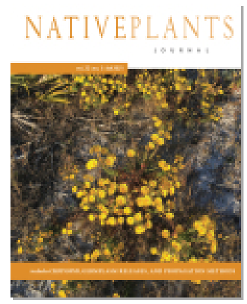
Ecology of *Asclepias brachystephana* : a plant for roadside and right-of-way management



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Native Plants Journal, Volume 22, Number 3, Fall 2021, pp. 256-267 (Article)

Published by University of Wisconsin Press

Bract milkweed (*Asclepias brachystephana*) growing roadside in Eddy County, New Mexico, with queen butterfly larvae (*Danaus gilippus*) and oleander aphids (*Aphis nerii*).

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ABSTRACT

Declining insect abundance is occurring around the world, and some management projects are aiming to utilize roadsides and other right-of-ways as insect conservation areas. In the US, the decline of the monarch butterfly (*Danaus plexippus* Linnaeus [Nymphalidae]) populations has led to multiple studies focusing on a small number of milkweed species (*Asclepias* [Apocynaceae]) that occur in the major flyways. Here we survey a poorly studied milkweed, bract milkweed (*A. brachystephana* Engelm. ex Torr.), to document where it grows, which organisms make use of the plants, seed production, and concentrations of milkweed toxins (cardenolides) and to investigate if this species is suitable for roadside or right-of-ways management projects. Our results show that the range of *A. brachystephana* includes the Chihuahuan Desert and neighboring ecoregions. Plant populations were also observed occurring on roadsides and right-of-ways, rarely spreading into neighboring habitats. We document a variety of native pollinators utilizing floral resources and a few herbivores feeding on plant tissue. Chemical analyses show wild plants produce higher concentrations of toxic cardenolide than many other milkweed species. These data suggest *A. brachystephana* should be considered for roadside and right-of-way plantings, restoration projects, or seeding throughout the Chihuahuan Desert and adjoining ecoregions.

McCoshum SM, Agrawal AA. 2021. Ecology of *Asclepias brachystephana:* a plant for roadside and right-of-way management. Native Plants Journal 22(3):256–267.

KEY WORDS
roadside, bract milkweed, cardenolides, milkweed, Apocynaceae

NOMENCLATURE
Asclepias brachystephana Engelm. ex Torr. Published W. H. Emory, Rep. U.S. Mex. bound. 2(1):163. 1859
Additional Plants: USDA NRCS (2021)
Insects: (ITIS 2021)

Photos by Shaun M McCoshum

Declining insect abundance is occurring around the world (Kluser and Peduzzi 2007; Colla and Packer 2008; Potts and others 2010; Cameron and others 2011; Hallmann and others 2017; McArt and others 2017). Habitat loss is one of the leading causes of these declines, and such losses can include habitat conversion (Kremen and Ricketts 2000; Kremen and others 2002; Buchmann and Ascher 2005; Potts and others 2010) and vegetation community conversion for roads, urbanization, and right-of-ways (Winfree and others 2007; Potts and others 2010; Jantz and others 2015; McCoshum and Geber 2020). Monarch butterfly (*Danaus plexippus* Linnaeus [Nymphalidae]) population declines have brought attention to habitat loss because larval host plant habitat and abundance have been reduced (Hartzler 2010; Pleasants and Oberhauser 2013; Pleasants 2017; Zaya and others 2017), although data are available that question the causality of this relationship (Inamine and others 2016; Agrawal and Inamine 2018). Landowners and conservation groups have started reintroducing larval host plants, specifically in the genus *Asclepias* (Apocynaceae), or the milkweeds, to areas including gardens as a conservation strategy (Thogmartin and others 2017; Geest and others 2019), while further research elucidates the ecology of monarch host plants (Hartzler and Buhler 2000; Hartzler 2010; Baker and Potter 2018) and restoration (Kasten and others 2016; Pleasants 2017; Thogmartin and others 2017; Pitman and others 2018), which is primarily focused on a handful of common milkweed species.

Milkweeds produce cardenolides as chemical defense (Züst and others 2019), which most organisms cannot ingest, and plant toxicity can vary depending on growing conditions (Agrawal and others 2012a, 2012b). Some insects have evolved resistance to these chemicals and even sequester these compounds for their own defenses (Birnbaum and others 2017; Birnbaum and Abbot 2018). Furthermore, many insects, including beneficial insects and pollinators, utilize milkweed flowers (Jennersten and Morse 1991; Ivey and others 2003; Nabhan and others 2015; James and others 2016). Approximately 130 species of *Asclepias* occur in North America (Woodson 1954; Weitemier and others 2015; Fishbein and others 2018), with a wide range of preferred habitats (Wilbur 1976; Borkin 1982; Fishbein and others 2011). For example, there are desert species such as desert milkweed (*A. erosa* Torr.), soil specialists such as serpentine milkweed (*A. solanoana* Woodson) (Lynch 1977), prairie species such as showy milkweed and green antelopehorns (*A. speciosa* Torr. and *A. viridis* Walter), and wetland-obligate species that include swamp milkweed and aquatic milkweed (*A. incarnata* L. and *A. perennis* Walter).

In the arid Southwest, climatic variables include hot, dry months as well as monsoon seasons that vary in rainfall totals across the region (Hochstrasser and others 2002; Weiss and others 2004). The region is governed by both the US and Mexico and contains the Warm Deserts, Southern Semi-arid Highlands, Temperate Sierras, and the Tropical Dry Forests (USDA Ecoregions of North America Level II). Numerous cities, roads, right-of-ways, and other disturbed habitats occur throughout the area, which makes it important to study the plants that can live in these disturbed habitats in order to create robust local conservation plantings. Approximately 50 species of *Asclepias* are known to occur in the arid Southwest (Nabhan and others 2015; GBIF 2021). Within the area, the Chihuahuan Desert is the largest ecoregion with the northeastern portion having populations of bract milkweed (*A. brachystephana* Engelm. ex Torr.), broadleaf milkweed (*A. latifolia* (Torr.) Raf.), zizotes milkweed (*A. oenotheroides* Cham. & Schitdl.), and horsetail milkweed (*A. subverticillata* (A. Gray) Vail) (GBIF 2021).

Our project focuses on *A. brachystephana,* which is commonly known as "Inmortal pequeño," "Kacosi," and "Lechosillo" in Spanish or Indigenous names and as "short-crowned milkweed" and "bract milkweed" in English (Nabhan and others 2015). Bract milkweed is poorly studied, but the few known details of the species include: It is toxic to mammals (Rowe and others 1970; Mellado and others 2003); it is closely related to *A. fournieri* Woodson (Fishbein and others 2011, 2018), which occurs in the southern and western range of bract milkweed; and various insects can forage on it (Agrawal and others 2015; Navarro and others 2015). By determining the concentration of defense chemicals in this species, we can determine the suitability of this species for insect development, including monarch and queen butterflies (*Danaus gillipus* Kramer [Nymphalidae]). In this article, we investigate the ecology of bract milkweed by 1) modeling the potential range using MaxEnt; 2) documenting where populations occur in west Texas and southeastern New Mexico, focusing in particular on populations growing near roadsides and right-of-ways; 3) exploring reproductive biology including candidate pollinators and how many seeds a plant can produce; and 4) determining which insect herbivores utilize the plant and the concentration of defensive cardenolides in wild plants compared to laboratory-grown offspring.

METHODS

Field data collection for *Asclepias brachystephana* occurred opportunistically year-round in 2018, 2019, and 2020 by way of foot and driving surveys throughout western Texas and southeastern New Mexico (Figure 1) as part of broader vegetation surveys. We visited most populations only once; however, populations in Ector, Midland, and Reeves Counties, which were publicly accessible, were visited multiple times for phenological data, seed collections, and insect surveys from April through November. We treat pre-existing, managed right-of-ways and roadsides as similar habitat as these areas are mowed at least once a year and experience some vehicle traffic. We also downloaded occurrence data from the Global Biodiversity

Figure 1. We set up one-time, paired 5 m x 50 m (16.5 ft x 165 ft) transects when we found *Asclepias brachystephana* growing in managed right-of-ways including roadsides and pipelines. One transect occurred in the right-of-way (R-o-W) (roadsides, energy, and pipeline right-of-ways) where *A. brachystephana* was observed growing. The other transect was set up in the less managed to unmanaged neighboring vegetation community (Un VC) with the intent to include *A. brachystephana* if present.

Information Facility (GBIF 2020) and utilized photos from iNaturalist uploaded before August 2020.

Eco-Niche Models

We combined our field survey data, which are uploaded on iNaturalist and GBIF, with occurrence data for bract milkweed from GBIF (GBIF 2020) to create models for the potential range of *A. brachystephana.* Data were rarefied at 10 km (6 mi), 20 km (12 mi), and 50 km (31 mi) to reduce spatial bias, using the SDMtoolbox (Brown 2014). Environmental data (30-s resolution) were downloaded from WorldClim (http://www.worldclim.org) (Hijmans and others 2005). Using the occurrence data (GBIF 2020) we created a clip window 2 degrees farther in each north, south, east, and west direction from the farthest point to isolate environmental data and to reduce correlation bias from areas outside the species range. Clipped data were analyzed using a correlation matrix to identify and remove layers that were strongly correlated ($r \geq |0.7|$) (Boria and others 2014). We started with annual minimum temperature because many plants are sensitive to cold temperatures, then precipitation of the driest month, followed by precipitation of the wettest month, which left temperature seasonality. All other layers had correlation values of $r \geq |0.7|$.

Models were run for each of the 3 spatially rarefied occurrence data combined with the above low-correlated environmental data in Maximum Entropy algorithm (MaxEnt v. 3.3.3k), which uses covariates at occurrence points to calculate the conditional probability for an organism to exist at these locations (Elith and others 2011). We ran 100 replicates for each rarefication and evaluated the median and average outputs that failed to include data in the northern range. We selected the average output for the 50 km (31 mi) rarefied data points because it included the most observations for the selection polygon to clip the Worldclim data a second time and create new models.

All WorldClim data were cut to the selected model output and analyzed again using a correlation matrix to identify and remove layers that were strongly correlated ($r \geq |0.7|$) (Boria and others 2014). We again started with annual minimum temperature, then precipitation of the driest month, followed by precipitation of the wettest month, and moved through the layers until all selected layers had correlation values less than 0.7. Final models used Mean Diurnal Range (BIO2), Max Temperature of Warmest Month (BIO5), Minimum Temperature of Coldest Month (Bio6), Mean Temperature of Driest Quarter (BIO9), Precipitation of Wettest Month (BIO13), Precipitation of Driest Month (BIO14), Precipitation Seasonality (BIO15), Precipitation of the Coldest Quarter (BIO19), and 50 km spatially rarefied data.

Plant Phenology

To further elucidate the biology of bract milkweed, we investigated flowering times, seed production, and growth using photos posted to iNaturalist (GBIF 2020) and our own survey data in which we documented presence of flowers and seedpods. We also documented if plants had vegetation, flowers, and (or) mature seedpods. Each observation was kept with the GPS coordinates. These data were then correlated using latitude and dates using Pearson's correlation to clarify if annual phenology correlated with latitude.

Occurrence and Roadside Surveys

When we encountered *A. brachystephana* plants on roadsides or right-of-ways during much broader vegetation surveys, we set up paired, 5 m x 50 m (16.5 ft x 165 ft) transect surveys (N = 41 pairs, 82 transects), once per population, with one transect in the managed area and one transect in neighboring, less often mowed to unmanaged vegetation community (Figure 1). Each transect was surveyed for the total number of plants (that grow from a single crown) and total present seedpods. Milkweeds in these surveys and any surrounding areas were also inspected for herbivorous insects and floral visitors, as well as used for seed collection when possible.

Seed Counts

During plant surveys and on repeat visits to some populations in Ector, Midland, and Reeves Counties, each plant was inspected for maturing and recently dehisced seedpods. Seedpod totals were documented for each population. Old pods that had dehisced and dried were not counted, but freshly dehisced pods were. One mature seedpod was collected from the population when more than 5 seedpods were present at the time (N = 11). When populations could be visited multiple times, repeat seed collections occurred more than 3 mo apart. In total we collected and counted 27 seedpods, from 24 individual plants, across 11 separate populations.

Herbivory and Floral Visitors

During surveys conducted from 2018–2020, and on repeat visits to some populations in Ector, Midland, and Reeves Counties, animals directly feeding on *A. brachystephana* were documented. Nectaring insects were observed for pollinia attached to their legs to identify potential pollinators. Bees and wasps were collected when possible and have been submitted to the Museum of Southwestern Biology, Albuquerque, New Mexico, and USDA ARS Bee Biology Lab, Logan, Utah. We also searched photos posted on iNaturalist under bract milkweed for other insects also captured while utilizing the plants.

Chemical Extractions

Tissue and seed collections were performed in 2018 and 2019, from 4 different populations growing in mowed areas of Ector, Midland, and Upton Counties. A single branch with more than 10 leaves, and flowers if present, were cut and pressed. When present, seeds were also collected and kept with mother plant information.

Tissue and seeds were collected from the plant growing along the roadside in Upton County, Texas. Dehiscing seedpods are visible.

We determined cardenolide concentration (mg/g dry tissue) by high-performance liquid chromatography using a Gemini C18 reversed-phase, 3 µm, 150 mm x 4.6 mm column and an Agilent 1100 series instrument with a diode array detector. Briefly, 50 mg of air-dried pulverized leaf tissue (either from air-dried field-collected leaves or from offspring plants grown in a growth chamber) was analyzed by a methanolic extract. Plants were grown from field-collected seed (see above) using standardized protocols (Züst and others 2019). For both field-collected and chamber-grown tissues, fully expanded leaves were used for chemical analysis.

Using 100% methanol (including a 20 µg digitoxin spike as an internal standard), we added 1.5 ml to each sample with 20 FastPrep beads (MP Biomedicals, California, USA) and agitated twice on a FastPrep-24 homogenizer for 45 s at 6.5 m/s each time, followed by centrifugation at 20,800 g for 12 min. Supernatants were dried down in a vacuum concentrator; resuspended in 16% methanol, 16% acetonitrile, and 68% water solution; and filtered using 0.45 µm hydrophilic polytetrafluoroethylene (PTFE) membranes. Cardenolides were eluted at a constant flow of 0.7 ml/min with a gradient of acetonitrile and water as follows: 0–2 min at 16% acetonitrile; 2–25 min from 16% to 70%; 25–30 min from 70% to 95%; 30–35 min at 95%; followed by 10 min reconditioning at 16% acetonitrile. Peaks were recorded at 218 nanometer (nm) and absorbance spectra were recorded between 200 nm to 300 nm. Peaks showing a characteristic single absorption maximum between 214 and 222 nm, corresponding to an unsaturated lactone functional group, were considered cardenolides. Concentrations of cardenolide compounds were calculated by relating peak areas to the area of the internal standard.

RESULTS

Eco-Niche Model

Our models suggest climatic suitability occurs throughout the Chihuahuan Desert and extends into surrounding ecoregions. The range encompasses areas just south of Mexico City, north to the southern regions of Arizona and central New Mexico, and from the Texas Panhandle west to the Sierra Madre Occidental mountain range. We identify a few isolated areas with potential climatic suitability in Arizona and western Mexico (Figure 2).

Plant Phenology

Analyses of our own survey data and observations with photos on iNaturalist show plants emerge in early to mid-March in the southern regions, and mid to late March in the northern regions (r = 0.343, d.f. = 238, $P < 0.001$). Flowers appeared

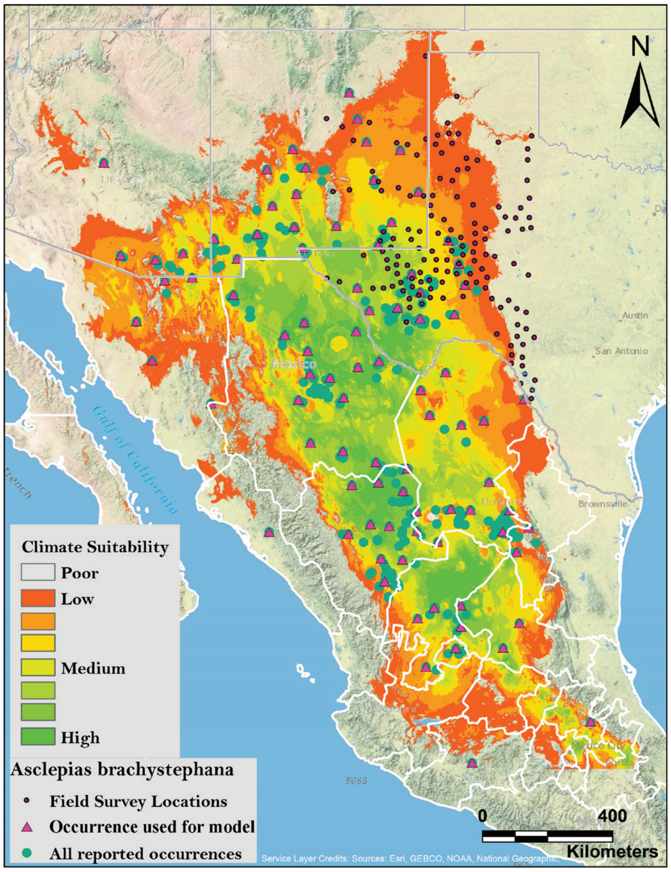

Figure 2. Climate suitability model created using WorldClim data in MaxEnt and occurrence data from GBIF and our surveys. Locations where bract milkweed has been observed are displayed, as are the rarefied observations that were used to create the model. Broader vegetation survey locations are also rarefied to show where we did not encounter bract milkweed growing. This model fails to include 3 observations in the northern, western, and southern extents.

in March, but our analyses suggest seed set occurs later with pods first forming in the southern regions and peaking around August in the northern regions (r = 0.349, d.f. = 60, $P < 0.01$) (Figure 3).

Occurrence and Roadside Surveys

We observed bract milkweed plants in Eddy and Lea Counties in New Mexico and in Andrews, Ector, Glasscock, Midland, Pecos, Reeves, and Upton Counties in Texas growing mostly on roadsides and a few pipeline right-of-ways. During broader vegetation surveys, hundreds of miles were surveyed on foot in less managed, natural areas that were not roadsides or right-of-ways and mostly comprised mesquite shrublands, desert thornscrub, dry grasslands, and yucca-dominated plant communities. Only 3 populations, all of which had less than 10 individuals, were encountered with these surveys. We also surveyed hundreds of miles of roadsides and right-of-ways and found more than 40 bract milkweed populations in these disturbed areas. We investigated bract milkweed density in these managed roadsides and right-of-ways and if populations spread into less managed areas (N = 41 locations, 82 transects) and found no milkweeds occurring in parallel transects outside of the mowed roadside or right-of-way. Density of plants within transects on roadsides and right-of-ways (250 m^2) ranged from 1 to 61 plants per transect.

Seed Counts

The populations of bract milkweed that we surveyed produced a maximum of 90 seedpods at one time per 250 m^2 (2690 ft^2), which occurred in the transect with the most plants. Of the plants we surveyed, seedpod counts ranged from 0 to

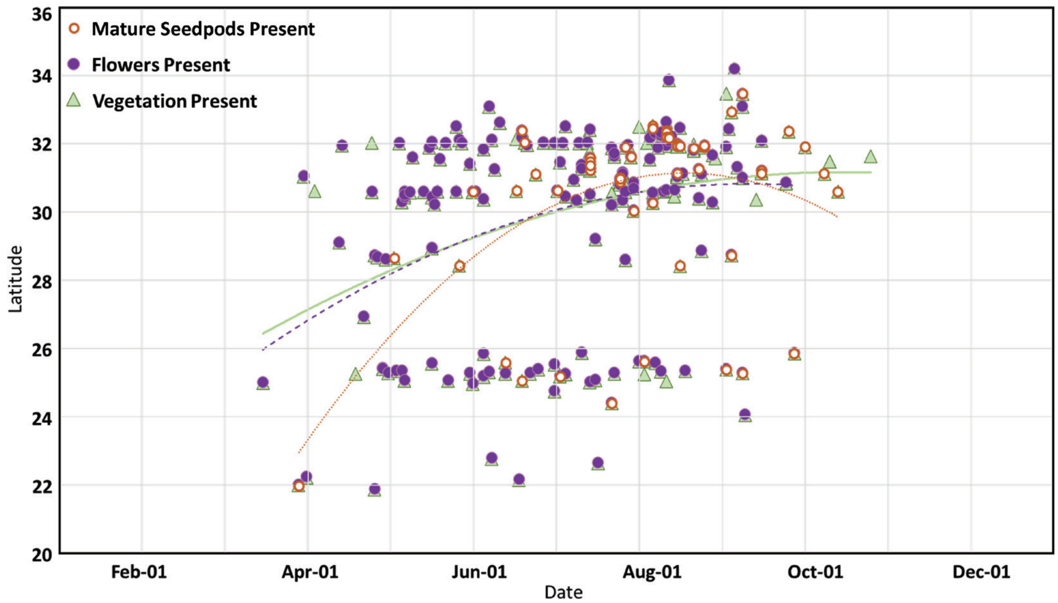

Figure 3. Plant phenology of bract milkweed observed from both *in situ* and photographed observations on iNaturalist, plotted by date and latitude. Seed set and blooming occur first in southern latitudes.

36 pods per transect, with the average seedpods per plant at any given time being 1.24. Seeds per pod ranged from 40 to 86 seeds, with an average of 65 ± 12.38 (n = 27) seeds per pod.

Floral Visitors and Herbivory

We observed 5 species of butterflies, 5 bee genera that we were unable to identify to species, 3 bee species we could identify, and 3 wasp species (Table 1). Of all the specimens we observed, only Red-legged *Centris* bees (*Centris rhodognatha* Cockerell [Apidae]) were found with pollinia attached to their legs.

Among insect herbivores, we encountered oleander aphids feeding on bract milkweed most often. We also observed western milkweed bugs present on plants and seedpods. Less commonly we observed small milkweed bugs and large milkweed bugs feeding on seedpods. Over the course of 2 y, we found only 2 caterpillars, both were queen butterflies (Table 1). Using photographs from iNaturalist, we were able to find additional photos of larval queen butterflies on bract milkweed, as well as larvae of *Lerina incarnata* (Erebidae) and a milkweed tussock moth larva (*Euchaetes* sp. [Erebidae]).

Cardenolide Concentrations

Tissue collected from the wild had 35% higher concentrations of cardenolides than did the offspring grown in a laboratory ($F_{1,17}$ = 13.442, P < 0.001), and populations were highly variable ($F_{3,17}$ = 13.292, P < 0.001) (Figure 4).

DISCUSSION

Our analyses suggest climatic suitability for bract milkweed exists throughout the Chihuahuan Desert and neighboring

TABLE 1

Insect species observed eating bract milkweed and visiting flowers.

Common name	Scientific name
Herbivores	
Oleander aphid	*Aphis nerii* Fonscolombe (Aphididae)
Queen butterfly larvae	*Danaus gillipus* (larvae) Kramer (Nymphalidae)
Milkweed tussock moth (larvae)	*Euchaetes* sp. (larvae) Harris (Erebidae)
Crimson-bodied lichen moth (larvae)	*Lerina incarnata* (larvae) Walker (Erebidae)
Predators	
Seven-spotted lady beetle	*Coccinella septempunctata* Linnaeus (Coccinellidae)
Convergent lady beetle	*Hippodamia convergens* Guérin-Méneville (Coccinellidae)
Syrphid fly (larvae and pupae)	Syrphidae (larvae and pupae)
Seed Eaters	
Western small milkweed bug	*Lygaeus kalmia* ssp. *kalmii* Stål (Lygaeidae)
Small milkweed bug	*Lygaeus reclivatus reclivatus* Say (Lygaeidae)
Large milkweed bug	*Oncopeltus fasciatus* Dallas (Lygaeidae)
Floral Visitors	
Honey-tailed sweat bee	*Agapostemon melliventris* Cresson (Halictidae)
Metallic green sweat bee	*Agapostemon* sp. Guérin-Méneville (Halictidae)
Augochloropsis metallica (bee)	*Augochloropsis metallica* Fabricius (Halictidae)
Anthophorula compactula (bee)	*Anthophorula compactula* Cockerell (Apidae)
Western Pygmy-Blue (butterfly)	*Brephidium exilis* Boisduval (Lycaenidae)
Red-legged *Centris* (bee)	*Centris rhodopus* Cockerell (Apidae); *Centris rhodognatha* Cockerell
Reakirt's blue (butterfly)	*Echinargus isola* Reakirt (Lycaenidae)
Metallic sweat bee	*Lasioglossum (Dialictus)* spp. Curtis (Halictidae)
Metallic sweat bee	*Lasioglossum* spp. Curtis (Halictidae)
Eufala Skipper (butterfly)	*Lerodea eufala* Edwards (Hesperiidae)
Leaf cutter bee (bee)	*Megachile* sp. Latreille (Megachilidae)
Leda minstreak (butterfly)	*Ministrymon leda* Edwards (Lycaenidae)
Paracentris sp. (bee)	*Centris* (*Paracentris*) sp. Fabricus (Apidae)
Apache paper wasp	*Polistes apachus* Saussure (Vespidae)

Red-legged *Centris* bees visiting bract milkweed flowers in a roadside population, Reeves County, Texas. These bees were collected with pollinia on their legs, making them a likely pollinator of this milkweed.

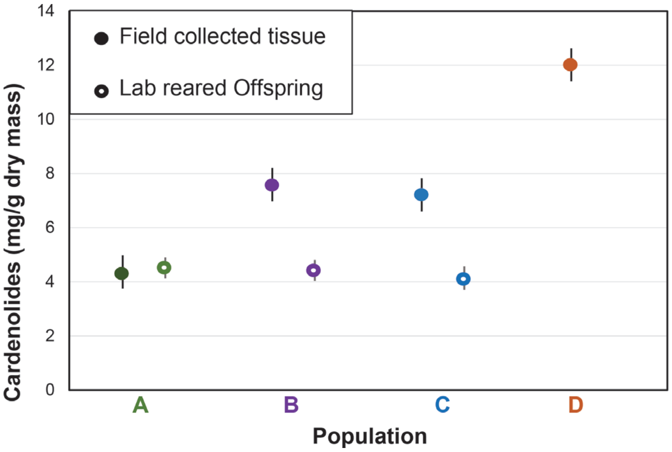

Figure 4. Cardenolide concentrations of bract milkweed from collected tissue of 4 maternal plants from wild populations and their laboratory-reared offspring. Population D did not produce any seeds. All populations occurred in areas that appeared to be mowed annually. Populations are Roadside (Faudree Rd) Ector County (A); Annually mowed vacant lot, Midland, Texas (B); Disc golf area in Tumbleweed Park, Midland, Texas (C); Roadside (349) Upton County, Texas (D).

ecoregions. Our models used data from GBIF and our own field surveys, which show populations occurring from north-central New Mexico to just south of Mexico City (Figure 2). In comparison, previous reports from the Xerces Society report bract milkweed from the northern extent of southeastern Arizona to West Texas and south through Coahuila and Sonora Mexico (Nabhan and others 2015), which agrees with our models and older reports (Woodson 1954). Although we thoroughly surveyed across Eddy and Lea Counties, New Mexico, and Andrews, Crane, Ector, Midland, Pecos, Reeves, Ward, and Winkler Counties, Texas, we did not find any bract milkweed populations around the southeastern corner of New Mexico (Figure 2). Our MaxEnt models, however, suggest these same areas where we did not find any populations of bract milkweed are climatically suitable. Therefore, other environmental factors, such as soil, are likely to be important for populations to establish.

Our surveys of bract milkweed illustrate this plant is already successful in colonizing roadsides and right-of-ways throughout the northeastern region of its predicted range (Figure 2) and is utilized by a variety of insects (Table 1). Additionally, analyses of our roadside and right-of-way surveys suggest populations prefer these disturbed, managed areas more than non-managed areas. At every population we encountered during the surveys, we further inspected each location looking for bract milkweed outside of transects to gather more seed, insect, and phenology data. No encountered populations were observed to be spreading into unmanaged areas, indicating that if plants are used in roadside conservation plans, they are unlikely to aggressively spread into nearby, less-managed properties. The 3 populations in areas outside of right-of-ways that we encountered during hundreds of miles of surveys were not close enough to any managed area to create a paired transect. Furthermore, these plants did not have any insects or seedpods, so they were used only for our range and phenology analyses.

Where plants are grown, the stimulus they receive (including mowing and herbivory), as well as genetic factors can affect the toxicity of plants (Karban and Myers 1989; Karban and Baldwin 1997). Plant tissue we collected from areas that were clearly mowed at least once a year produced more cardenolides than laboratory-grown offspring (Figure 4). The offspring grown in similar conditions to one another had similar cardenolide concentrations, whereas collected wild tissue had more variation. We do not know how often or how recently plants may have been mowed, which may affect the observed chemical defense concentrations. Nonetheless, bract milkweed has high cardenolide concentrations compared to many other milkweed species (Agrawal and others 2012b), which may make it less palatable to some insect and mammalian herbivores (Rowe and others 1970; Mellado and others 2003).

During our surveys, we found queen butterfly larvae (Table 1), which were consuming plants growing on roadsides, and it is reported that monarch butterflies can successfully mature on bract milkweed (Agrawal and others 2015; Navarro and others 2015). This finding indicates bract milkweed might be suitable for butterfly gardens and conservation plantings. In addition, we documented oleander aphids most often feeding on plants both in surveyed roadsides and right-of-ways as well as in photographs. However, oleander aphids are known to be negatively affected by higher concentrations of cardenolides (Birnbaum and others 2017), and we did not collect data to measure the health of these aphids. We also encountered 3 species of seed eaters (Table 1), which may cause problems if these plants are grown for seed production or for conservation projects. Additionally, our surveys documented several species of predatory insects, including native and invasive lady beetles and syrphid fly larvae (Table 1) that we presume were feeding on oleander aphids; these insects may also nectar-feed on flowers, suggesting bract milkweed supports a variety of insects.

Our analyses show bract milkweed starts blooming in mid-March (Figure 3), which is earlier than previous reports published in 1954 documenting blooms appearing in April (Woodson 1954). This earlier bloom may be attributed to climate change (Bartomeus and others 2011; Fazlioglu 2019) or possibly because of more thorough sampling of the range and annual phenology. Flowers were used by numerous insects including various butterflies and bees (Table 1), suggesting bract milkweed will benefit a variety of pollinators if used in conservation plantings. Since our data were collected opportunistically and mostly in the afternoon and late evenings, more research is needed to document the total breadth of insect species visiting flowers and feeding on plants. Of all the insects we collected from bract milkweed flowers, red-legged *Centris* bees were the only insect with pollinia attached to legs, suggesting it is a candidate pollinator for this milkweed species. Among other milkweed species, large-bodied hymenopterans including larger species within Apidae (bumble bees, honey bees, carpenter bees) as well as representatives from Pompilidae, Scoliidae, and Vespidae are common pollinators (Kephart 1983; Fishbein and Venable 1996; Hallett and others 2017).

In recent decades, studies have shown that conservation plans on right-of-ways with proper vegetation management can slow insect-pollinator declines (Donald and Evans 2006; Carvalheiro and others 2013) and in some cases can be useful in insect conservation areas (Ries and others 2001; Hopwood 2008; Wojcik and Buchmann 2012).With more than 25,000,000 km (15,535,000 mi) of road and 300,000 km (186,420 mi) of electrical right-of-ways in the US (Wojcik and Buchmann 2012) as well as pipeline and railroad right-of-ways, interest is growing in using these areas for wildlife habitat conservation (Hopwood 2008; Wojcik and Buchmann 2012). Although localized assessments of suitable plant species are needed for regional groups to identify appropriate native plants to reach conservation goals, a few common characteristics have been identified (Karim and Mallik 2008; Haan and others 2012; Bochet and García-Fayos 2015). These characteristics should presumably work for suitability or other right-of-ways that maintain early successional habitats. Characteristics of roadside habitat that plants must be able to tolerate include:

Reduced humidity and higher ambient temperatures (Forman and others 2003);

Non-native soil parameters including imported soil, gravel substrate lacking topsoils and nutrients (Forman and others 2003);

Compaction (Berli and others 2003), which occurs from vehicles as well as construction and maintenance equipment;

Various mowing regimes (Baum and Mueller 2015; Knight and others 2019);

Pollutants including heavy metals (Wheeler and Rolfe 1979; Ho and Tai 1988; Jaradat and Momani 1999);

Salts used for ice control (Bryson and Barker 2002; Green and others 2008);

NOx (nitrogen oxides) from vehicle emissions, which increases soil nitrogen (Green and others 2008; Mitchell and others 2020); in addition to

Regular climatic variables that determine the range of a species.

Our data suggest bract milkweed is already successful on roadsides, can produce many seeds per plant each year, and is utilized by various insects including pollinators. Therefore, we conclude bract milkweed is likely well suited for roadside restoration projects.

CONCLUSIONS

Bract milkweed occurs throughout the Chihuahuan Desert with populations occurring in nearby ecoregions. A myriad of insects including beneficial pollinators utilize the floral resources and a small number of insect-herbivores feed on the plant tissue of this cardenolide-rich milkweed species. Our surveys suggest bract milkweed is a successful roadside colonizer and is therefore a good candidate for roadside restoration and right-of-way re-seeding projects.

ACKNOWLEDGMENTS

We thank Flatrock Engineering and Environmental for their assistance with field surveys and U.S. National Science Foundation Grant IOS-1907491, which supported chemical analyses.

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