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Mosquito Pest Management

Bulletin 641

Contents

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Most Important Mosquitoes in Ohio and the United States

The ten most important mosquitoes in Ohio are *Aedes canadensis*, *Aedes sollicitans*, *Aedes sticticus*, *Aedes stimulans*, *Aedes triseriatus*, *Aedes trivittatus*, *Aedes vexans*, *Anopheles punctipennis*, *Coquillettidia perturbans* and *Culex pipiens pipiens*.

The ten most important mosquitoes in the United States are *Aedes aegypti*, *Aedes albopictus*, *Aedes sollicitans*, *Aedes taeniorhynchus*, *Aedes triseriatus*, *Aedes vexans*, *Anopheles quadrimaculatus*, *Culex pipiens quinquefasciatus*, *Culex tarsalis* and *Psorophora columbiae*.

Mosquitoes are a problem throughout Ohio. At least 58 different species of mosquitoes are found in the state. Fortunately, only a few species cause annoyance. Nevertheless, their presence affects most everyone. Mosquitoes, whether in the home, yard, park or elsewhere, interfere with work and leisure activities. Some mosquitoes attack pets and even farm animals, causing weight loss and decreased milk production. Others transmit diseases such as malaria to humans, encephalitis to humans and horses, and heartworm to dogs.

Licensing

Any person who applies a pesticide on public property must be licensed by the Ohio Department of Agriculture or be a trained applicator working under the supervision of a licensed applicator. This is true even if the pesticide is not restricted. For application procedures and additional information, contact:

Pesticide Regulation Section
Ohio Department of Agriculture
Reynoldsburg, Ohio 43068
1-800-282-1955
614-728-6383

Disclaimer

This publication contains pesticide recommendations that are subject to change at any time. These recommendations are provided only as a guide. It is always the pesticide applicator's responsibility, by law, to read and follow all current label directions for the specific pesticide being used. Due to constantly changing labels and product registration, some of the recommendations given in this writing may no longer be legal by the time you read them. If any information in these recommendations disagrees with the label, the recommendation must be disregarded. No endorsement is intended for products listed, nor is criticism meant for products not listed. Ohio State University Extension assumes no liability resulting from the use of these recommendations.

Introduction

Most control is usually directed for relief from bites and the irritating reaction that follows. However, disease transmission is also of importance. From 1979 to 1993, 241 cases of imported malaria were reported in Ohio. All cases were acquired in other countries. Without adequate human surveillance and treatment of these imported cases, malaria could become a serious problem in Ohio because the vector mosquitoes occur here. Three types of encephalitis virus are transmitted by mosquitoes in Ohio: LaCrosse encephalitis (LAC) (formally called California), St. Louis encephalitis (SLE) and Eastern equine encephalitis (EEE). From 1963 through 1993, 757 human cases of LAC were diagnosed in Ohio, including five deaths. LAC is transmitted by *Aedes* mosquitoes, with animals of the squirrel family being the normal hosts. Aside from acquiring the virus from feeding on infected rodents LAC can also be transmitted transovarially, that is, it can be passed from an infected female to her offspring.

St. Louis encephalitis (SLE) is transmitted by *Culex* mosquitoes. From 1964 through 1993, there were 441 human cases of SLE diagnosed in Ohio, with 32 deaths. In 1975, 416 cases of SLE occurred, including 29 deaths, in the worst epidemic of SLE in the state's history. Birds are the normal vertebrate hosts for both SLE and EEE.

Eastern equine encephalitis (EEE) is a very rare disease, however, it is the most severe form of encephalitis. The human case fatality rate is about 30 percent and many of those who recover suffer some form of permanent mental impairment. A human case has never been diagnosed in Ohio. Prior to 1991, Ohio had only recorded one case of EEE. This was a fatal equine case. During August and September of 1991, however, EEE was implicated in over 40 equine fatalities occurring in the Killbuck Creek valley of Holmes County and Wayne County, Ohio. EEE was confirmed by tissue sample in only 17 of these fatalities. EEE is most common in the Atlantic coast states. Michigan has been the only Midwestern state to have recurring outbreaks. Humans and horses are both considered dead-end hosts. Neither circulate sufficient levels of virus to infect additional mosquitoes. *Coquillettidia perturbans* and *Culiseta melanura* are the primary mosquitoes implicated in EEE outbreaks.

Canine heartworm is a serious and potentially fatal disease of dogs. The heartworm is a nematode (*Dirofilaria immitis*) that is transmitted to healthy dogs by several species of mosquitoes. Adult heartworms, which reach a length of 6 to 24 inches, are found in the heart and pulmonary arteries of the dog. They will cause death if left untreated. To reduce heartworm infections, confine dogs indoors during periods of heavy mosquito activity, reduce local mosquito populations or consult a veterinarian for preventative drug treatment.

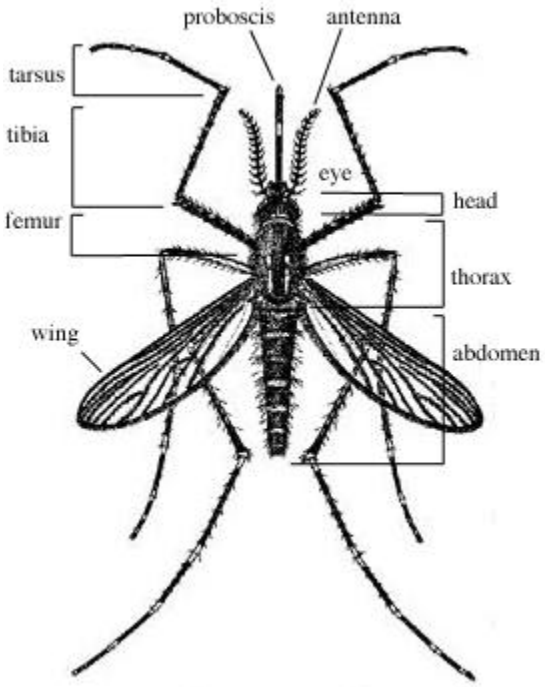
Despite national and statewide educational campaigns on AIDS, many people are concerned that mosquitoes can transmit the virus (HIV). Evidence by the Centers for Disease Control gathered thus far indicates that arthropod transmission of HIV is not occurring in the continental United States or other parts of the world. Their research indicates that the arthropod-borne transmission

of HIV is virtually impossible because the amount of blood that could be ingested and carried by the mosquito is too small to hold an infective dose of HIV. If you would like further information on this subject, contact the Vector-borne Disease Unit of the Ohio Department of Health.

Characteristics

Adult mosquitoes are small, fragile insects with slender bodies, one pair of narrow wings and three pairs of long, slender legs. They vary in length from 3/16 to 1/2 inch (5mm to 13mm). Mosquitoes have an elongate proboscis with piercing mouthparts with which the female bites and feeds on blood. Male mosquitoes feed only on plant nectar. Mosquitoes differ from other flies in that they have an elongate proboscis and scales on the veins of their wings. Often, the layperson confuses mosquitoes with midges, crane flies, punkies, biting gnats and other flies.

It is important to understand the various parts of the mosquito:



Antenna Pair of segmented appendages located on the head and sensory in function.

Abdomen The posterior of the three main body divisions of insects.

Eye A compound eye consisting of many individual elements or ommatidia, each of which is represented externally by a facet.

Femur The segment of the leg between the tibia and thorax.

Head The anterior body region which bears the mouthparts, eyes and antennae.

Proboscis The elongate straw-like mouthparts.

Tarsus The foot, the distal part of the insect leg, consisting of from one to five segments.
Tibia The segment of the leg between the femur and tarsus.
Thorax The body region behind the head, which bears the legs and wings.
Wing An organ of flight; movable paired appendages with which certain insects are able to fly.

Biology

A mosquito passes through four stages in its life cycle. The stages are the egg, larva, pupa and adult. Eggs, larvae and pupae must have standing water to develop. There are four larval growth stages, called "larval instars." All larval stages resemble each other, except each is larger than the preceding one. The first stage hatches from the egg and the fourth stage molts to become the pupa. Female mosquitoes lay their eggs on the water surface or in places that later become flooded. Eggs are elongate, about 1/40 inch (0.6mm) long and are dark brown or black when ready to hatch. Eggs are laid singly or in batches of 50 to 400. Several batches may be laid by one female. Usually, bloodsucking females require a blood meal before producing each batch of eggs.
Eggs of most mosquitoes hatch in two to three days, whereas others require a drying period and may remain dormant for many months or years, then hatch within minutes or days after being flooded by rainfall or a tide.
Larvae or "wigglers," which hatch from the eggs, feed on bits of organic matter in the water. Most larvae come to the surface of the water for air. Larvae mature in seven to ten days and change into a pupa or "tumbler" stage. Pupae are comma-shaped forms, called tumblers because of their tumbling motion when disturbed in the water.
Pupae usually transform into adults two to three days later. In another one to two days, females are ready to bite. The time required from egg hatch to adult may be as short as ten days or as long as seven months, depending on

environmental conditions. Cool weather will delay development. Some mosquitoes have only one generation each year, whereas others may have four or more generations each year, building to large populations by late summer. Adults usually remain close to the hatching areas; however, they can be blown by the wind for distances up to 40 miles. The usual range of migration is five to ten miles. Adult mosquitoes may live three weeks or more.

Some Troublesome Mosquitoes in Ohio

The layperson should learn to recognize the difference between eggs, larvae (wigglers), pupae (tumblers) and adults. Only trained specialists can tell the difference between mosquito species. However, knowing what species is causing the problem can be of great benefit in planning control. Some of the most troublesome mosquitoes in Ohio and their habits are listed below.

Aedes canadensis

This dark mosquito has the tarsi banded with white at both ends of the segments. It is a serious pest in woodlands. This species overwinters in the egg stage and is one of the first mosquitoes to appear in early spring. Larvae breed in woodland pools filled by melting snows or by spring rains. It shows preference for pools with a bottom of dead and decaying leaves, although it is sometimes found in roadside puddles, sink holes, wooded swamps, etc. There is one generation per year with the adults living for several months. Eggs are laid singly on the ground or above the waterline in woodland pools. Eggs hatch only after they have been flooded. Eggs are able to survive long periods of drying. Biting occurs most frequently during the evening hours, but can occur during the day or night. *Aedes canadensis* is a secondary vector of LaCrosse encephalitis in Ohio.

Aedes triseriatus (Tree-Hole Mosquito)

These black mosquitoes have silvery white scales at the sides of the thorax. They breed principally in tree holes, tires and other artificial containers. The bites are painful and sometimes very troublesome in the woods. They do not wander far from the breeding places. Larval development is rather slow with nearly a month required to reach maturity. *Aedes triseriatus* is the principal vector of LaCrosse encephalitis in Ohio. This species has several generations a year and overwinters in the egg stage.

Aedes trivittatus

The upper surface of this mosquito's thorax is marked with two conspicuous whitish stripes. It is a fierce biter and can be extremely annoying. Larvae occur mostly in floodwater pools and temporary rain pools. Young larvae feed at the water surface with later instars spending most of their time concealed in the vegetation at the bottom of the pool. Larvae are seldom encountered, even though adults can be present in large numbers. Adult emergence begins about eight days after hatching. Adults rest among shaded grasses and other vegetation during the daytime but bite if disturbed. They bite mostly in the evening and do not migrate far. This species overwinters in the egg stage.

Aedes vexans

A medium-sized brown mosquito, it has narrow rings of white scales on the hind tarsi and a "V"- shaped notch at the middle of each band of white scales on the upper surface of the abdomen. This mosquito is very abundant and breeds in rain pools, flood waters, roadside puddles and most all temporary bodies of fresh water. Eggs are laid on the ground above the water line, hatching when flooding occurs. Larvae can be found in huge numbers. In receding water, up to 500 or more larvae are found to each pint of water. Development of the aquatic stages requires ten days to three weeks, depending on the temperature. Adults fly long distances from their breeding places with flights of five to ten miles being rather common. Adult females are vicious biters and are especially annoying at dusk

and after dark. Adults live for nearly two months and are attracted to light. They rest during the day in shaded grass and other vegetation. *Aedes vexans* overwinters in the egg stage. It is considered the principal pest mosquito in Ohio and in many parts of the United States. It may also be a secondary vector of the Eastern equine encephalitis virus.

Anopheles quadrimaculatus (Malarial Mosquito)

These large, dark brown mosquitoes have four dark spots near the center of each wing. The tarsi are entirely dark. Eggs are laid singly on the water surface with lateral floats to keep them at the surface. One hundred or more eggs are laid at a time. A single female may lay as many as 12 batches of eggs and a total of more than 3,000 eggs. This species is the most important vector of malaria attacking humans in the eastern United States and can be found frequently in houses and other shelters. Their bites are less painful than many other mosquitoes and often go unnoticed. These mosquitoes breed chiefly in permanent freshwater pools, ponds and swamps that contain aquatic vegetation or floating debris. Common habitats include borrow pits, sloughs, city park ponds, sluggish streams and shallow margins of reservoirs and lakes. During the daytime, adults remain inactive, resting in cool, damp, dark shelters such as buildings, caves, under bridges, etc. Feeding occurs at night. These mosquitoes enter houses to feed on humans. Cows, horses, mules, pigs and chickens are also attacked. Adults fly about one half mile from their breeding site but are not taken in light traps in great numbers. Breeding occurs throughout the summer months, with overwintering taking place as an adult fertilized female.

Coquillettidia (Mansonia) *perturbans*

The scales on the wings of this mosquito give the wings a "peppered" appearance. The mosquito also has a rounded abdomen and white bands on the tarsi and proboscis. It breeds in permanent water, especially marshes with emergent plants. Larvae and pupae attach to the roots and underwater stems of

a wide variety of aquatic plants, most commonly cattails (*Typha* sp.). Overwintering occurs as larvae in mud. There may be more than one generation produced in a year. There is usually a very large emergence of adults in May, with the population peaking in June and declining through July and August. It is primarily a mammal feeder and readily attacks humans. This species can fly long distances from its breeding site and is primarily a pest species in Ohio. It has been shown to be involved in the transmission cycles of California group viruses, Eastern equine encephalitis virus, and dog heartworm in other areas of the U.S.

Culex pipiens pipiens (Northern House Mosquito)

These brown mosquitoes of medium size have cross bands of white scales on the abdominal segments, but are without other prominent markings. They commonly enter houses. This mosquito is a vector of St. Louis encephalitis. Breeding occurs in rain barrels, tin cans, tires, storm-sewer catch basins, street gutters, polluted ground pools, cesspools, open septic tanks, etc. Eggs are laid in clusters of 100 to 400, known as egg rafts, which float on the water surface. Hatching occurs in a day or two in warm weather, and from eight to ten days are needed for completion of the larval and pupal stages. In cooler weather of early spring or late fall, two weeks or more may be required. Breeding continues throughout the warm months of the year. One subspecies can survive and produce fertile eggs without a blood meal. This mosquito does not fly far, except when great numbers are produced. Adults are active only at night and can be found resting during the day in and around houses, outbuildings and various shelters near their breeding places. They are readily attracted to carbon dioxide (CO_2) baited light traps. This mosquito overwinters as a fertilized adult female.

Psorophora ciliata (Gallinipper Mosquito)

This is a very large (almost 1/2 inch long), yellowish-brown, floodwater mosquito with shaggy legs (long erect scales on the hind tibiae). It is a vicious biter presenting a rather terrifying appearance due to its large size. When present in

numbers, it is a severe pest, attacking during the daytime as well as in the evening. It is not known to be a vector of human disease. Eggs are laid on low-lying dry land (withstands drying), but hatch quickly during flooding conditions. Larvae develop rapidly and feed on other aquatic insects including mosquito larvae. Fourth instar larvae may consume three or four other larvae in one day. Larvae are easily recognized since they are two to three times as large as most other mosquito species. They hang almost straight down from the water surface. This mosquito overwinters in the egg stage.

Mosquitoes Imported into Ohio

Due to modern technology, as well as the mobility of today's society, Ohio is facing new threats from exotic mosquito species. These include *Aedes aegypti*, *Aedes albopictus*, *Aedes atropalpus*, and others. Most of these exotic species are imported when they lay their eggs in containers such as tires that are subsequently transported into Ohio.
Aedes albopictus, otherwise known as the Asian Tiger Mosquito, is the imported species causing the most recent concern among state and national health officials. It is an aggressive biter and has the potential to transmit numerous diseases. These include dengue, yellow fever, LaCrosse encephalitis, and dog heartworm. LaCrosse encephalitis is of particular concern to Ohioans since Ohio has more recorded cases of this disease than any other state. *Aedes albopictus* is an average size black and white mosquito with a distinctive single white band down the length of the back of its thorax.

Mosquito Control Programs

Effective mosquito control requires a well-planned program. Such programs are often expensive and complex and require the cooperation and planning of individual homeowners as well as from groups in industry, agriculture and local and state governments. A mosquito control program may be justified when it can be demonstrated that annoyance prevents the reasonable use of yards and

gardens, or when health factors develop beyond the reasonable control of the individual property owner.
Demand can be expressed in the form of petitions or resolutions from such agencies as garden clubs, women's clubs and civic or service organizations addressed to local authorities. If public health is directly involved, the request may be initiated to local health authorities.

Surveillance

Mosquito collections and surveys can be made by hand and traps. Identifying the collection will indicate the species present and their relative density. The species will give a fair indication of the breeding places. Location of breeding places should be found to determine control methods most suitable from a practical and economical standpoint. Mosquitoes can be examined for the presence or absence of encephalitis and other viruses at the Ohio Department of Health, Vector- borne Disease Unit, Columbus, Ohio 43229.

Breeding Site Reduction

Water management to prevent mosquito breeding is essential for effective control. Eggs do not hatch unless they are on or in water. Tires, in particular, require special mention because they are primarily breeding places for vector mosquitoes. Tires are often next to dwellings in close proximity to people. Locate standing water and eliminate if possible and practical.
Follow these steps:

- Remove tin cans, old tires, buckets, glass jars, broken toys and other water-holding containers.
- Change the water in bird baths and wading pools once a week.
- Clean out roof gutters so that water does not accumulate.
- Examine flat roofs after rains, making certain that no water remains more than one week.
- Place tight covers over cisterns, cesspools, septic tanks, fire barrels, rain barrels and tubs where water is stored.

- Do not over-apply lawn and garden irrigation, causing puddling in low areas.
- Fill tree holes with Treekote and mortar after draining.
- Drain or fill stagnant water pools, puddles and ditches of swampy areas around the home.
- Eliminate water-holding tree stumps and keep the grass mowed around ponds and other bodies of water, taking care to keep clippings out of water.
- Stock ponds and reservoirs with mosquito-eating fish such as green sunfish, bluegills, guppies or any surface-feeding minnow. The mosquitofish, Gambusia affinis, is the most commonly used fish for mosquito control in the world. Also, predatory mosquitoes, Toxorhynchites spp, and mermithid nematodes have been used on an operational basis as biocontrol agents.
- Check the water in flower pots and other containers for mosquito larvae.
- Maintain farm ponds according to good management practices. Excessive amounts of emergent aquatic vegetation will shelter mosquitoes. In some cases, fish, such as the White Amur or Grass Carp, can be used to clear vegetation and reduce the mosquito breeding capacity of the pond. Stagnant ponds, which are highly septic, and waste lagoons can also produce large numbers of mosquitoes.
- Keep drainage ditches on property clean and flowing.

Protecting Honey Bees

Ohio Use and Applicator Law Regulation Ag-6567.01 requires that "No pesticide which is required to carry a special warning on its label, indicating that it is especially toxic to honey bees, shall be dispensed over an area of one-half acre or more in which the crop plant is in flower unless the owner or caretaker of any registered apiary located within one-half mile of the treatment site shall be notified no less than 24 hours in advance of such intended treatment; provided, however, that these locations are registered and identified as required by Section 909.02 of the Revised Code of Ohio, and that such apiary locations have been posted with the name and telephone number of the owner or caretaker."

"Since ULV and thermal fog applications are not residual type applications to crops, notification of beekeepers prior to the application is not required. Many mosquito control agencies, however, will notify beekeepers in the area and publish their adulticiding schedule regardless."

"Applications of pesticides which are hazardous to honey bees shall be made at times when pollinating insects are not actively working in the target area;

however, application of calyx sprays on fruits and other similar application may be made."

The Ohio law also states that records of all pesticide applications are required to be maintained for a period of three years from the date of the pesticide application. In addition, applicators and operators must be licensed through the Ohio Department of Agriculture to apply pesticides.

Larval Control (Larviciding)

Solving the mosquito problem primarily through larval control is the most logical approach of reducing annoyance. This is the only time in the insect's life cycle when it is truly confined, concentrated and most readily controlled.

When standing water cannot be eliminated from the premises, it should be examined each week to determine whether or not larvae are present. Water can be dipped with either a pan or cup. A white utensil is preferred because brown larvae can be seen easily against a white background. Should larvae be present, an insecticide should be applied at once. Some insecticides labeled for control of mosquito larvae are listed in Table 1.

Table 1. Larvicides for Mosquito Breeding Waters (Follow Label Directions and Safety Precautions)

Insecticide	Formulation	Amount Formulation per Acre	Remarks
***Bacillus thuringiensis* Berliner var. *israelensis* (B.t.i.)**			The higher recommended rates must be used in water having high concentrations of organic pollutants and/or abundant algae. This may be due to a lower ingestion of B.t.i. as a result of food source competition from other organisms and organic debris ingested by the larvae. Or it may be due to the removal or alteration of the active ingredient by absorptive binding to suspended particulate matter. Other
(Bactimos)	10% B	1 Briquet/100 $ft.^2$	
	50% WP	2 to 12 oz.	
	5.0% P	2 to 8 lb.	
	2.5% G	4 to 8 lb.	

(Teknar)	1.6% HP-D	0.25 to 1.0 pt.	water quality parameters such as salinity and pH have little, if any, effect on the activity of B.t.i. Water temperature, as it influences larval metabolic activity and thus larval feeding and development, can be a factor in determining the application rate. This larvicide is non-toxic to non-target beneficial organisms. There is a homeowner label of Bactimos 10 percent Briquet known as "Mosquito Dunks." (Kills mosquito larvae growing in bird baths, rain barrels, old automobile tires, ponds, ditches, unused swimming pools, tree holes, flower pots, roof gutters or wherever water accumulates.)
(Vectobac)	0.2% G	2.5 to 20.0 lb.	
	0.2% CG	2.5 to 20.0 lb.	
	1.2% 12 AS	0.25 to 2.0 pt.	
methoprene			This product is an insect growth regulator (IGR), which acts by inducing morphological changes interfering with normal development. These effects are not immediately apparent and result in the failure of adult mosquitoes to emerge from pupae. Apply to 2nd, 3rd and/or 4th instar larvae, not pupae or adults. Treated larvae develop to the pupal stage where they die.
(Altosid)	5% ALL	0.75 to 1.0 oz.	
	20% ALL Concentrate	1 Briquet/100 $ft.^2$	
	7.9% B	1 Briquet/100 $ft.^2$	
	1.8% ERB	2.5 to 10 lb.	
	4.0% P	3.0 to 4.0 oz.	
oil*			Use high rate in areas of heavy vegetative cover and in waters high in organic matter. Do not apply to fish hatcheries.
(GB-1111)	Petroleum distillate	2 to 5 gal.	
(Bonide)		1 to 5 gal.	
temephos*			Use the high rate in polluted water and areas with organophosphate insecticide-resistant mosquitoes. For tire treatment, apply 1 lb. of 5 percent CCG per 100 square feet of tire pile service area. Do not use on food, forage or pasture
(Abate)	44% EC	0.5 to 1.5 oz.	
	1% SG	5 to 20 lb.	
	2% CG	2.5 to 20 lb.	
	5% CG	2 to 10 lb.	

	5% P	4 to 10 lb.	crops. Repeat as needed.
	5% CCG	2 to 100 lb. (Varies according to tires per acre.)	
*To be applied only by licensed, certified pesticide applicators.			
ALL=Altosid Liquid Larvicide, AS=Aqueous Suspension, B=Briquet, CCG=Corn Cob Granular, CG=Celatom Granule, EC=Emulsifiable Concentrate, ERB=Extended Residual Briquet, G=Granule, HP-D=Higher Potency-Double, P=Pellet, SG=Sand Granule, WP=Wettable Powder			

Adult Control (Adulticiding)

Adult control programs are necessary in disease situations such as encephalitis-stricken areas and in areas where a high density of pest mosquitoes occurs. The larger the area treated, the more successful the control. Adult mosquito populations can be temporarily reduced to less annoying levels. Ultra-low volume application generally is regarded as the most efficient adulticiding method.

Ultra-Low Volume Application

Special nozzle adaptations make it possible to break up undiluted, specially formulated insecticides into microscopic droplets that give effective coverage for adult mosquito control. These kinds of applications are known as ultra-low volume (ULV), ULV non-thermal, cold fog or ULV aerosol. For every 50 percent decrease in the droplet diameter of a set volume of insecticide, the spray surface area is increased eightfold. Such application techniques make it possible to effectively use very low application rates of insecticide. A comparison of malathion ULV rates for selected uses is given below:

Selected Use	ounces/acre
Mosquito Control	0.7
Cattle Feed Lots	8
Peas	8

Green Beans	8
Blueberries	10
Pasture and Range Grass	12
Alfalfa	16
Cherries	16

The droplet size of the pesticide must be checked according to the manufacturer's recommendations. Records verifying compliance with label specifications must be kept for a period of three years.

Ground ULV application is usually done at 10 mph, using a swath width of 300 feet. Because the primary activity period for most mosquito species is during the evening (sunset) or just before sunrise, adult mosquito control by ULV and thermal fog is most effective when done during these periods when there is no wind.

Aerial application of mosquito adulticides is recommended only in extreme cases. These may include encephalitis epidemics or severe numbers of pest mosquitoes. In such cases, a ULV adulticide application is the method of choice because it will bring about an immediate reduction in the number of adult mosquitoes. This is especially important during an epidemic of EEE or SLE. Newly hatched mosquitoes will be virus free at least until their first blood meal. Killing off the older infected mosquitoes breaks the disease transmission cycle. Some insecticides labeled for ground ULV application are given in Table 2.

Table 2. Area Ultra-Low Volume Application by Ground Equipment for Adult Mosquito Control (Follow Label Directions and Safety Precautions)

Insecticide	Flow Rate Per Minute (Average Vehicle Speed)	Formulation	Remarks
chlorpyrifos*			For application only by public health officials and trained personnel of mosquito abatement programs. This
(Mosquitomist One ULV)	13.62% S	3.88 to7.75 oz.(10 mph)	

(Mosquitomist 1.5 ULV)	19.36% S	2.7 to 5.3 oz. (10 mph)	product is toxic to fish, wildlife and birds. Apply this product only as specified on the label.
(Mosquitomist Two ULV)	24.6% S	4 oz. (10 mph)	
chlorpyrifos + permethrin*			This product is toxic to birds and wildlife and is extremely toxic to bees, fish and aquatic organisms. Do not apply directly to water or contaminate water when disposing of equipment washwater.
(ULV Mosquito Master 412)	12% + 4%	4.5 to 18 oz. (10 mph)	
malathion			Do not apply during heavy bee activity. Car finish may be spotted if droplet size is too large or application is improper. If exposure occurs, wash car immediately.
(Fyfanon)	95% C	2 to 4.3 oz. (10 mph)	
naled			Use the low vehicle speed at the recommended rate to penetrate dense vegetation. Use a dilute solution of two quarts of the 85 percent concentrate in soybean oil or HAN to make a five gallon solution. Car finish may be spotted. To prevent serious corrosion, spray equipment should be rinsed thoroughly after application.
(Dibrom)	85% C	6 to 12 oz. (10 mph)	
permethrin*	57% OS	0.54 to 3.25 oz. (10 mph)	Do not get in eyes, on skin or clothing. Follow label directions.
permethrin + piperonyl butoxide			Do not apply these products within 100 feet (30 meters) of lakes and streams. These products are extremely toxic to fish. Do not apply directly to water or wetlands (swamps, bogs, marshes, and potholes.) Drift and runoff from treated areas may be hazardous to aquatic organisms in adjacent areas. Do not contaminate water when disposing of equipment washwaters. These products are highly toxic to bees exposed to direct treatment on blooming crops or weeds.
(Biomist)*	4% + 12% S	4.5 to 18 oz. (10 mph)	
	4% + 4% S	4.5 to 18 oz. (10 mph)	
	3% + 15% S	3 to 18 oz. (10 mph)	
	1.5% + 7.5% S	6 to 18 oz. (10 mph)	

	12% + 60% S	1 to 3 oz. undiluted (10 mph)	Do not apply this product or allow it to drift to blooming crops or weeds while bees are actively visiting the treatment area.
	30% + 30% S	1 to 3 oz. undiluted (10 mph)	
	31% + 66% S	1 to 6 oz. undiluted (10 mph)	
(Permanone)	3.98% RTU	12 to 18 oz. (10 mph)	
pyrethrins + synergist*	3% C	6.66 to 7.50 oz. (10 mph)	Apply when temperature is 75 degrees F or less and upwind of area to be controlled. Dilute as recommended on the label.
	5% C		
resmethrin + piperonyl butoxide*			Apply when air currents are 2 to 8 mph or less and upwind of area to be controlled. Dilute as recommended on the label.
(Scourge)	18% + 54% C	May be diluted (10 mph)	
	4% + 12% S	3 to 18 oz. (10 mph)	
(Oblique)	1.5% + 4.5% RTU	4.5 to 9 oz. (2 mph)	
*To be applied only by licensed, certified pesticide applicators.			
C=Concentrate, OS = Oil Soluble, RTU = Ready-to-Use, S=Sprayable			

Thermal Fogging

Fog can be effective as a space treatment against adult mosquitoes. Mix the insecticide in oil (kerosene-type oils, fuel oils, diesel oils and other base oils suitable for insecticide use) and apply in late evening, at night or early morning when the air is calm (less than 5 mph). Do not fog during daylight hours. Fogging is effective as a contact application with no residual effect. Frequent applications are needed during heavy adult mosquito migrations. Calibrate machines according to manufacturer's recommendations or to deliver 40 gallons per hour traveling at 5 mph to treat a swath of about 300 feet. If

labelling directs otherwise, then follow product label recommendations. Operate in a manner so the fog drifts with the wind through the target area. Some insecticides labeled for thermal fog application are listed in Table 3.

Table 3. Thermal Fog for Adult Mosquito Control (Follow Label Directions and Safety Precautions)

Insecticide	Formulation	Amount of Formulation to Use	Remarks
chlorpyrifos*			Apply a 300 ft. swath, from a speed of 5 mph, at a rate of 52.5 gallons per hour. For application only by licensed public health officials and trained personnel of mosquito abatement districts and other public mosquito control programs.
(Mosquitomist One)	13.62% S	9 gal. per 91 gal. oil	
(Mosquitomist 1.5)	19.36% S	6 gal. per 94 gal. oil	
malathion			Deliver 40 gal./hr. at 5 mph, 300 to 400 ft. swath. Test oil solubility and sludge to prevent clogging valves of thermal fog machine. Co-solvents or sludge inhibitors may be needed with some oils. Car finish may be spotted. May be toxic to certain species of fish in shallow water. Highly toxic to bees exposed to direct treatment.
(Fyfanon)	95% C	3.9 to 5.2 gal. per 96.1 to 94.8 gal. oil	
naled			Deliver 40 gal./hr. at 5 mph, 300 to 400 ft. swath. Rinse spray equipment after application to prevent corrosion. Car finish may be spotted.
(Dibrom)	85% C	3.1 qt. per 99 gal. oil	
resmethrin + piperonyl butoxide*	3.0% C	1 gal. per 14 gal. oil	Fog at a rate of 3.75 gal. per acre, when wind velocity is less than 3 mph. Avoid inhalation of fog. Do not reenter area until fog has dissipated. Avoid wetting of foliage.
(Oblique)	1.5% + 4.5%	1 gal. per 9 gal. oil	

*To be applied only by licensed, certified pesticide applicators.

C=Concentrate, S=Sprayable

Residual Spraying

Residual sprays are applied in water or oil, using mist blowers, pump sprayers, power backpacks or hand sprayers. They are designed to remain active for several days to several weeks, but environmental factors such as rain, high temperatures or exposure to strong sunlight may reduce their longevity. When applied to foliage, the rate of plant growth may also influence the efficacy of residual sprays. Residual sprays can be applied as barrier treatments to tall grasses, weeds, shrubs, fences, and other harborages surrounding parks, playgrounds, residences, or even subdivisions to help reduce adult mosquito populations. For best results, target areas just before the period of maximum use.

Mist spraying can be particularly useful because large areas can be treated. In some cases, it can also be used for larvicide application. Mist spraying is the application of a very fine mist of insecticide in water. The fine droplets settle out faster as a mist than as a fog or aerosol. Mist spraying should be done early in the morning or evening, when wind velocities are less than ten mph. Avoid direct application to parked cars, trailers, watercraft, dwellings, and other nontarget objects. Car finishes may be damaged if spray droplets are not washed off immediately. Some insecticides labeled for residual spraying are listed in Table 4.

Table 4. Mist and/or Residual Spraying for Adult Mosquito Control (Follow Label Directions and Safety Precautions)

Insecticide	Formulation	Amount Formulation Per Acre	Concentration of Active Ingredient in Prepaired Spray	Remarks
carbaryl				Sevin is highly toxic to bees. Sevin injures
(Sevin)	41.2% SUS	0.5 to 1 qt.	---	

	variuos	---	1%	Boston ivy, Virginia creeper and maidenhair fern. Treat when adult mosquitoes are active in early morning or at dusk. Repeat at seven to ten day intervals. Do not allow public use of treated areas during application or until sprays have dried.
chlorpyrifos*				Read complete Environmental and Use Precaution sections and consult your State Fish and Game Department before using this product for mosquito control.
(Dursban)	44.9% EC	0.8 to 1.6 oz.	---	
	22.1% EC	1.6 to 3.2 oz.	---	
(Empire)	20% F	---	0.2 to 0.5%	
(Mosquitomist Two)	24.6% EC	1.5 to 3.2 oz.	---	
chlorpyrifos + pyrethrins				Labeled for use in animal quarters only. Do not allow spray to contact foodstuffs, water supplies, animals or poultry. This product is toxic to birds, fish and wildlife and highly toxic to bees. Avoid exposure to reptiles.
(Dual Use)	31.9% + 3.3% EC	---	0.5%	
cyfluthrin*				Apply 1 oz. per 100 gallons of water. Apply as a general spray concentrating on damp areas beneath shrubbery and in areas of tall grass or weeds. Do not allow spray or drift to contact fish inhabiting water or any food crops.
(Tempo)	24.3% C	4 oz.	0.05 to 0.1%	
cypermethrin*				Cypermethrin is

(Cynoff, Cyper-Active, Vikor)	various	---	0.1%	extremely toxic to fish. Do not contaminate any body of water. Do not apply to edible plants. Do not allow adults, children or pets to contact treated surfaces until spray has dried completely.
deltamethrin*				Labeled for use in unoccupied livestock and poultry barns. Extremely toxic to fish and aquatic invertebrates.
(Suspend)	4.75% SC	---	0.03%	
diazinon	various	---	0.5%	Toxic to fish, birds and wildlife.
malathion	57% EC	8 to 13 oz.	---	May be toxic to certain species of fish in shallow water. Do not use during heavy bee activity. Car finish may be spotted. If exposure occurs, cars should be washed immediately. Repeat applications as needed.
	50% EC	3.0 oz.	---	
methoxychlor				Do not apply to food crops. Toxic to fish and bees.
(Marlate)	25% EC	1 part 25% EC in 4 parts water for 5% spray. Apply 0.5 gal. spray/acre	3%	
naled				Apply two to eight

(Dibrom)	58% EC	0.8 to 1.6 oz.	---	quarts diluted spray per acre. Concentrate may cause skin injury. To prevent serious corrosion, spray equipment should be thoroughly rinsed after application. Car finish may be spotted.
permethrin				Highly toxic to bees and fish. Do not use on food, forage or pasture crops or surface water supplies.
(Permethrin)*	57% OS	2.5 fl. oz.	---	
	13.3% EC	5.0 oz. per one gal. water	---	
(Permanone)	10% EC	6.5 oz. per one gal. water	---	
propoxur				For use only on exterior structural surface. Do not treat plants such as trees, shrubs, lawns or other flowering ornamentals. Toxic to fish, birds and wildlife.
(Baygon)	various	---	1.1%	
pyrethrins	25% S	0.6 gal	---	Do not dilute further.
	6% S	2.56 oz.	---	
	1% S	3.96 to 4.95 oz.	---	
	various	---	0.1 to 3%	
tralomethrin*				Do not apply to edible

(Saga)	40% WP	---	0.03%	plants. Do not allow adults, children or pets to contact treated surfaces until spray has dried completely. Extremely toxic to fish and other aquatic organisms.
*To be applied only by licensed, certified pesticide applicators.				
C=Concentrate, EC=Emulsifiable Concentrate, F=Flowable, OS=Oil soluble, S=Sprayable, SC=Suspended Concentrate, SUS=Suspension, WP=Wettable Powder				

Combination Products

Combination products contain two or more active ingredients. One active ingredient generally has fast knockdown characteristics, while a second active ingredient is slower acting with a longer residual life. In some cases, a synergist, such as piperonyl butoxide, is used to prevent recovery.

Some mosquito abatement districts, which conduct ULV applications at cool temperatures (about 60 degrees F), use a mixture of seven parts oil, three parts malathion, and one part Scourge (resmethrin + piperonyl butoxide-18% + 54%). Malathion has a positive temperature coefficient. As the temperature decreases, the efficacy of the malathion will also decrease. Conversely, resmethrin has a negative temperature coefficient. Its efficacy will increase as the temperature decreases. The mixture works well in cool and warm weather, provided it is warm enough for mosquitoes to be flying.

The following are chemicals commonly formulated with another active ingredient and a brief description of their general characteristics:

Pyrethrins - A botanical insecticide with fast knockdown action and a very short residual life. Insects may recover from doses sufficient to produce knockdown.

Resmethrin - A synthetic pyrethroid with fast knockdown action and a very short residual life. Insects generally will recover from a sublethal dose.

Chlorpyrifos - An organophosphate insecticide with moderate residual activity.
Permethrin - A synthetic pyrethroid with fast knockdown action and moderate residual activity (usually greater than two weeks). Insects may recover from doses sufficient to produce knockdown.
Diazinon - An organophosphate insecticide with moderate residual activity.
Malathion - An organophosphate insecticide with some residual activity when applied as a mist or residual spray.
Methoxychlor - A chlorinated-hydrocarbon insecticide with moderate residual activity.
Note: Residual activity of these products depends on the method of application and environmental conditions. Ultra low volume and thermal fog applications are not residual type applications. Typically, these will leave negligible residues.

Indoor Control

Mosquitoes found inside the house can be killed with any good household spray that is sold for control of flying insects indoors. Space sprays or aerosols containing synergized pyrethrins or synthetic pyrethroids are effective.
An aerosol bomb containing pyrethrum is easy to use. Best results are obtained if doors and windows are kept closed during the spraying and for five to ten minutes after spraying. Only products labeled for flying insect control should be used. Residual spray products labeled for control of crawling insects packaged in aerosol bombs are hazardous if sprayed into the air even though windows and doors are open.
Be sure to keep the windows, doors and porches tightly screened to exclude as many mosquitoes as possible. Avoid spraying food, dishes and other eating utensils.

Repellents

Repellents can protect humans from mosquito bites for one to five hours, depending on the amount of perspiration and rubbing of the skin and abundance

of mosquitoes. Cover evenly the area of skin to be protected, because mosquitoes will find and bite untreated spots. Spray on the outer clothing and on exposed parts of the body.

Keep repellents away from the eyes, nostrils and lips. Repellents may damage plastics, nail polish and certain painted or varnished surfaces. Repellents used in commercial products include N, N-Diethyl-meta-toluamide or DEET (in OFF), and dimethyl carbate. DEET is a very effective repellent but should not be used indiscriminately as severe allergies can develop.

- Read all directions before using this product.
- Do not spray in enclosed areas (for aerosols).
- Do not apply over cuts, wounds, or irritated skin.
- Do not apply to eyes and mouth.
- Do not apply to the hands of young children.
- On children, use a product containing less than 20 percent DEET.
- Do not spray directly over the face.
- Avoid breathing DEET aerosol.
- Do not use near food.

Use just enough repellent to cover exposed skin and/or clothing. Do not use under clothing. Avoid overexposure. Frequent reapplication and saturation is unnecessary for effectiveness.

After returning indoors, wash treated skin with soap and water. Wash treated clothing.

Use of this product may cause skin reactions. If you suspect that you or your child is reacting to this product, call your local poison information center. If you go to the doctor, take the repellent with you.

An important consideration to make in the selection of a repellent is the amount (percent) active ingredient present. This can be easily determined because the active ingredients and percent concentration are presented on the label. Different formulations of the same product may contain varying percentages of active ingredients.

To be sure that the product contains a sufficient quality and quantity of active ingredients to be effective, it should have an EPA registration number and list the active ingredients.
Several area repellents are currently available and can be used to protect patios or yards from mosquitoes. The active ingredients in these products may include napthalene or citronella.

Repelling Devices and Plants

Recent scientific evaluations of the performance of electronic and ultrasonic mosquito repeller devices have indicated that they have no significant effect on mosquito behavior.
Electric and black light "bug zappers" are not effective in reducing the biting mosquito population.
The scented geranium plant , *Pellargonium* sp., more commonly known as the Citrosa "Mosquito Fighter" plant, has little proven merit and further research is needed to demonstrate any mosquito repelling qualities that it may possess.

Livestock Control

Sprays on livestock will provide only temporary control of mosquitoes, and applications should be made daily. One of the more effective insecticides is: **pyrethrins 0.1% plus synergist** Mist spray one to two fluid ounces per animal. Repeat as needed. Do not wet skin. No pre-slaughter interval.
Insecticidal treatment of pasture will provide limited control because there is the constant problem of mosquitoes migrating into the treated areas. Malathion and carbaryl (Sevin), as recommended for residual lawn and vegetation spraying, can be used. **Follow label directions and safety precautions.**
For additional information on controlling insect pests of livestock, refer to Ohio State University Extension Bulletin 473, "Pest Management Recommendations for Livestock and Livestock Buildings."

General Pesticide Precautions

Before using a pesticide, read the label carefully.

- Follow the directions and heed all precautions on the pesticide container label.
- Store pesticides in plainly labeled containers, safely away from livestock, pets and children. Also, store them in a separate area where they will not contaminate food or feed.
- Avoid repeated and prolonged skin contact with the pesticide, and keep out of eyes, nose and mouth.
- Wash your hands and face immediately after applying a pesticide and before eating, drinking or smoking.
- Take care not to spill pesticides on skin or clothing. If this happens, remove contaminated clothing at once and wash skin and clothing thoroughly.
- Don't contaminate wells, ponds or streams when cleaning spray equipment.
- Dispose of empty pesticide containers by following instructions on the pesticide container label.

Rinse 'Em Out

Hazardous waste regulations require that empty containers that contained chemicals classified by Environmental Protection Agency (EPA) as "hazardous waste" and "waste pesticides" be disposed of in a designated hazardous waste site, unless triple rinsing and other requirements are followed by commercial pesticide applicators.

Triple rinsing each emptied pesticide container, using the rinse in the tank mix whenever possible, or disposing of the residue on the farm is required. Triple-rinsed containers may be disposed of at a sanitary landfill.

Ohio's Restricted Pesticides

Under Ohio's Pesticide Use and Applicator Law, certain pesticides are restricted and can be obtained and used only by pesticide applicators and public operators licensed by the Ohio Department of Agriculture and by those individuals who obtain a user's permit from their county Extension agent.
Certain restricted pesticides, when used, require that notification be given to occupants of lands within 1,000 feet of the boundaries of an open area or field to be treated at least 24 hours prior to the application. Occupants should also be informed of the precautions necessary for safety of humans and animals.

Pesticide Toxicity

The toxicity of a pesticide is expressed through the terms "oral" and "dermal" LD50. The lower the LD50 value, the more toxic the material. LD50 is the dosage of poison that kills 50 percent of the test animals (usually rats or rabbits) with a single application of the "pure" pesticide for a given weight of animal (mg/kg of body weight). Oral LD50 is the measure of the toxicity of pure pesticide when administered internally to test animals. Dermal LD50 is the measure of the toxicity of pure pesticide when applied to the skin of test animals.

Metric Conversion Table		
English	**Multiply By**	**Metric**
Square foot (sq. ft.)	0.09	Square meter (m^2)
Acre (A)	0.4	Hectare (ha)
Pound	0.45	Kilogram (kg)
Tablespoon (Tbsp.)	15	Milliliter (ml)
Fluid ounce (fl. oz.)	30	Milliliter (ml)
Pint (pt.)	0.45	Liter (l)
Gallon (gal.)	3.8	Liter (l)

LD50 Values of Mosquito Insecticides		
Insecticide	**Oral LD50 (mg/kg) Rat**	**Dermal LD50 (mg/kg) Rabbit**
Moderately Toxic		

carbaryl (Sevin)	246	---
chlorpyrifos (Mosquitomist)	96	2000
cypermethrin (Cynoff, Cyper-Active, Vikor)	250	>2000
deltamethrin (Suspend)	129	>2000
naled (Dibrom)	92	360
permethrin (Biomist, Permanone)	430	>2000
propoxur (Baygon)	50	>5000 (Rat)
Slightly Toxic		
cyfluthrin (Tempo)	826	>5000
Relatively Non-Toxic		
Bacillus thuringiensis Berliner var. israelensis	---	---
malathion (Fyfanon)	5500	>2000 (Rat)
methoxychlor	6000	---
methroprene (Altosid)	>34,600	>3000
pyrethrins	1500	>1800 (Rat)
resmethrin (Oblique, Scourge)	>2500	>3000 (Rat)
temephos (Abate)	4204	2000
tralomethrin (Saga)	1073	>2000
Source: Farm Chemicals Handbook '94, Meister Publishing Company, Willoughby, OH 44094.		

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