COLLEGE OF AGRICULTURE AND LIFE SCIENCES
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MOSQUITO AND TICK REPELLENTS

Dawn H. Gouge, Shujuan (Lucy) Li, Shaku Nair, Kathleen Walker, Christopher S. Bibbs

Introduction

Personal repellents (often referred to as "**bug sprays**") are substances applied to skin, clothing, or other surfaces to repel or discourage insects and other arthropods such as ticks from feeding on humans. Repellents help people avoid bites from mosquitoes, ticks, and other biting arthropods that may transmit disease-causing pathogens, and allow them to engage freely in outdoor activities.

Mosquitoes and ticks are medically significant pests that affect the health and wellbeing of Arizona residents. They can cause a variety of health problems due to their ability to vector (transfer) viruses and other disease-causing pathogens. Southern house (*Culex quinquefasciatus*), western encephalitis (*Culex tarsalis*), and yellow fever (*Aedes aegypti*) mosquitoes are of greatest concern to most people. Mosquito-vectored diseases of humans include West Nile fever and St. Louis encephalitis. Emerging diseases of concern include dengue fever, chikungunya, and Zika. Different mosquitoes vector specific diseases, for more information see https://cals.arizona.edu/apmc/docs/Gouge-Mosquitoes_arboV.pdf. Many mosquito species are not vectors of any human disease-causing pathogens.

Other than mosquito vectors, brown dog ticks (*Rhipicephalus sanguineus*), and "soft ticks" (*Ornithodorus*) are the most important in-state disease vectors. Brown-dog ticks vector *Rickettsia rickettsia*, which causes Rocky Mountain spotted fever, and soft ticks vector *Borrelia* bacteria which causes tick-borne relapsing fever. Lyme disease is caused by the bacteria *Borrelia burgdorferi* and is vectored by the western black-legged tick (*Ixodes pacificus*), which is found only in the higher elevations of the Hualapai Mountains. Gulf Coast ticks (*Amblyomma maculatum)* have been found to vector *Rickettsia parkeri* in Arizona. The American dog tick (*Dermacentor variabilis*) and Rocky Mountain wood tick (*Dermacentor andersoni*) found in northern Arizona are also vectors of *Rickettsia rickettsia*, and the bacterium *Francisella tularensis* the bacterium that causes Tularemia.

West Nile fever is currently the most common vector-borne disease affecting humans in Arizona. The elderly are at a higher risk of suffering severe medical symptoms. Between 2010-2015, the CDC reported an average of 2,376 West Nile cases in the continental U.S. per year (around 100 each year in Arizona). The number of cases varies greatly in the continental U.S. year to year and, sadly, an average of 125 deaths occur annually. **These deaths are preventable.**

Arizona is also home to a number of biting flies, including biting midges, black flies, horse flies, and deer flies which can inflict painful bites that cause irritation that persists for days. Chiggers are immature Trombiculidae mites, and generally are more prevalent during the monsoon season. Chiggers do not burrow under the skin, but cause irritation and discomfort by feeding on the skin surface. Chiggers attach themselves to the skin surface, hair follicles or pores, using very short and delicate mouthparts. Bites from some of these organisms are relatively painless, but during feeding, they inject an irritating fluid that may cause itchy, uncomfortable reactions.

Application of repellents to the skin is a common personal protection practice. The effectiveness of this technique, however, depends on many factors.

This article provides details about how to choose a repellent, details on the different types of repellents, and advice on how to use personal repellents safely.

Choosing a Personal Repellent

Personal repellents are available in various forms and concentrations. Aerosol and pump-spray products are often intended for skin applications as well as for treating clothing. Liquid, cream, lotion, spray, and stick products facilitate direct application to the skin. Products with a low concentration of active ingredient may be appropriate for situations where exposure to biting arthropods is minimal. A higher concentration of active ingredients is often useful in highly infested areas. In addition to repellent use, always practice non-chemical ways to deter biting arthropods, such as window and door screens, bed netting when camping, and light-colored clothing with loose fitting long-sleeves, long pants and socks. Use protective clothing when exposure to mosquitoes or ticks cannot be avoided (Gouge et al. 2016). However, ticks are very capable of moving inside clothing layers.

Be aware that most repellents are not effective against stinging insects (bees, wasps, hornets, etc.) or bed bugs.

Before selecting a repellent, here is what you need to consider:

1) Do you need protection from mosquitoes, ticks or both?
2) How long (in hours) will you need protection?
3) What will you be doing (consider heat, sun, and water exposure)?
4) Who is using the repellent? If applying repellent to children, be aware that not all repellents are appropriate for young children.

A convenient tool for selecting a repellent is available at https://www.epa.gov/insect-repellents/find-insect-repellent-right-you

Using Personal Repellents Safely

Properly apply repellents even if you are outside for just a short period of time, and share your repellent with those around you. Most repellents are classed as pesticides, and must be registered by the U.S. EPA. Repellent product labels give specific use instructions that should be followed carefully.

Most mosquito repellents work by reducing overall attraction of the blood-seeking female mosquito to the human host. However, manufacturer longevity estimates may not be a reliable guide. Temperature and activity level can dramatically influence how long repellents remain effective. Some repellents containing permethrin actually kill biting pests on contact.

The Centers of Disease Control and Prevention (CDC) recommend the use of products registered with the EPA: those containing DEET, picaridin, IR3535, and some oil of lemon eucalyptus and para-menthane-diol products are well established as the most effective active ingredients of repellents. In general, repellents containing a higher percentage of the active ingredient typically provide longer-lasting protection.

The following is a list of precautions recommended by CDC and EPA:

- Apply repellents only to exposed skin and/or clothing (as directed on the product label). Do not apply repellents under your clothing.
- Never use repellents over cuts, wounds or irritated skin.
- Do not apply to eyes or mouth, and apply sparingly around ears. When using repellent sprays, do not spray directly on your face—spray on your hands first and then apply to your face.
- Do not allow children to handle or spray the product. When using on children, apply to your own hands first and then put it on the child. Avoid applying repellent to children's hands because children frequently put their hands in their eyes and mouths.

- Use just enough repellent to cover exposed skin and/or clothing. Heavy application does not give you better or longer lasting protection.
- After returning indoors, wash treated skin with soap and water or bathe. This is particularly important when repellents are used repeatedly in a day or on consecutive days.
- If you (or your child) get a rash or other reaction from a repellent, stop using the repellent, wash the repellent off with mild soap and water, and call a local poison control center for further guidance. If you go to a doctor, it might be helpful to take the repellent with you.
- Products containing oil of lemon eucalyptus should not to be used on children under the age of three years.
- Do not apply repellent on babies under 2 months old. Use mosquito netting or avoid mosquito habitats in which you are likely to encounter mosquitoes as much as possible. Most products specify the youngest age allowable for a given product.
- Do not spray in enclosed areas. Avoid breathing in a repellent spray, and do not spray products near food.
- Using repellent and sunscreen products at the same time is an acceptable practice. In general, the recommendation is to apply sunscreen first, followed by repellent. Combination products that contain both an insect repellent and a sunscreen have improved greatly in recent years, but as repellents do not need to be reapplied as often as sunscreen, combination products are best used if outdoor activities are limited to a few hours.
- Wash treated clothing before wearing it again.
- EPA does not recommend any additional precautions for repellent use by pregnant or nursing women
- Get specific information about repellents and other pesticides by calling the National Pesticide Information Center (NPIC) at 1.800.858.7378, or email npic@ace.orst.edu or visit http://npic.orst.edu/ingred/ptype/repel.html

Important Information on Using Repellents

- Read the entire label before using a repellent. Even if you have used it before, read the label again - product directions change.
- Follow the use directions carefully. Use only the amount directed, at the time and under the conditions specified, and for the purpose listed. For example, if you need a tick repellent, make sure that the product label lists this use (Figure 1).

  If ticks are not listed, the product may be ineffective. Be aware of repellency awareness graphics https://www.epa.gov/insect-repellents.

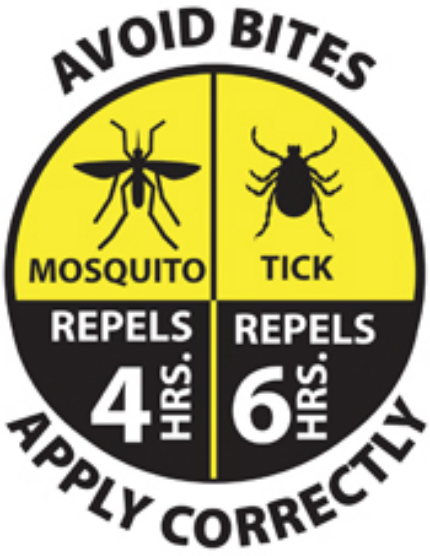


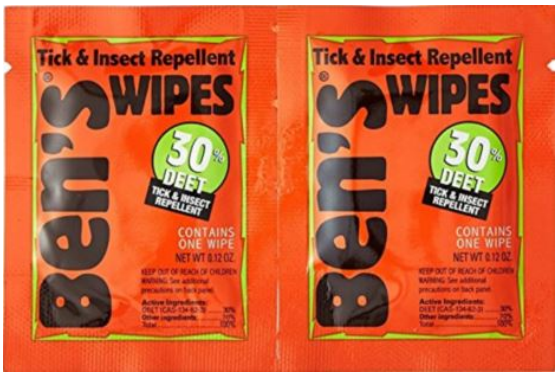
Figure 1. The Repellency Awareness Graphic shown here indicates that the product will protect against both mosquito and tick bites. However, not all products do.

- Store repellents away from children in a locked utility cabinet.
- The effectiveness of outdoor foggers, candles, and coils is highly variable and depends largely on the active ingredients and specific design.
- Insect Repellent Wristbands have not been found to be effective.
- Studies have demonstrated that ultrasonic mosquito repellers are ineffective, and that some can even increase the number of mosquito bites people receive (Carlos et al. 2010).

Types of Repellents

According to the CDC, of the products registered with the EPA, those containing DEET, picaridin, oil of lemon eucalyptus, IR3535, and para-menthane-diol provide longer-lasting protection. Reactions to DEET are uncommon, but picaridin products are less likely to trigger dermal reactions.

EPA characterizes the active ingredients DEET and Picaridin as conventional repellents and Oil of Lemon Eucalyptus, PMD, and IR3535 as bio-repellents, which are derived from natural materials. For more information on repellent active ingredients see (https://www.epa.gov/insect-repellents/skin-applied-repellent-ingredients).



Ben's Wipes 30% DEET

Coleman 100 Max Insect Repellent 98.11% DEET

Off! Familycare Smooth & Dry 15% DEET

Cutter Backwoods Insect Repellent (Pump Spray) 25% DEET

Figure 2. Some insect repellents that contain different concentrations of DEET.

❖ Topical Repellents

1. DEET (Chemical Name: N,N-diethyl-m-toluamide or N,N-diethly-3-methyl-benzamide)

DEET was developed by U.S. Army in 1946 and has been used by millions since 1957. It is the world's most widely used repellent and is the active ingredient in many personal repellent products.

Products containing DEET are currently available to the public in a variety of liquids, lotions, sprays, skin wipes and impregnated materials e.g., wrist bands (the latter being less reliable than the skin and clothing applied products) (see some example products in Figure 2).

Formulations registered for direct application to human skin contain DEET concentrations ranging from 4 (for about 2 hours of protection) to 100% (up to 10 hours protection). DEET is designed for direct application to human skin. **Skin sensitivity to DEET can develop after repeated use.**

If at all possible, use an alternative repellent on a child, or products that contain lower levels (<6%) of DEET, or apply to the child's clothing and not onto their skin. Do not use DEET on infants or if you are pregnant.

Some DEET based products are repellent to ticks as well as mosquitoes.

The longevity of protection afforded by the repellent will vary depending upon a number of environmental factors (Fradin and Day 2002; Barnard and Xue 2004). As a general rule the higher the temperature, the shorter the protective period will be. Swimming, sweating and sunscreen will also reduce the longevity of protection. General guidelines are given in Table 1. DEET impregnated wrist bands have not proven to be effective at protecting the entire body.

Washing repellents off before bed is important.

Table 1. General guidelines on longevity of protection afforded by the DEET repellent to mosquito bites.

Amount DEET	Approx. Hours of Protection
30%	6.5
15%	5
10%	3
5%	2

If DEET gets into the eyes, it can cause irritation, pain and watery eyes. People that have left DEET products on their skin for extended periods of time have experienced irritation, redness, a rash, and swelling. People that have swallowed products containing DEET have experienced stomach upset, vomiting, and nausea.

Be aware: DEET can damage rubber, plastic, leather, vinyl, rayon, spandex, elastic and auto paint. After applying DEET, wash hands before handling these materials (for example, be careful with plastic eyeglass frames). However, DEET will not damage cotton, wool and nylon.

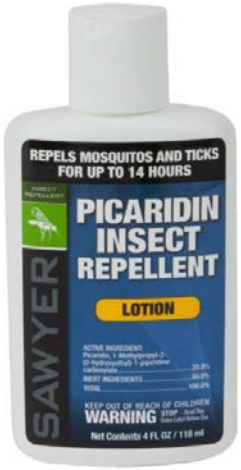
2. Picaridin (KBR 3023 (Chemical Name: 2-(2-hydroxyethyl)-1-piperidinecarboxylic acid 1-methylpropyl ester)

Picaridin, a DEET alternative, was developed primarily in Europe beginning in 1998. It has been available in U.S. since 2005. See example products in (Figure 3).

Products containing picaridin are very effective against many species of mosquitoes. Picaridin is slightly toxic by eye, dermal and oral routes, but is not a dermal sensitizer. Products are virtually odorless and have a very light feel.

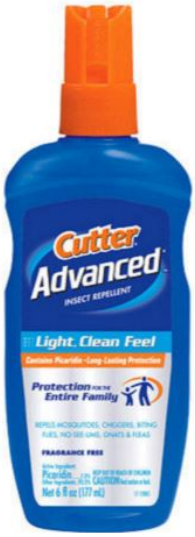
Picaridin doesn't damage fabrics, surfaces or materials. All repellents should be kept off infants under 2 months.

Some picaridin based products are repellent to ticks as well as mosquitoes.



Sawyer Picaridin Insect Repellent 20% picaridin

Avon Skin-So-Soft Bug Guard Plus Picaridin 10% picaridin



Cutter Advanced Insect Repellent 7% picaridin

Off! Familycare 5% picaridin

Figure 3. Some insect repellents that contain different concentrations of picaridin.

3. Oil of Lemon Eucalyptus and para-menthane-diol (PMD for short)

Oil of lemon eucalyptus is the name of a natural oil extracted from the leaves and twigs of lemon-scented gum eucalyptus, *Eucalyptus citriodora*. PMD is a chemically synthesized version of oil of lemon eucalyptus, not an essential oil (see example products in Figure 4). PMD and the "pure" unrefined oil of lemon eucalyptus are chemically different. PMD may cause a reaction on sensitive skin and eye irritation if it enters the eye.

4. IR3535 (Chemical name: 3-[N-Butyl-N-acetyl]-aminopropionic acid, ethyl ester)

IR3535 is a chemical insect repellent that has been used in Europe for over 20 years with no substantial adverse effects and it was approved for use in U.S. in 1999 (see example products in Figure 5). IR3535 may cause eye irritation if it enters a person's eyes.

Repel Lemon Eucalyptus Pump, contains 26% oil of lemon eucalyptus

Cutter Lemon Eucalyptus Insect Repellent, contains 30% oil of lemon eucalyptus

Figure 4. Some products containing PMD.

Avon Skin-So-Soft Bug Guard Plus with SPF 30, contains 19.6% IR3535

Bull Frog Mosquito Coast Sunscreen and Insect Repellent, contains 20% IR3535

Coleman Skin Smart Insect Repellent, contains 20% IR3535

Figure 5. Some products containing IR 3535.

5. Botanical Oil Mixes

There are a number of high-performing botanical repellents made from plant oils such as soybean, geranium, castor, coconut, cedar, citronella, lemongrass, peppermint and rosemary. Soybean oil is a common ingredient in food. When USDA researchers tested the success of a soybean oil repellent, they found that it provided protection from bites for hours depending on the species of mosquito they studied. Evaluations of soybean oil used as a pesticide have found few hazards.

Examples of products performing well in laboratory and field tests against mosquitoes can be found in Figure 6.

6. Citronella and Lavender Oil

It is recommended that personal repellents such as citronella and oil of lavender not be used on children under 2 years of age. Oil of citronella shows little or no toxicity, but may cause skin irritation.

Registered citronella oil repellents protect people against mosquito bites for 20 minutes or less. Slow release products do not provide significant added benefit. Similarly, the registered lavender oil repellent protects for half an hour or less.

Based on animal studies, citronella-based products appear to be potential dermal sensitizers. Therefore, allergic reactions may occur in some individuals.

Homs Bite Blocker Xtreme Sportsman Organic Insect Repellent, containing Soybean Oil (3%), Geranium Oil (6%), & Castor Oil (8%).

Off! Botanicals Plant-based Repellent, containing p-Menthane-3,8-Diol.

All Terrain Kids Herbal Armor Natural Insect Repellent, containing soybean (11.5%), citronella (10%), peppermint (2%), cedar (1.9%), lemongrass (1%) and geranium (0.05%).

Burt's Bees All Natural Outdoor Herbal Insect Repellent, contains citronella, soybean, castor, rosemary, lemongrass, cedar, peppermint, clove, and geranium.

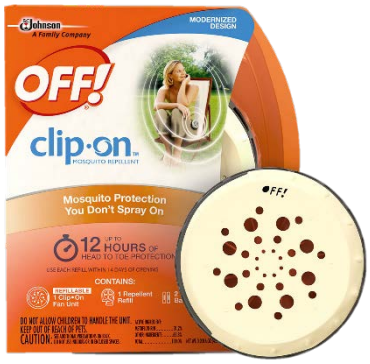
California Baby Natural Bug Blend Bug Repellent Spray, contains Pure essential oils of citronella (5%), lemongrass (0.5%), cedar (0.5%).

Figure 6. Some products made from plant-based oils.

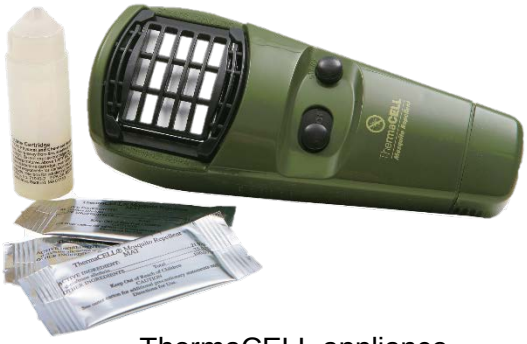
❖ Spatial Repellents

An alternative to topical repellents are spatial repellent devices. Spatial repellents create a protected zone in a relatively large area around a host and have the potential to protect more than one person within a space. The concept of spatial repellency has been around for centuries, and originated with indigenous cultures all over the world burning grasses and other plants to release repellents into the air. The active ingredients are not applied to the skin, and instead are emitted from coils, lamps, candles, vaporizers, and other emanators that the consumer can electively wear or keep near them when outdoors. Some examples of these are in Figure 7.

Ingredients vary, but research supports that metofluthrin and allethrin significantly reduce contact with mosquitoes through a combination of repelling and killing the approaching vector. **Spatial repellent devices should only be used outdoors**. **Ticks are not specifically included on spatial repellent labels**, but there is evidence showing ticks are affected by some spatial repellents.



Off! Clip-on wearable device containing 31.2% metofluthrin.

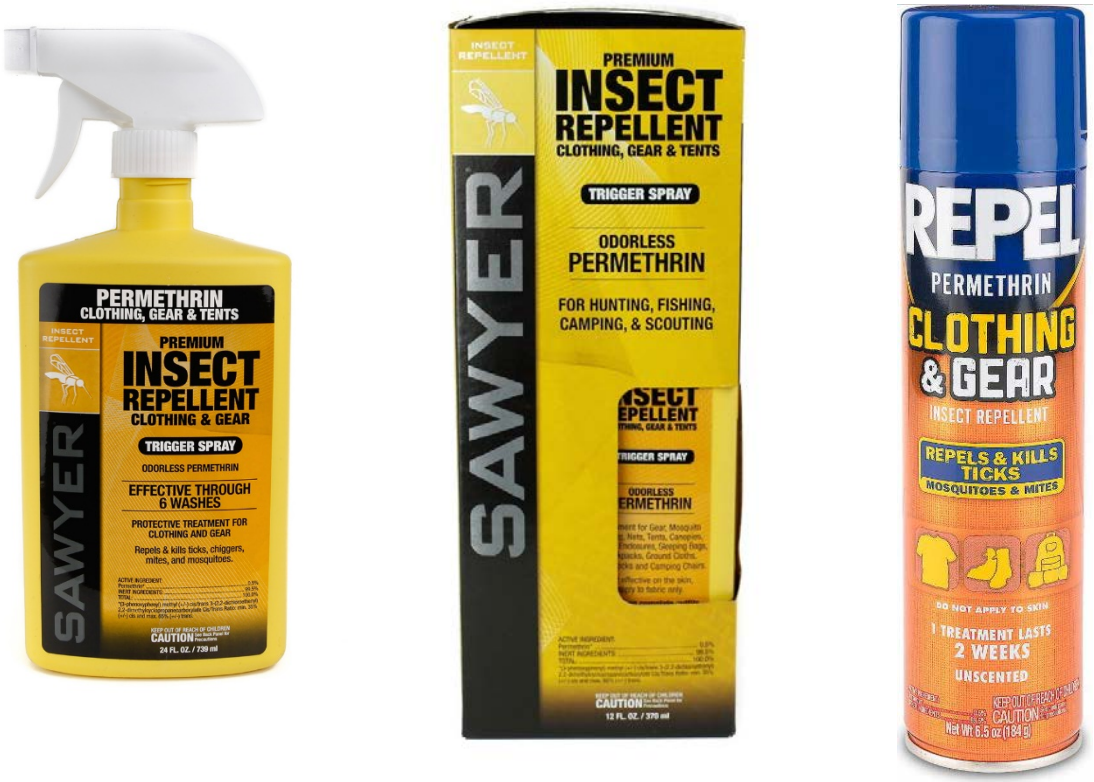


ThermaCELL appliance containing 21.9% d-allethrin.

Mosquito coils which could contain various spatial repellent pyrethroids.

Candle and lamp devices that could contain various spatial repellent ingredients

Figure 7. Spatial repellent devices.



Sawyer Premium Insect Repellent Clothing & Gear, and Repel Permethrin Clothing & Gear Insect Repellent, both contain 0.5% Permethrin.

Figure 8. Permethrin repellents for clothing and gear.

❖ Permethrin: Repellent for Clothing

Permethrin is an insecticide which also has repellent properties. Special formulations for spraying on clothing and clothing pre-treated with permethrin are commercially available. **Permethrin-based repellents are for clothing only. NEVER apply directly to the skin.**

First registered for use as a repellent on clothing in 1990 by the military, permethrin is a synthetic pyrethroid registered as both a repellent and an insecticide. It is a contact insecticide; it kills ticks, mosquitoes, and other arthropods when they come into contact with treated clothing. It should be used on clothing, tents and gear only.

Avoid contact with skin and eyes while applying and allow clothing to dry for at least 2 hours. Only outer clothing should be treated. The EPA has determined permethrin to be safe for use on clothing. Given the dermal exposure to permethrin associated with the use of impregnated clothing, however, we recommend their use primarily to avoid vector-borne disease rather than simply to reduce nuisance biting.

Please note, permethrin can be deadly to cats.

For more information on the safety and regulation of permethrin for treating clothing, see https://www.epa.gov/insect-repellents/repellent-treated-clothing.

Permethrin-treated clothing are typically used by military personnel and others who are outdoors for extended periods of time in areas at high risk for mosquito or tick-borne disease transmission (Sukumaran et al 2014; Vaughn et al. 2014). As a clothing or gear treatment, permethrin is very effective at keeping ticks from attaching to you and at reducing mosquito bites. Spray applications of permethrin can remain effective up to 14 days of exposure to light and air, or through two aggressive washings. By storing the treated clothing in black plastic bags between uses, the fourteen days of protection can be extended considerably. If necessary a heavier application can remain effective even longer. Bed nets can also be treated with permethrin. See examples of spray products in Figure 8.

Long-lasting permethrin-impregnated (LLPI) clothing offers similar protection without the need for individuals to apply the treatment themselves. While protection from ticks and mosquitoes declines over time and with repeated washing, studies indicate significant protection from vector-borne diseases for at least one year with LLPI clothing (Sukumaran et al 2014; Vaughn et al. 2014). New micro-encapsulated permethrin formulations may extend the durability and efficacy of the treatment (Yao et al. 2015).

Use a permethrin based repellent in high-risk situations, where disease vectoring is a concern.

For information on mosquito management: https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1706-2016.pdf

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COLLEGE OF AGRICULTURE & LIFE SCIENCES
Cooperative Extension

DAWN H. GOUGE
Department of Entomology - College of Agriculture & Life Sciences, University of Arizona

SHUJUAN (LUCY) LI
Cooperative Extension - Arizona Pest Management Center, Maricopa Agricultural Center, University of Arizona

SHAKU NAIR
Cooperative Extension - Arizona Pest Management Center, Maricopa Agricultural Center, University of Arizona

KATHLEEN WALKER
Department of Entomology - College of Agriculture & Life Sciences, University of Arizona

CHRISTOPHER S. BIBBS
Anastasia Mosquito Control District, FL

This information has been reviewed by University faculty.

CONTACT:
DAWN H. GOUGE
dhgouge@email.arizona.edu

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