# FALL AVAILABLE TROPICAL MILKWEED (*ASCLEPIAS CURASSAVICA* L.) MAY BE A POPULATION SINK FOR THE MONARCH BUTTERFLY

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## ABSTRACT

Native plants provide the best habitat for pollinators, but non-native plants can supply resources to native pollinators. The non-native tropical milkweed (bloodflower or scarlet milkweed), *Asclepias curassavica* L., is a larval food source for the native monarch butterfly (*Danaus plexippus*). *Asclepias curassavica* has been widely planted in the southern U.S. where it blooms until late fall, retains healthy vegetation until frost, and does not die back until a hard freeze. In contrast, native *Asclepias* species senesce and are usually not suitable for monarch larvae consumption in the fall. The late availability of the non-native milkweed may trigger monarchs, normally migrating to Mexico, to break reproductive diapause and lay eggs on their host plant. To determine if non-native *A. curassavica* was more likely than native *Asclepias* species to attract egg-laying monarchs, we grew native *Asclepias viridis* Walter and *Asclepias speciosa* Torr. along with *A. curassavica* in Oklahoma and recorded the number of monarch eggs and caterpillars on each plant. From August 2019 until the first freeze, we observed 145 eggs and 39 caterpillars on 40 of 48 *A. curassavica* plants and one egg on one of 19 native *Asclepias* plants. First freeze occurred on 12 October. A majority of eggs were laid after 12 September resulting in most eggs having insufficient time to mature. This freeze date was nearly 3 weeks earlier than the average for this area. Our evidence suggests that the monarchs are differentially reacting to the availability of non-native and native *Asclepias* during late summer and fall.

## INTRODUCTION

Pollinator gardens have become a popular landscaping trend in recent years (Majewska and Altizer 2018). With the continued loss and fragmentation of native habitats, millions of private citizens have decided to take conservation action at their own home, school, and businesses (Phillips 2019). Using native plants in a garden or planned landscape provides the best habitat for native pollinators (Burghardt et al. 2009). However, the availability of native species for landscaping lags behind non-native cultivars. Yet, there are a variety of non-native species that can provide food, both for adults and larvae, for our native pollinators. The advantage of using some non-natives in a pollinator garden is that they are easy to grow and widely available.

One of the most popular species to attract to pollinator gardens in North


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America is the monarch butterfly (*Danaus plexippus*). The most common conservation action associated with the monarch butterfly is to plant the larval host plant – milkweed (*Asclepias*). The easily cultivated and widely available tropical milkweed (also known as bloodflower and scarlet milkweed), *Asclepias curassavica* L., is a popular species grown in Oklahoma and other southern states (Figure 1). This species is also the most popular species for rearing monarchs indoors, although this practice has been called into question because of potentially negative effects captive rearing has on the migratory behavior of the species (Tenger-Trolander et al. 2019). *Asclepias curassavica* is a non-native species that, when grown in Oklahoma, blooms late into the fall, retains healthy vegetation until frost, and does not fully die back until the first hard freeze. In contrast, by late summer, vegetation of native *Asclepias* species is often old, tough, or senesced and generally not suitable as a food source for monarch larvae (Zalucki and Kitching 1982, Baum and Sharber 2012).

Figure 1 Tropical milkweed, *Asclepias curassavica*, a non-native species, is a popular plant to grow in Oklahoma and other southern states because it is easily cultivated, with a long blooming season of strikingly bold flowers. Not only is it a showy addition to gardens, it also is a host plant for the monarch butterfly caterpillar. However, our research suggests that late summer and fall availability of *A. curassavica* may be detrimental to migrating monarch butterflies.

The charismatic monarch butterfly has caught the attention of the public and conservationists, who have made it a symbol of nature, environmental health, spiritual renewal, and safe passage across borders (Gustafsson et al. 2015). In 2014, the U. S. Fish and Wildlife Service was petitioned by the Center for Biological Diversity to list the monarch butterfly as an Endangered Species (U. S. Fish and Wildlife Service 2020). With the potential for required conservation activities if listed as endangered, many entities are interested in proactive conservation that will bolster the population without the need for federal regulation. This situation has inspired conservation actions by citizen groups, tribal collaborations, state agencies, and agricultural organizations within Oklahoma (Oklahoma Monarch and Pollinator Collaborative 2016).

Oklahoma lies directly in the path of monarch butterfly migration from Mexico to the upper Midwest, making our location critical for monarch conservation both during the spring and fall migrations. The annual monarch migration takes four to five generations to complete the entire migratory cycle. Monarchs that populate central and eastern North America in the summer will overwinter as adults in mountainous habitat in Mexico. In the early spring, the overwintering adults become reproductively active and begin to migrate north. Depending on the weather conditions, adults usually lay eggs on host plants in Texas and Oklahoma during the spring to produce the first generation of the year. After those eggs hatch, develop through the caterpillar instars, pupate in chrysalises, and eclose as adults, the first-generation butterflies will continue to travel north and have two to three more generations, a majority of them in the upper Midwest. In the late summer, adult butterflies will begin the return journey south. Some will be reproductively active and will lay eggs on available host plants in Oklahoma during August through October for the 4$^{th}$ or 5$^{th}$ generation of monarchs for the year (Baum and Sharber 2012, Flockhart et al. 2013, 2017).

Monarchs have been shown to enter reproductive diapause during the fall migration based on three environmental cues: photoperiod, temperature, and availability of milkweed host plants (Zalucki and Kitching 1982, Goehring and Oberhauser 2002, Baum and Sharber 2012). If one of these cues changes, such as warm fall temperatures or available milkweed, monarchs will break diapause and reproduce during the typical fall migratory time (Goehring and Oberhauser 2002, Malcolm 2018). This has implications for the persistence of the migratory behavior under climate change scenarios (Tenger-Trolander et al. 2019). While much of the native milkweed has senesced in the late summer and early fall, *A. curassavica* is available with attractive vegetation well into fall until the first hard freeze. Majewska and Altizer (2019) demonstrated that captive-reared monarch larvae fed a diet of *A. curassavica* under fall-like conditions are more likely to be reproductively active than those reared on native species. Additionally they demonstrated that female monarchs caught during fall migration showed greater egg development when exposed to *A. curassavica* (Majewska and Altizer 2019). Depending on the timing, additional reproduction during what is typically considered the fall migration period could positively or negatively affect the monarch population. Reproduction in late summer may add a generation to the annual cycle, allowing younger individuals to complete the now-shorter migration to Mexico. However, laying eggs in late fall may be a reproductive sink if larvae do not have time to mature to the adult butterfly stage before freezing temperatures and continue the migration south.

We were interested in investigating what effect the availability of *Asclepias*, both native and non-native species, had on the reproductive behavior of monarchs moving across Oklahoma in late summer. To determine if the non-native *A. curassavica* was more likely than native *Asclepias* species to attract egg-laying monarch butterflies late into the growing season and during the migratory period, we grew two native *Asclepias* species and *A. curassavica* outdoors in central Oklahoma and made observations of monarch eggs and caterpillars during the late summer and early fall of 2019.

## METHODS

We cultivated two milkweed species native to Oklahoma, *Asclepias viridis* Walter and *A. speciosa* Torr. and the non-native *A. curassavica* in outdoor raised beds at the Aquatic Research Facility on the campus of the University of Oklahoma, Norman, OK (35.1833 N, -97.4485 W). This research site, on the edge of an urban area, has natural habitat within 0.25 km of our raised beds. The environment surrounding the beds is mowed lawn and artificial ponds used for aquatic research. Within a circular fabric raised bed (1.25 m diameter x 0.3 m tall, Smart Pot® www.smartpots.com), we planted eight greenhouse-raised plants of a single species of milkweed surrounding native nectar plants, including *Symphyotrichum novae-angliae* (L.) G. L. Nesom and *Vernonia fasciculata* Michx. with *Verbesina encelioides* (Car.) Benth. & Hook. f. ex A. Gray dominating. We planted six beds of each milkweed species, totaling 48 individuals of each species (Figure 2). Beds were arranged in a 3 x 6 grid and *Asclepias* species were randomly assigned beds. Beds were watered equally as needed during the growing season. Walkways between beds were covered with landscape weed barrier fabric. Non-target species were removed by hand from within the beds and cut using a string trimmer outside of the beds. Nectar plants were pruned regularly to ensure the *Asclepias* had ample room to grow (Figure 3). Following the methods of Zalucki and Kitching (1982) we inspected all milkweed foliage, including the underside of the leaves, for monarch egg and caterpillar presence twice a week (Figures 4 and 5). Based on monarch sightings in Oklahoma reported to Journey North's migratory database (https://maps.journeynorth.org/maps), our observations began 12 August when monarchs were beginning to be reported in northern Oklahoma. We recorded the number of eggs and caterpillars found on each plant and noted caterpillar instar, 1-5 (Oberhauser and Kuda 1997).

## RESULTS

Many plants of the two native *Asclepias* species failed to thrive, with only two out 48 *A. viridis* plants and 17 out of 48 *A. speciosa* plants having live aboveground vegetation in the late summer. However, all native plants that survived the summer had senesced by late August. All 48 *A. curassavica* survived through the summer and fall until our first freeze.

From 12 August to 15 October, we observed 145 eggs and 39 caterpillars on 40 of the 48 *A. curassavica* plants and 1 egg on an *A. viridis* plant. Because of the loss of 77 of the 96 native *Asclepias* plants, we were not able to conduct a statistical analysis to compare the native versus non-native milkweed usage by monarchs. Yet, despite the unequal and small sample size, our data indicate that monarchs were highly attracted to the *A. curassavica* vegetation for egg laying during fall migration.

The majority of the eggs were laid between 10 September and 26 September (Figure 6). During this interval, 101 eggs and 39 caterpillars were recorded. The final eggs we found were on 1 October. The total number of eggs observed during the duration of the study was 145. Additionally, during the entire duration of the study, we found no caterpillars older than 3rd instar and no chrysalises. On 12 October, nighttime temperature dropped below freezing, killing all aboveground vegetation of *A. curassavica*. We continued to inspect the area for caterpillars and eggs until 15 October. In ideal temperature conditions monarchs need 24 days to mature from egg to adult (Zalucki 1982). Development of larvae is generally slower during the cooler fall conditions. In 2019, our first freeze occurred on 12 October and more than half of the eggs were laid after 12 September. Consequently, the majority of monarch eggs had insufficient time to mature before the first freeze.

Figure 2 Circular fabric raised beds (1.25 m diameter x 0.3 m tall, Smart Pot® www.smartpots.com) were filled with commercial topsoil and arranged in a 3 x 6 grid with landscape weed barrier fabric between beds. The research site, on the edge of an urban area, has natural habitat within 0.25 km of our raised beds.

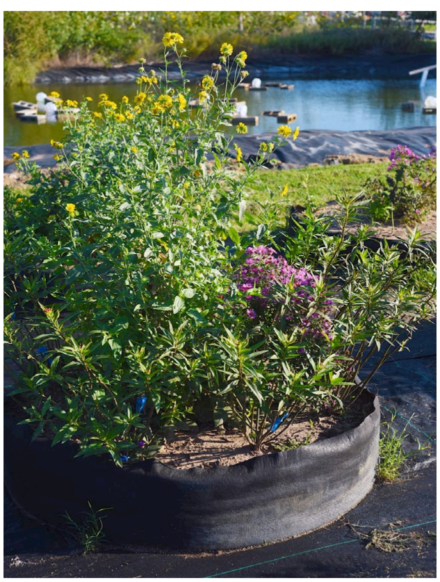

Figure 3 Raised bed of *A. curassavica* and nectar plants in bloom on 27 September 2019

Figure 4 Monarch butterfly egg, circled in red, on the underside of an *A. curassavica* leaf (yellow aphids can also be seen to the upper left)

Figure 5 Third instar monarch caterpillar on the lowest leaf of one of 48 *A. curassavica* plants in the research beds

## DISCUSSION

As an easy-to-cultivate plant with a long blooming season of strikingly bold flowers, gardeners have embraced *A. curassavica* as a beautiful addition to their garden that also has conservation value. Yet, the use of *A. curassavica* as a species for monarch conservation has been under scrutiny for the past several years by conservationists (Monarch Joint Venture n.d., Wheeler 2018). Monarch researchers have shown *A. curassavica* to be a problematic species for monarchs because of the increased likelihood of this species to harbor the deadly protozoan *Ophryocystis elektroscirrha* (*OE*) from season to season (Satterfield et al. 2015). This organism is a natural parasite of the monarch butterfly, but where *Asclepias* does not die back at the end of the growing season *OE* can reach high levels and wipe out local monarch populations. When *Asclepias* is available all year, overwintering and winter reproduction has been documented in Florida, Texas, South Carolina, Louisiana, Georgia, Alabama, Mississippi, and North Carolina (Howard et al. 2010). There is a concern that increased *OE* will eliminate these populations. In Oklahoma, our winter conditions do not currently allow year-round growth of *A. curassavica*, but that is likely to change with global climate change. Areas in Texas, Florida, and along the Gulf Coast are already seeing signs of *A. curassavica* becoming invasive (EDDMapS 2020). Additionally, captive-bred monarchs are more susceptible to diseases, and in particular *OE* can easily spread to natural populations when captives are released for education or entertainment, such as at festivals, weddings, or other celebrations (Journey North 2015).

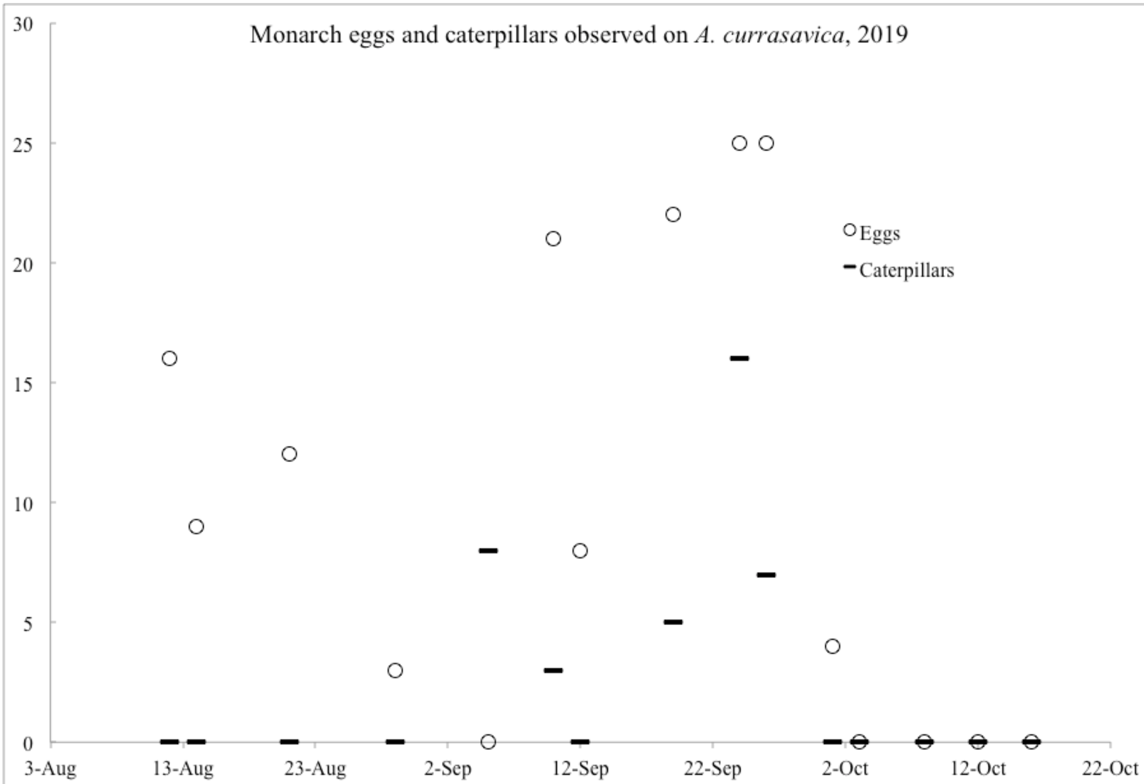


Figure 6 Egg and caterpillar abundance over the course of the study.

The results of our study indicate that the availability of *A. curassavica* in the fall could be detrimental to migrating monarchs. Instead of fueling their flight to Mexico, monarchs exposed to *A. curassavica* may break reproductive diapause to lay eggs late in the season and not complete the fall migration. These late-laid eggs may not have sufficient developmental time to reach the adult butterfly stage and continue the migration south to overwintering sites. The presence of *A. curassavica* has been shown to trigger reproductive physiology and behavior in monarchs. Majewska and Altizer (2019) exposed migrating females to *A. curassavica* and found they showed greater egg development when compared to exposure to native milkweeds. While the native *Asclepias* in our research beds did not thrive in the summer, the 19 native plants with foliage during this period only attracted a single female to lay a solo egg on a 5.1 cm tall *A. viridis* plant. The presence of 48 *A. curassavica* plants in our study, however, enticed reproductive females to lay over 100 eggs throughout the late summer and fall. Research by Baum in Oklahoma (Baum and Sharber 2012, Dee and Baum 2019) show that mowing and fire can stimulate new growth in native *Asclepias*, making fresh foliage available and attractive to monarchs during the late summer and early fall. Unfortunately, since the native species did not grow well during our study, the data we collected in 2019 are insufficient to demonstrate that *A. curassavica* is more likely to attract reproductive females than native species. Growth of the native species in the raised research beds during the 2020 growing season indicate that we will be able to make better comparisons during a second year of observation.

Our observations from the fall of 2019 do indicate that none of the eggs laid during the late summer and early fall reached adulthood. The first eggs were laid at our research site on 12 August, which would have been plenty of time to reach maturity. However, no caterpillars beyond the 3rd instar or chrysalises were found during the entirety of the study. This is not unexpected given that fewer than 10% of monarch eggs will become adults due to basic mortality causes (Zalucki and Kitching 1982, Goehring and Oberhauser 2002). However, the larval host plant might have contributed to greater mortality. Compared to *Asclepias* species native to northern North America, *A. curassavica* has higher levels of cardenolides, a secondary compound that *Asclepias* plants generate to deter herbivory (Rasmann and Agrawal 2011). Instead of being repelled by them, the monarch caterpillar exploits the cardenolides by sequestering the toxin as a predator and parasite defense. The production of cardenolides in *A. curassavica* is increased with increasing temperature with the potential of high enough concentrations to negatively impact caterpillar fitness. Faldyn et al. (2018) found that monarch fitness was lowered when feeding on *A. curassavica* that was exposed to daytime temperatures of 35°C, which stimulated increased concentration of cardenolides. The average high temperature during August 2019 in central Oklahoma was 34.4°C with 15 days exceeding 35°C (Brock et al. 1994, McPherson et al. 2007, Oklahoma Climatological Survey 2020). These temperatures could have activated the increased production of cardenolides in the *A. curassavica* in our research beds, contributing to caterpillar mortality. Future research into the cardenolide concentrations in fall-growing *A. curassavica* could help to elucidate this confounding factor.

In our study, a majority of the eggs were laid less than one month before the first freeze of the year. While adult monarchs have been known to survive freezing temperatures during their fall migration (Troyer et al. 1996), caterpillars are less tolerant of freezing temperatures and development significantly slows at temperatures below 16°C (Rawlins and Lederhouse 1981). *A. curassavica* is relatively tender and cannot tolerate temperatures below freezing (Floridata n.d.). In 2019, the first hard freeze in central Oklahoma occurred on 12 October (Brock et al. 1994, McPherson et al. 2007, Oklahoma Climatological Survey 2020), causing all *A. curassavica* foliage to die and leaving any remaining eggs or caterpillars without a host plant. This was one of the earliest fall freeze dates on record for this area. The average date of the first freeze in central Oklahoma occurs between 28 October and 2 November. Over the past decade, the first freeze date ranged from 12 October to 19 November (Table 1; Brock et al. 1994, McPherson et al. 2007, Oklahoma Climatological Survey 2020). Therefore, in eight years of the last decade, eggs laid as late as 1 October would have had ample time to reach maturity. As first freeze date shifts later in the year due to climate change, we can expect that eggs as late as 15 October might reach maturity. In an average year, most of the eggs laid in our research beds would have reached maturity. It is uncertain, however, how many more eggs would have been laid by adults if we did not have the early cold snap.

Table 1 Date of first freeze in central Oklahoma as recorded by Norman Mesonet weather station (Brock et al. 1994, McPherson et al. 2007, Oklahoma Climatological Survey 2020) *Complete metamorphosis is estimated to be 24 days from egg to adult under ideal temperature conditions (Zalucki 1982). During late summer and early fall, the temperature will drop below this ideal range and cause larval development to slow. Consequently, this date is likely to be significantly earlier.

| Year | Date of first freeze | Last date of egg laid that could possibly reach maturity* |
|---|---|---|
| 2009 | 18 Nov | 26 Oct |
| 2010 | 5 Nov | 12 Oct |
| 2011 | 3 Nov | 10 Oct |
| 2012 | 27 Oct | 3 Oct |
| 2013 | 12 Nov | 18 Oct |
| 2014 | 1 Nov | 8 Oct |
| 2015 | 13 Nov | 19 Oct |
| 2016 | 19 Nov | 27 Oct |
| 2017 | 27 Oct | 3 Oct |
| 2018 | 9 Nov | 15 Oct |
| 2019 | 12 Oct | 17 Sept |

As ecologists, we cannot make firm conclusions on ecological phenomena from one year of data, especially a year with weather data well outside the average. The planting of milkweed for monarchs seems to be a straightforward conservation strategy, but our evidence and that from many other researchers supports the use of native *Asclepias* species rather than non-native species for pollinator conservation gardens and landscaping. With the increased demand of native plants to be commercially available to the public, we anticipate the availability of native *Asclepias* will increase and provide a supply to gardeners and conservationists who want to improve their habitat for monarchs. We will continue to observe the use of the native and non-native *Asclepias* in central Oklahoma with the hope that our work can help direct conservation strategies to best protect this iconic migratory invertebrate.

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