBNPP 2014; Kildisheva et al. 2018; Jensen, USFS RMRS, personal communication, Jan 2020) are similar to those reported in Table 2.

Table 2. Seed yield and quality of nakedstem sunray seed lots collected in the Intermountain region, cleaned by the Bend Seed Extractory, and tested by the Oregon State Seed Laboratory or the USFS National Seed Laboratory (USFS BSE 2017).

Seed lot characteristic	Mean	Range	Samples (no.)
Bulk weight (lbs)	0.42	0.18Ð0.99	4
Clean weight (lbs)	0.19	0.02Ð0.43	4
CleanDout ratio	0.42	0.09Ð0.62	4
Purity (%)	98	98Ð98	4
Fill (%) ¹	96	92Ð98	4
Viability (%) ²	92	84Ð97	4
Seeds/lb	66,162	43,901Ð84,013	4

¹ 100 seed XDray test

² Tetrazolium chloride test

Marketing Standards

Acceptable seed purity, viability, and germination specifications vary with revegetation plans. Purity needs are highest for precision seeding equipment used in nurseries, while some rangeland seeding equipment handles less clean seed quite well.

Agricultural Seed Production

Nakedstem sunray seed production plots were grown and evaluated by the RMRS Provo Shrub Sciences Laboratory (PSSL) at Fountain Green, Utah (Fig.8) (Jensen, USFS RMRS, personal communication, Jan 2020) and at the Oregon State UniversityÕs Malheur Experiment Station (OSU MES) in Ontario, Oregon (Shock et al. 2018). At both sites, stand establishment was spotty and seed production often less than 50 lbs/ac (56 kg/ha). Seed is produced in the first growing season and at OSU MES was harvested for up to 3 years (Shock et al. 2018).



Figure 8. Large nakedstem sunray plant growing in a seed production field in Utah. Photo: Provo Shrub Sciences Laboratory, USFS, Rocky Mountain Research Station.

Agricultural Seed Certification

In order to minimize genetic changes in specific accessions of native species when increased in cultivated fields, it is essential to track the geographic source and prevent inadvertent hybridization or selection pressure. This is accomplished by following third party seed certification protocols for Pre-Variety Germplasm (PVG) as established by the Association of Official Seed Certification Agencies (AOSCA). AOSCA members in the U.S., Canada, and other countries administer PVG requirements and standards that track the source and generation of planting stock. Field and cleaning facility inspections then monitor stand establishment, proper isolation distances, control of prohibited weeds, seed harvesting, cleaning, sampling, testing, and labeling for commercial sales (Young et al. 2020; UCIA 2015).

Seed growers apply for certification of their production fields prior to planting and plant only certified stock seed of an allowed generation (usually less than four). The systematic and sequential tracking through the certification process requires preplanning, knowing state regulations and deadlines, and is most smoothly navigated by working closely with state certification agency personnel. See the [Wildland Seed Certification](#) section for more information on stock seed sourcing.

Site Preparation

At both the Utah and Oregon sites, nakedstem sunray was planted into weed-free plots. Row cover improved final emergence of nakedstem sunray in Oregon (Shock et al. 2014) but not in Utah (Jensen, USFS RMRS, personal communication, Jan 2020). At Fountain Green, Utah (5,700 ft [1,700 m]), soils are gravelly loams and the dominant shrub in surrounding vegetation is mountain big sagebrush (*Artemisia tridentata* subsp. *vaseyana*). At Fountain Green, fields were disked, fallowed, tilled and compacted prior to fall seeding nakedstem sunray (Jensen, USFS RMRS, personal communication, Jan 2020).

At OSUDMES, emergence of nakedstem sunray was improved when seeds were fungicide treated and covered with row cover (Shock et al. 2014). Seeded areas were weed-free, silt loam soils with pH of 8.3 and 1.1% organic matter (Shock et al. 2018). Soil crusting and bird damage were causes of poor stand emergence in earlier fall seeding of other forbs at OSU MES but observations revealed natural emergence of seed shed by established perennials occurred when seeds were covered by organic debris (Shock et al. 2014). So began tests of various seed protection measures, including row cover (N-sulate, DeWitt Co, Sikeston, MO) to protect against soil desiccation and bird damage; sawdust (0.26 oz/ft [24 g/m] of row) to mimic protection by organic debris; sand (0.65 oz/ft [60 g/m]) to hold seed in place, distributed over the sawdust when both were used; hydroseeding mulch (Hydrostraw, Manteno, IL) at 0.26 oz/ft (24 g/m); and fungicide seed pretreatment (0.35 oz [10 g] each of Metalaxyl [Ridomil] and Captan in 1.1 pints (0.5 L) of water) to protect from damping off. Row cover and fungicide treatments together resulted in the greatest emergence of nakedstem sunray, which was still low (11.5%) Seeding occurred on November 15, 2012. Plots were drip irrigated for 24 hours on November 20, 2009, and emergence results evaluated on March 10, 2010 (Table 3; Shock et al. 2014).

Table 3. Emergence of nakedstem sunray on April 18, 2013 (5 mo after fall seeding) with various combinations of seed protection treatments at Oregon State University's Malheur Experiment Station in Ontario, OR (Shock et al. 2014).

Row cover	Sawdust	Sand	Mulch	Fungicide seed treatment	% of seed planted*
Yes	Yes	No	No	Yes	10.9b
Yes	No	No	No	Yes	11.5b
Yes	Yes	No	No	No	6.4ab
No	Yes	No	No	Yes	0.1a
Yes	Yes	Yes	No	Yes	7.8ab
No	No	No	Yes	Yes	0a
No	No	No	No	No	3.7a

*Emergence percentages followed by different letters are significantly different ($P < 0.05$).

Weed Management

In seed production plots in Oregon and Utah, weeds were largely controlled by hand or mechanically with periodic herbicide treatments. At OSU MES, stands were hand weeded, except in the fall of the second post-seeding year when pendimethalin, a pre-emergent, was broadcast applied at 2 pints/ac (2.3 L/ha) to control weed emergence in established stands. Success of the weed treatments was not reported (Shock et al. 2018). In Utah, imazapic applied at 5 oz/ac (350 g/ha) in the fall when nakedstem sunray plants were entirely dormant, caused no stand mortality. Although the treatment effect on seed production was not quantified, casual observation suggested it did not impact seed production in the following year (Jensen, USFS RMRS, personal communication, Jan 2020).

Herbicides are not registered for this species, and the results do not constitute an endorsement of specific companies or products or recommendations for use. The research, however, could contribute to future registration efforts.

Seeding

Fall seeding at shallow depths was used to establish nakedstem sunray (Shock et al. 2018; Jensen, USFS RMRS, personal communication, Jan 2020). At Fountain Green, Utah, nakedstem sunray was seeded 0.25 in (0.6 cm) deep, at a rate of 25 PLS/linear ft (82 PLS/linear m). In a seeding depth study, field emergence was reduced as seeding depth increased from 0.5 to 1.6 in (1.4–4.1 cm) and averaged 0.73% over all seeding depths at three field sites (Jensen, USFS RMRS, personal communication, Jan 2020).

At OSU MES, nakedstem sunray was seeded first on October 3, 2012 using a small-plot grain drill. Seed was deposited on the soil surface at 20 to 30 PLS/ft (66–98 PLS/m) of row, and rows were spaced 30 in (76 cm) apart. A narrow band of sawdust was applied over the seed at 0.26 oz/ft (18.7 g/m) of row, and plots were covered with N-sulate row cover. Because of poor stand establishment and growth, plots were seeded again on November 2, 2015, using the same method (Shock et al. 2018).

Establishment And Growth

In the seed production test plots in Oregon and Utah, nakedstem sunray failed to establish dense stands and this may have been a result of excess moisture (Shock et al. 2018; Jensen, USFS RMRS, personal communication, Jan 2020). Initial stand establishment after fall seeding in Utah was fair, but up to 50% mortality occurred within the first 2 post-seeding years. Researchers suspected root rot caused mortality from inadequate soil drainage, but noted that longevity of surviving plants was good (Jensen, USFS RMRS, personal communication, Jan 2020).

At OSU MES, several measures were used to prevent bird predation of emerging seedlings. Row cover protected seedlings from birds until March, when it was replaced with bird netting. As seedlings emerged, bird seed was provided away from the plots to distract California quail (*Callipepla californica*) (Shock et al. 2018).

Irrigation

Although supplemental irrigation increased nakedstem sunray seed production in some years at OSU MES, it was also associated with a decline in stand density (Shock et al. 2018). Irrigation trials began in March 2013 in plots seeded in late October 2012 and reseeded in early November 2015. Irrigation treatments of 0, 4, or 8 in (101 or 203 mm) of water were delivered at about 2-week intervals beginning at the time of bud formation and flowering (Table 4) through drip tape buried 12 in (30 cm) deep. Winter and spring precipitation was lower than the 5-year average in 2013 and in 2017, and fall, winter, and spring precipitation was lower in 2018 than average. Growing degree days were greater than average in 2013 through 2016 and in 2018 and near average in 2017 (Table 5). Extensive die off of nakedstem sunray stands occurred over the winter of 2014–2015 and was most severe in plots receiving the highest

levels of irrigation. Reseeding that occurred in fall 2015 was successful but stands continued to decline, especially irrigated plots (Table 7; Shock et al. 2018).

Table 4. Timing of flowering and seed harvest dates for seed production fields growing over a period of 6 years at Oregon State University’s Malheur Experiment Station in Ontario, OR (Shock et al. 2018). Seed yields are provided in Table 7.

Year	Flower start	Flower peak	Flower end	Weekly harvest
	Date			
2013	30 Jun		15 Sept	8–30 Aug
2014	5 May	1 July	30 July	14 July–30 Aug
2015	28 Apr	13 May	5 Aug	2 Jun–15 Aug
2016	20 Apr		30 July	27 Apr–29 July
2017	11 May	7 Jun	20 Aug	4 Jun–15 Aug
2018	30 Apr	26 Jun	30 July	27 Apr–27 July

Table 5. Precipitation (in) and growing degree hours (°F) at Oregon State University’s Malheur Experiment Station in Ontario, OR (Shock et al. 2018).

Year	Spring (in)	Winter + Spring (in)	Fall + Winter + Spring (in)	Growing degree hrs (50–86 °F) Jan–June
2013	0.9	2.4	5.3	1319
2014	1.7	5.1	8.1	1333
2015	3.2	5.9	10.4	1610
2016	2.2	5.0	10.1	1458
2017	4.0	9.7	12.7	1196
2018	1.9	4.9	5.8	1342
5-yr ave	2.4	5.6	9.3	1207 (25-yr ave)

Pollinator Management

At Fountain Green, Utah, pollination by native pollinators was excellent throughout the season and no insect damage issues with seed production were noted (Jensen, USFS RMRS, personal communication, Jan 2020).

Pest Management

Powdery mildew (*Leveillula picridis*) was collected from nakedstem sunray plants growing at OSU MES (Braun and Mohan 2013). Infected plants were not treated and infection was not reported as impacting growth or seed production.

Seed Harvesting

Flowering and seed production of nakedstem sunray is indeterminate, and to maximize seed yields multiple harvests are required. In Utah, seed was harvested by hand up to eight times a season, but the last harvest was done with a

flail vac (Jensen, USFS RMRS, personal communication, Jan 2020). In Oregon, seed was harvested weekly using a blower in vacuum mode (Shock et al. 2018).

Seed Yields And Stand Life

Seed yields were typically less than 50 lbs/ac (56 kg/ha) in the Utah and Oregon test plots due to low density stands. However, longevity of surviving plants was good (Shock et al. 2018; Jensen, USFS RMRS, personal communication, Jan 2020).

Seed yield varied by accession at plots in Utah. Seed was harvested from 2011 through 2013 in fields seeded in the fall of 2010. Results of multiple harvests made between June 20 and July 13 in 2013 are provided in Table 6 (Gunnell 2017).

Table 6. Plant growth and seed production for 2 accessions of nakedstem sunray seeded in 2010 in Fountain Green, Utah. Plot size was 5 × 80 ft, but because of the limited ability to capture highly variable plants/area this measurement was not reported (Gunnell 2017).

Accession	Plant height (in)	No. of plants	Clean seed yield (g)	1000 seeds/weight (g)
Crystal Peak	14.6	180	500	6
Painted Pot	16.9	103	520	6.3

At OSU MES, nakedstem sunray seed production was increased with irrigation in 2 of 6 years and maximum seed production occurred without irrigation in one year (Table 7). The maximum average seed yield was 26 lbs/ac (29 kg/ha) but in 2015 non-irrigated stands produced 105 lbs/ac (118 kg/ha) (Table 7). Stands produced low levels of harvestable seed for up to 3 years (Shock et al. 2018).

Table 7. Seed yield (lbs/ac) for showy goldeneye stands with and without growing season irrigation at Oregon State University’s Malheur Experiment Station in Ontario, OR (Shock et al. 2018).

Year*	0 in	4 in	8 in
	labeled lbs/ac		
2013	2.3	6.8	5.9
2014	1.5a	34.6b	29.1b
2015	15.7b**	3.2a	4.4a
2016	10.5a	47.6b	45.9b
2017	105.0b	43.2a	25.0a
2018	20.1	20.5	20.1
Mean	25.9	26.2	21.7

*Seed was hand harvested weekly each year.
**Values within a year followed by different letters are significantly different ($P \leq 0.1$).

Nursery Practice

Nakedstem sunray was grown from wild-collected achenes at California State Polytechnic University. Soil used was eight parts pumice, four parts commercial container soil, one part gypsum. Seedlings were grown indoors and then

transferred to 8-in (20 cm) pots and kept outdoors. No other details were provided (Sanders and Clark 1987), but in a later publication, Clark (1998) reported that nakedstem sunray was difficult to cultivate.

Wildland Seeding And Planting

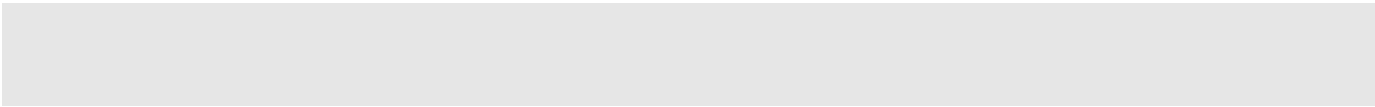
At the Rancho Santa Ana Botanic Garden, a relative of nakedstem sunray, Panamint daisy, was grown in the nursery from wildland seed collected in Inyo County, California. Germination was rapid, and researchers reported a high level of success in getting plants to the nursery stage, but poor levels of success in transferring plants from the nursery to outdoor gardens. Of 287 nursery-grown seedlings planted outdoors between 1937 and 1948, none were alive in 1950. Specimens from only one of the collections flowered, but because of insect damage it failed to produce seed (Everett 1957).

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