Dutchess County Department of Behavioral & Community Health

Tick-Borne Disease Prevention FAQ Series

PERSONAL PROTECTION MEASURES: INSECT REPELLENTS

Personal Protection Measure: Application of repellents or acaricides to skin or clothing

Definitions:

Repellent- A substance which discourages arthropods (insects and arachnids) from landing and climbing on a surface. Most of the substances used for tick bite prevention function as repellents.

Acaricide- A drug or formulation for killing mites and ticks. Permethrin is the most common substance used for tick bite prevention that is an acaricide. It also has repellent properties.

Summary of Scientific Evidence

- Epidemiologic surveys have generally found the use of repellents to be beneficial in reducing exposure to ticks and to Lyme disease, although a few studies have not been able to demonstrate a protective effect.
- A much larger data base on the efficacy and safety of products that are EPA registered exists than for products that are not EPA registered. The majority of non-EPA registered products have not been tested for efficacy.
- The existing evidence makes it difficult to draw definitive conclusions about which individual repellents are the most effective in reducing exposure to ticks and tick borne disease. However, the following general statements can be made:
    - When selecting a repellent for use on skin, attention needs to be paid to formulation as well as active ingredient. Oil or polymer based (rather than alcohol based) formulations, with active ingredients in high concentrations, tend to be more efficacious for longer durations. This will be reflected in the stated duration of action on EPA registered product labels.
    - For the active ingredients that are EPA registered for use on skin, the following is a rough rank order of evidence for protective benefits: IR3535, DEET, 2-undecanone, Picaridin, and PMD.
    - Ample evidence exists to support the protective benefits of treating clothing with permethrin. The most benefit can be obtained from treating shoes and from using clothing that has been commercially impregnated with permethrin.
    - Limited evidence exists to support the usefulness of the following non-EPA registered active ingredients: eugenol, myrental, cedar oil, geraniol, citronellol, dodecanoic acid, methyl jasmonate, and oil of citronella.

The following pages contain more detailed information with references to scientific studies that have attempted to measure the efficacy of tick repellents and acaricides in reducing exposure to ticks and tick borne disease. The difference between EPA registered and non-registered products is explained and resources to aid in repellent selection are provided. Finally, scientific evidence for active ingredients are examined individually. The list of active ingredients is extensive, but should not be considered comprehensive, as product availability is frequently subject to change.

Evidence for Protective Benefits of Repellent Use

For the most part, studies support the use of repellents to decrease risk of tick-borne disease. A 1988 epidemiological study of occupational exposure to Lyme disease in New Jersey showed workers reporting any use of insect repellent were less likely to be seropositive for Lyme disease (Goldstein et al., 1990). A 1998 study in Chester County, PA found a protective benefit from the use of insect repellents before work or recreational activities away from home. Also of note in this study: use of acaricides was actually associated with an increased risk of Lyme disease; and respondents were less likely to use repellents or acaricides prior to spending time outdoors near home than if they were venturing out of the home environment (Smith, Wileyto, Hopkins, Cherry, & Maher, 2001). A 2002-2003 survey of Connecticut residents found that the reported use of tick repellents conferred a 20% protective benefit on users (Vazquez et al., 2008). However, another Connecticut study found no protective benefit against Lyme disease incurred by the use of repellents (Connally et al., 2009).

One explanation for the lackluster evidence for the efficacy of repellents in preventing Lyme disease can be found in a 1995 study by Schreck et al. In this study, repellents were tested on skin for efficacy against the lone star tick, *Amblyomma americanum,* and the black legged tick, *Ixodes scapularis. A. americanum* is the vector that transmits tularemia and Rocky Mountain spotted fever. *I. scapularis* is the major vector that transmits Lyme disease, borreliosis, anaplasmosis, and ehrlichiosis in the northeastern United States. Twenty nine repellents were tested against *A. americanum*, and of these twenty nine, the seven most effective were then tested against *I. scapularis.* Of the compounds tested, piperidine showed the longest duration of efficacy against *A. americanum* (4 hours). DEET was effective for 2.7 hours. None of the compounds tested had a duration of efficacy greater than 1 hour against *I. scapularis* ticks. The authors concluded that *I. scapularis* is less sensitive to repellents applied to skin than *A. americanum* (Schreck, Fish, & McGovern, 1995).

EPA registered versus non-EPA registered repellents.

Consumers have many different repellent products to choose from. Commercially available products can be broadly placed into one of two categories: those that contain active ingredients requiring EPA registration, and those that contain active ingredients which do not require EPA registration. Data supporting the safety and effectiveness of products, when applied according to label instructions, is required for EPA registration. In other words, this means that EPA registered products have had to prove that they can do what their labels say they do. These products must display an EPA registration number on the label. Products that do not require EPA registration contain active ingredients that were evaluated for safety in the 1990s and deemed a minimal risk to human health. The effectiveness of products that are not EPA registered have not been evaluated by a regulatory body. EPA is currently re-evaluating this policy for minimum risk pesticides that claim to control pests that have public health significance. At this time, the CDC and other public health authorities recommend using EPA registered products as per label instructions, for greatest assurance of safety and efficacy (EPA, 2014a).

Tick repellents requiring EPA registration contain one or more of the following active ingredients: 2-undecanone, DEET, IR3535, Oil of Lemon Eucalyptus, Picaridin, or p-Menthane-3,8 diol. DEET is by far the most common active ingredient on the market. Repellents providing the longest duration of activity (10-14 hours) are formulated with the active ingredients DEET, IR3535, or Picaridin (EPA, 2014a).

Choosing an EPA Registered Repellent

Product selection should be based on the pest you want to repel and how long you want it to work after it has been applied. In order to make it easier for consumers to choose an appropriate repellent, the EPA has recently introduced a new graphic on repellent labels displaying this information. Not all EPA registered repellents will display this graphic because companies must apply for it, and cite scientific data to support the validity of the claim made in the graphic (EPA, 2014b).

The EPA also provides a useful online tool to help consumers choose which repellent best meets their needs. It provides a searchable database of EPA registered products labeled for use on **skin**. Users can search based on what species they wish to repel (ticks, mosquitoes, or both), and how long they need the product to be effective. The tool produces a list of registered products that meet the search criteria, providing product name, duration of action, active ingredient, and percent active ingredient. This tool can be found at: http://cfpub.epa.gov/oppref/insect/index.cfm#searchform. The National Pesticide Information Center provides a similar tools ("Insect Repellent Locator" and "My Repellent Finder App") available at http://npic.orst.edu/pest/tick/index.html (NPIC, 2014)

Studies Comparing Repellents

Coming to evidence based conclusions about the relative effectiveness of tick repellents is hampered by the lack of standardization in testing methods. Studies differ in the time frames over which repellents are tested, the species and life stage of ticks utilized, the formulations and percent active ingredients utilized, whether they are done in the field or the laboratory, materials to which repellents are applied, and what tick behaviors are examined or measured. These inconsistencies in study methodology make it difficult to draw conclusions about the real-world use of repellents for personal protection (Bissinger & Roe, 2010).

One recent study compared the repellency of seven products containing six different EPA registered active ingredients against the ticks *Amblyomma americanum* and *Dermacentor variabilis* in a petri dish. BioUD (7.75 2-undecanone), Cutter (30% oil of lemon eucalyptus), Jungle Juice (98.1% DEET), and Skin-so-soft Expedition Bug Guard Plus (19.6% IR3535) had the highest mean repellency against both ticks. Cutter Advanced Outdoorsmen (15% Picaridin) did slightly worse, and the lowest mean repellency of the products tested was seen from Premium Clothing insect repellent (.5% permethrin) (Bissinger et al., 2009). In 2011 Semmler et al. compared the efficacy of nine different tick repellents used commonly in the USA and Europe against the ticks *Ixodes ricinus, Dermacentor reticulatus,* and *Rhipicephalus sanguineus* on both skin and clothing. 5.8% Icaridin and vitex extract (Viticks Cool) had the longest duration of repellency against *I. ricinus* on both skin and clothing at 6 hours. PMD and vitex extract (Picksan Tickstop) had the second longest duration of repellency against *I. ricinus* on both skin and clothing at 5-6 hours (Semmler, Abdel-Ghaffar, Al-Rasheid, & Mehlhorn, 2011).

Several literature reviews have attempted to summarize the research in this area (Bissinger & Roe, 2010; Cisak, Wojcik-Fatla, Zajac, & Dutkiewicz, 2012; Pages et al., 2014). Bissinger emphasizes that not just active ingredient, but also formulation plays a large role in the efficacy of repellents. It is suggested that oil or polymer based formulations (rather than alcohol) increase duration of activity and decrease skin absorption of repellents (Bissinger & Roe, 2010).

The following contains more detailed information about studies of the efficacy of individual repellents. An additional useful reference is the chart of repellents and evidence for their efficacy on the website of the department of entomology at the University of Wisconsin-Madison: http://labs.russell.wisc.edu/wisconsin-ticks/on-people/.

Another source of information is the publication **Public Health Pesticides- an Inventory of Chemical Tools for Vector Control** produced by the IR-4 project, which is a cooperative effort of the USDA and Rutgers University. In addition to background information on public health pesticides and their regulation, this document provides an inventory of available pesticides with public health uses. Charts on pesticides used for tick control can be found on pages 137-146. Pesticides are classified by active ingredient, with information on use pattern (repellent or toxicant, topical use or environmental use), regulatory status, and a statement on evidence for efficacy provided for each (Malamud-Roam, 2012). There is an associated web-based searchable database that will be maintained as market availability changes: http://ir4.rutgers.edu/PublicHealth/publichealthDB.cfm

Active Ingredients requiring EPA registration:

1. DEET (*N,N*-Diethyl-m-toluamide) is the active ingredient most common in commercially available tick repellents for use on skin or clothing (Pages et al., 2014). It has been the most extensively used personal arthropod repellent for over fifty years. It is used by 30% of the US population annually. Though reports of negative health effects attributable to DEET are infrequent, safety concerns persist in the public (Bissinger & Roe, 2010). A recent review of safety surveillance revealed no association between DEET and severe adverse events. Since 1957 there have been a total of 14 case reports of neurologic symptoms possibly associated with DEET toxicity. Allergic reactions to DEET may occur in a small percentage of the population (Chen-Hussey, Behrens, & Logan, 2014). For the greatest assurance of safety with DEET and all repellents, always follow product instructions. Adults should apply repellents for children, avoiding hands, eyes, and mouth (CDC, 2011).

DEET efficacy studies show widely variable results depending on study design, product formulation, and species and life stages of ticks utilized (Bissinger 2010). Due to its long history of use, DEET has the largest body of evidence supporting its effectiveness against a variety of blood-feeding organisms, and 20% DEET is commonly used as standard for comparison for other repellents. A 2002 study measured the effectiveness of a commercially available repellent (Parapic-Tick-Repellent: BIOMED AG, Dübendorf, Switzerland) containing both DEET and ethyl-butylacetylaminopropionate (EBAAP) against tick bites in an at risk population in Switzerland under real-life conditions. While this study was done in Europe, it is relevant to the northeast United States because *Ixodes ricinus,* the most common tick-borne disease vector in central Europe, is very similar to *Ixodes scapularis*, and is likely to react similarly to repellents. The study found that use of the repellent on uncovered skin and adjacent areas offered moderate protection from tick bites. The effectiveness was 41.1% compared to placebo (Staub, Debrunner, Amsler, & Steffen, 2002).

Long-acting formulations of DEET have been developed to increase duration of action and decrease systemic absorption through the skin. One such formulation is the liposomal preparation LIPODEET. When the ability of 20% LIPODEET to prevent the attachment of the ticks' *A. americanum* and *D. variabilis* to the ears of rabbits was compared to 20% DEET in isopropyl alcohol, LIPODEET was found to have a longer duration of efficacy (Salafsky, He, Li, Shibuya, & Ramaswamy, 2000).

In a 2011 study both 15% DEET (Off Smooth and Dry) and 29.55% DEET (Great Outdoors) were effective against *I. ricinus* for a mean of five hours (Semmler et al., 2011).

2. Picaridin (1-piperidinecarboxylic acid, also known as **Bayrepel, KBR 3023, Icaridin, and Saltidin)** was developed by Bayer in the 1980s and became commercially available in the US in 2005. The CDC recommends the use of picaridin or IR3535 for those desiring an alternative to DEET (Bissinger & Roe, 2010). Semmler et al found Off Clean Feel (low concentration picaridin) to be effective against *I. ricinus* for 2-3 hours, while 5.8% Icaridin in combination with vitex extract (Viticks Cool) was effective on skin and clothing for a mean of six hours. 5.8% Icaridin in combination with vitex extract and geraniol (Viticks Cool Plus) had similar performance. 20% Icaridin (Autan Active) was effective for a mean of five hours (Semmler et al., 2011).

3. IR3535 or **EBAAP** (ethyl butyl acetyl aminopropionate) is a synthetic biopesticide (plant derived) registered by the EPA. It has preferable safety parameters to DEET and has had no reported adverse reactions. The CDC recommends the use of Picaridin or IR3535 for those desiring an alternative to DEET. One study showed it to have greater repellency to *I. scapularis* nymphs than a similar concentration of DEET (Bissinger & Roe, 2010). In another study three different controlled release formulations were tested on human volunteers against *I. scapularis* nymphs and found to repel ticks for 9.1 hours (10% lotion), 11 hours (20% aerosol), and 12.2 hours (20% pump). The authors concluded that repellents containing IR3535 at concentrations of at least 10% have potential for benefit in the prevention of tick-borne disease due to this extended duration of efficacy (Carroll, 2008).

EBAAP (BZZZStop) was found to be a more effective repellent against the ticks *R. sanguineus* and *D. variabilis* when applied to skin versus clothing. EBAAP was effective against *R. sanguineus* on clothing for 3-4 hours and hands for 4 hours. It was effective against *D. variabilis* on clothing for 3 hours and skin for 5-6 hours (Semmler et al., 2011).

4. 2-undecanone is derived from the wild tomato plant and is the active ingredient in the commercial product **BioUD.** One study compared the repellency of BioUD and 98.1% DEET against *Amblyomma americanum*, *Ixodes scapularis,* and *Dermacentor variabilis* on filter paper. The performance of BioUD was better against *A. americanum* and *I. scapularis,* and comparable to the DEET formulation against *D. variabilis.* BioUD was more repellent against *D. variabilis* than 15% DEET on filter paper. BioUD has been found to be repellent to *D. variabilis* on human skin for at least 2.5 hours (Bissinger & Roe, 2010).

5. Para-menthane-3,8-diol (PMD) is the active ingredient in the commercial products **Citriodiol** and **MyggA Natural,** and is a byproduct of the distillation of leaves from the Australian lemon-scented gum tree, Corymbia citriodora. The essential oil of this tree is called **Oil of Lemon Eucalyptus**, and contains geraniol, citronella, citronellol, and other compounds that act as short term repellents of mosquitoes. PMD is less volatile than the essential oil, has a longer duration of repellency, and is also effective against ticks. In China it is known as **Quwenling** (Bissinger & Roe, 2010).
In one study PMD was found to inhibit the feeding of *I. ricinus* on the ears of rabbits for 43 hours. In a field test using human subjects, Citriodiol use resulted in fewer attached ticks on volunteers, but there was no difference found in the numbers of ticks crawling on volunteers using Citriodiol versus controls. Field tests measuring ticks on drag clothes showed 74% (MyggA Natural) and 85% (oil of lemon eucalyptus) repellency on the day of application (Bissinger & Roe, 2010).

In another study, the product Picksan Tickstop (PMD and vitex extract) was found to be effective against *I. ricinus* on hands or clothing for a mean of 5-6 hours (Semmler et al., 2011).

6. Permethrin

Permethrin is an acaricide with repellent properties registered by the EPA for use on clothing by the military in 1990 (EPA, 2014c; Vaughn & Meshnick, 2011). It occurs as a natural ingredient, but is synthesized for wide use (Cisak et al., 2012). Permethrin has been consistently found to be more effective than DEET when applied to clothing in a number of studies (Bissinger & Roe, 2010). Clothing and outdoor equipment can be dipped or sprayed with permethrin, and pre-treated, long lasting, permethrin impregnated clothing is commercially available (Pages et al., 2014).

In 2003 the EPA began to register commercial clothing impregnated with permethrin (EPA, 2014c). Clothing is treated with a polymer coating of permethrin and then heated to 130 degrees. Factory impregnated clothing showed both a faster "knockdown" of ticks, and a greater duration of efficacy (greater than 100 washings) when compared to standard protocols for dipping or spraying clothing with permethrin (Bissinger & Roe, 2010).

The potential benefits of commercially made permethrin impregnated clothing over permethrin dips and sprays include being more user friendly, and having a greater duration of efficacy. In 2008 a pilot study of a factory-based method for long-lasting permethrin impregnation of clothing developed by Insect Shield, Inc. was conducted using 16 outdoor workers in North Carolina. The study found that subjects using Insect Shield treated clothing had a 93% reduction in the incidence of tick bites as compared to subjects using standard tick bite prevention measures (Vaughn & Meshnick, 2011). A follow up double-blind randomized control trial found impregnated clothing to be 82% effective in the first year of use, and 34% effective in the second year of use (Vaughn et al., 2014). Insect Shield impregnated clothing has undergone extensive safety testing, is registered with the EPA for use by people of all ages, and carries no exclusion for pregnant women. It retains its effectiveness for over 70 washes and is available through outdoor retailers such as Orvis and LL Bean (Vaughn & Meshnick, 2011). Performance of permethrin impregnated clothing has also been documented in Germany, where a recent trial of permethrin impregnated military uniforms used during military training in tick infested habitats was 99.6% effective in reducing tick bite incidence. The same uniforms used the following year were 98.6% effective in reducing tick bite incidence. The use of non-impregnated jackets over the uniforms was found to decrease effectiveness. The authors concluded that all outer layers of clothing should be impregnated for maximum effectiveness (Faulde et al., 2014).

A 2011 clinical trial measured the effectiveness of using permethrin on clothing typically worn during summer months (shorts, t-shirts, sneakers, and socks). Subjects were divided into three groups: untreated clothing, clothing treated with permethrin using a do-it-yourself kit, and clothing commercially treated with permethrin. Subjects were exposed to pathogen free ticks, and the number of tick bites were recorded after 2.5 hours. Subjects wearing treated clothing were 3.36 times less likely to be bitten by ticks than subjects wearing untreated clothing. Subjects wearing commercially treated clothing had fewer tick bites than subject wearing kit-treated clothing, but the difference was not significant. Permethrin treatment of shoes and socks had the most protective value, making tick bites 74 times less likely to occur (Miller, Rainone, Dyer, Gonzalez, & Mather, 2011).

List of Active Ingredients Classified as Minimum Risk Pesticides (not currently requiring EPA registration):

Castor oil (U.S.P. or equivalent), cedar oil, cinnamon and cinnamon oil, citric acid, citronella and citronella oil, cloves and clove oil, corn gluten meal, corn oil, cottonseed oil, dried blood, eugenol, garlic and garlic oil, geraniol, geranium oil, lauryl sulfate, lemongrass oil, linseed oil, malic acid, mint and mint oil, peppermint and peppermint oil, 2-phenethyl propionate (2-phenylethyl propionate), potassium sorbate, putrescent whole egg solids, rosemary and rosemary oil, sesame and sesame seed oil, sodium chloride (common salt), sodium lauryl sulfate, thyme and thyme oil, white pepper, zinc metal strips (consisting solely of zinc metal and impurities) (EPA, 2014a).

Repellent Alternatives and Novel Active Ingredients Under investigation

In 1986 the EPA added a rule to the Federal Insecticide, Fungicide and Rodenticide Act (FIRPA) exempting compounds considered to be minimum risk from registration requirements. Additionally, registration of biologically-based repellents (biopesticides) by the US EPA tends to be more rapid than registration of synthetic compounds. Biopesticides are often registered in less than 1 year while conventional pesticides are registered in an average of 3 years (Bissinger & Roe, 2010). The fact that minimum risk ingredients and biopesticides are easier to bring to market, combined with perceived concern over toxicity of synthetic repellents (DEET) has spawned investigation of plant based alternatives. Some natural compounds may be safer for human use and provide the environmental advantage of being biodegradable. However, some are toxic, some are skin irritants, and some can contain carcinogens (methyl eugenol). Some plant based active ingredients require EPA registration (2-Undecanone). A wide variety of products can be found. The majority have not been tested for efficacy (Pages et al., 2014).

Plant derived repellents are produced from the secondary compounds produced by the plants themselves to ward off insects and arthropods. The majority of research has been done on the largest group of secondary plant chemicals known as terpenoids. The efficacy and duration of activity of repellents derived from the essential oils of plants tends to be limited by their volatility (tendency to evaporate). This can be overcome by increasing concentrations, but higher concentrations may cause contact dermatitis (Bissinger & Roe, 2010). In 2011 Semmler et al compared the efficacy of nine different tick repellents used commonly in the USA and Europe against the ticks *Ixodes ricinus, Dermacentor reticulatus,* and *Rhipicephalus sanguineus* on both skin and clothing. Tea tree oil was completely ineffective. Other essential oils tested in combinations (catnip oil, citronella, geraniol, caranja oil, lemongrass) were effective against *I. ricinus* for 1-2 hours. Vitex extract did appear to improve the efficacy of the Icaridin when the two were formulated in combination (Semmler et al., 2011). While comprehensive efficacy data does not exist at this time, novel pesticides are an active area of ongoing research. The following are some of the highlights.

1. Eugenol is an EPA exempt compound that is an active ingredient in products containing or derived from **sweet basil** (*Ocimum basilicum* L.), **clove oil, extract of southernwood, essential oil of carnation flower,** and other plant sources. In one study, eighteen substances closely related to eugenol chemically were investigated for repellency. Testing was done on *Ixodes ricinus* ticks in a petri dish. Some of the compounds show bioactivity similar to DEET. There is no data on toxicology, or persistence and efficacy under field conditions. The authors concluded that eugenol has potential as a novel ingredient in tick repellants, but further testing is required (DelFabbro & Nazzi, 2013). In other studies: Eugenol had inferior repellency as compared to DEET when treated filter paper was held in a human hand; Another laboratory study found >90% repellency to *I. ricinus* nymphs at eight hours; A study of 10% clove oil found 78% repellency of *I. ricinus* at eight hours, while 10% DEET produced 71% repellency (Bissinger & Roe, 2010).

In spite of the EPA exemption, eugenol is an eye and skin irritant, and has been shown to be carcinogenic (Bissinger & Roe, 2010).

2. Myrental is an active ingredient in the essential oils of several plants including citronella, peppermint and lemon balm. *I. ricinus* ticks have been shown to spend less time on filter paper treated with myrental than on untreated paper (Bissinger & Roe, 2010).

3. Nootkatone and **Carvacrol** (both terpenoids) are the active ingredients in **cedar oil** (EPA exempt). In one study, field trials were conducted to compare relative repellent activity of these two compounds against adult *I. scapularis* and *A. americanum* ticks to the commercially available products EcoSMART (EcoSMART Technologies, Inc., Alpharetta, GA), and Repel Permanone (Repel Permanone, Wisconsin Pharmacal Co., Inc., Jackson, WI) when applied to clothing. Repel Permanone is a permethrin based clothing repellent. EcoSMART is labeled as an organic insect repellent containing: Rosemary Oil 0.5%, Cinnamon Leaf Oil 0.5%, Lemongrass Oil 0.5%, Geraniol 1.0%, and other ingredients including isopropyl alcohol, isopropyl myristate, and wintergreen oil 97.5%. Trials were conducted at 1, 2, 5, and 7 days after treatment of fabric. Number of ticks retained on treated coveralls at three minutes was used as a measure of repellent activity. It should be noted that EcoSMART is labeled for use on skin rather than clothing. All products tested showed fewer ticks retained than control at all time periods measured. Of the repellents tested nootkatone had the greatest repellency against both species of ticks at all time periods tested. Cavracol showed a shorter duration of efficacy than any of the other repellents tested. The authors concluded formulation of repellents can have a significant influence on effectiveness, and the results suggest that nootkatone has considerable potential as a clothing repellent for both species of ticks tested. Further testing for optimal formulations of potential novel repellents is required (Jordan, Schulze, & Dolan, 2012).

4. Geraniol is an EPA exempt terpene derived from oil of citronella and other plants, and produced commercially as TT-4302 and TT-4228 by TyraTech, Morrisville, NC. In one study the ability to repel four species of ticks was compared for two formulations of Geraniol (TT-4302 and TT-4228, both 5% geraniol in isopropyl and ethanol base respectively) produced by TyraTech, and commercially available 15% DEET. Both formulations of Geraniol were compared in laboratory bioassays, and the TT-4228 formulation was compared to 15% DEET in a field trial where repellents were applied to socks in a standardized manner. Results for DEET and Geraniol formulations were similar in lab testing. Repellency results were superior for TT-4228 than DEET in the field (Bissinger & Roe, 2010).

5. Citronellol is a terpene derived from **carnations, oil of lily of the valley, citronella,** and other plants. One laboratory study using carnation oil found 84.1% repellency of *I. ricinus* nymphs at eight hours. In another study lily of the valley essential oil produced 67% repellency eight hours after application to filter paper (Bissinger & Roe, 2010).

6. Dodecanoic acid (DDA) is derived from coconut and palm kernel oil and is the active ingredient in the commercial product ContraZeck® (10% DDA) (Bissinger & Roe, 2010). A 2008 study compared the repellency of ContraZeck® (10% DDA) to Zanzarin® Bio-Hautschutz Lotion (a natural coconut oil product), and Autan® (a synthetic Icaridin repellent) by exposing human subjects to pathogen free *I. ricinus* ticks in a laboratory setting. ContraZeck® and Zanzarin® had equivalent repellency (63-83%) of *I. ricinus* nymphs over a six hour period. ContraZeck had better repellency than Autan® against adult *I. ricinus* adults (75-88%) over a six hour period (Schwantes, Dautel, & Jung, 2008).

7. Methyl Jasmonate is a plant growth and development regulator found in the essential oils of many plants. In laboratory studies, methyl jasmonate on cotton cloth provided 99% repellency of *I. ricinus* nymphs when used at high concentrations. In field trials using treated flannel drag clothes, methyl jasmonate provided 80.9% repellency on day one, but dropped to 28.5% repellency on day two (Bissinger & Roe, 2010).

8. Oil of Citronella is an EPA exempt compound containing citronellol and geraniol. It has been shown to be 83% repellent to *I. ricinus* nymphs at eight hours in laboratory testing (Bissinger & Roe, 2010).

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