

# Evaluation of the Efficacy of Linalool Candles as Spatial Repellents against Natural Populations of Mosquitoes

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## Abstract:

In this field study to characterize the action of linalool candles as spatial repellents against natural populations of mosquitoes, subjects received 25.8% fewer mosquito landings at positions with candles containing 65% +enantiomer of linalool with 35% -enantiomer of linalool compared with the unscented tea candle.

## Introduction

Spatial repellents can provide new technology for protection of humans from mosquito transmitted disease. Glouck et al. (1967) defined spatial repellent as a repellent that is effective at a distance from the point of application. Nolen et al. (2002) further defined a spatial repellent as an inhibiting compound, dispensed into the atmosphere of a three dimensional space, which inhibits the ability of mosquitoes to locate and track a target, such as humans or livestock. D.L. Kline (personal communication) observed that linalool, when used alone, attracts mosquitoes to a trap; however, when used with CO<sub>2</sub> or with CO<sub>2</sub> + octenol, linalool reduces mosquito collection sizes by as much as 50%. Kline et al. (2003) found that linalool manifests spatial repellency against *Aedes aegypti* in a dual port olfactometer study.

As early as 1911, linalool, C<sub>10</sub>H<sub>18</sub>O, was described in the British Pharmaceutical Codex as an unsaturated alcohol, isomeric with geraniol, that occurs in a large number of essential oils, such as oils of coriander, linaloe, bergamot, spike lavender, and thyme. Linalool was initially registered as a pesticide with the U.S. E.P.A. in 1985 for the control of fleas on pets and pet bedding (Cornell Fact Sheet 77, 1985). However, despite the long and common use of linalool, research into biological activity of linalool has recently revealed such divergent activities as being a mate attractant pheromone component in the bee *Colletes cunicularius* (Borg-Karlson et al., 2003), producing antinociception in two experimental models of pain in mice (Peana et al., 2003), and exhibiting antileishmanial activity in an in vitro study of *Leishmania amazonensis* in mouse peritoneal macrophages (Rosa et al., 2003).

Candles are commonly used to dispense odors into the atmosphere. Candles containing oil of citronella are sold commercially in the United States and Canada, with some manufacturers claiming that these products “reduce the annoyance of biting insects,” specifically mosquitoes. In a study of citronella candles using human test subjects, Lindsay et al. (1996) reported that the overall percent reduction in mosquito bites provided by the citronella candles was 42.3% and by plain candles was 23.1%. Considering the reduction in mosquito biting activity produced by the act of burning

candles, the addition of 3% citronella to candles further decreased biting activity by only 19.2%.

The purpose of this field study was to characterize the action of linalool candles as spatial repellents against natural populations of mosquitoes.

## Materials and Methods

The study was conducted on a trail through a deciduous woodlot in Northwest Park, Windsor, Connecticut USA (41.88° N, 72.67° W). This park is located in the Connecticut River valley. Four subjects (2 female, 2 male) were used in this study, which was conducted on 4 nights (August 12, 13, 14 & 15, 2003). An additional person timed landing rate counts. Subjects wore clothing that permitted exposure of legs from knee to ankle. Subjects had clean bare legs free of insect repellent, lotion, or other scent sources.

Four test stations were set up on folding metal chairs at 30 m. intervals on a 3 m. wide park trail adjacent to a swamp. Four wooden stakes driven to the height of 1 meter created a 2.5 m. square around each folding metal chair. Candles were placed on the top of the stakes so that each test station was surrounded by 4 candles of the treatment. The treatments were Fragrance A (65% +enantiomer of linalool with 35% -enantiomer of linalool), Fragrance B (linalool=35% -enantiomer of linalool with 65% +enantiomer of linalool), OFF® Citronella candle, and plain unscented tea candle. On the first night, four candles of OFF® Citronella candle were placed at “1” station, four candles of Fragrance A were placed at “2” station, four candles of plain unscented tea candle were placed at “3” station, and four candles of Fragrance B were placed at “4” station. On three subsequent nights, the candles were placed at different stations so that each type of candle was tested at each station. Candles were lit thirty minutes before beginning experiment to insure the presence of a molten pool of wax in each candle.

Landing rate counts were initiated by 1900 h each night. Subjects were assigned to one of the 4 test stations at the beginning of the evening and rotated through all 4 stations each night. Subjects sat on the back of the test station chair with feet on the seat of the chair. Subjects collected mosquitoes landing on their legs with a battery-operated hand aspirator for 10 minutes. The collection vials were removed and sealed for mosquito identification. For the three subsequent trials each night, human test subjects moved to another test station. After taking position at the new test station and inserting new collection vials in the aspirator, test subjects repeated the mosquito collections for 10 minutes. Each test subject tested at each station each night.

All mosquitoes collected were identified to species using the keys of Darsie and Ward (1981) and Darsie (2002). Weather information was obtained from the Bradley International Airport weather station located 1 km north of the study area (NOAA, 2003).

## Results

Each night 141-187 mosquitoes were collected (Table 1). The mosquito species collected and percent composition were: *Aedes cinereus* Meigen 1.2%, *Aedes vexans* (Meigen) 25.3%, *Anopheles punctipennis* (Say) 16.2%, *Anopheles quadrimaculatus* Say 3.3%, *Coquilletidia perturbans* (Walker) 24.7%, *Culex pipiens* Linnaeus 0.2%, *Ochlerotatus canadensis* (Theobald) 0.5%, *Ochlerotatus japonicus* (Theobald) 9.9%, *Ochlerotatus triseriatus* (Say) 0.5%, *Ochlerotatus trivittatus* (Coquillett) 18.2%, and *Ochlerotatus excrucians* (Walker) 0.5%. Daily high temperatures were 32.2° to 30.5° C. and daily low temperatures were 18.3° to 22.2° C. during the landing count evaluations. Wind speed was less than 5 km/h during all nights. No rain fell during the evaluations.

The data were subjected to analysis of variance (ANOVA) (Freund, 1984). The treatments were significantly different at a 90% confidence level (Table 2). Subjects received the fewest mosquito landings with Fragrance A candles and the greatest number of mosquito landings with OFF® Citronella candles (Table 3).

Subjects received 25.8% fewer mosquito landings at positions with Fragrance A (65% +enantiomer of linalool with 35% -enantiomer of linalool) compared with the unscented tea candle (Table 4). Mosquito landings on subjects surrounded by Fragrance A candles was less variable over the four nights than in the other 3 treatments (Graph 1).

Table 1. Total mosquitoes collected by treatment, day, and location.

	<i>Day 1</i>	<i>Day 2</i>	<i>Day 3</i>	<i>Day 4</i>
<i>Location 1</i>	Citronella =71	FragranceA=29	Tea Candle=45	FragranceB=35
<i>Location 2</i>	FragranceA=23	Tea Candle=46	FragranceB=53	Citronella=50
<i>Location 3</i>	Tea Candle=41	FragranceB=37	Citronella=43	FragranceA=33
<i>Location 4</i>	FragranceB=52	Citronella=48	FragranceA=30	Tea Candle=23
<i>Total</i>	187	160	171	141

Table 2. ANOVA totals for location, day, and treatments.

<i>Source of Variation</i>	<i>Degrees of Freedom</i>	<i>Sum of Squares</i>	<i>Mean Square</i>	<i>F</i>
<i>Location</i>	3	134.68	44.90	0.377
<i>Day</i>	3	280.18	93.40	0.783
<i>Treatment</i>	3	1238.18	412.73	3.462
<i>Error</i>	6	715.37	119.23	
<i>Total</i>	15	2368.44		

Table 3. Mean number of mosquitoes collected per 10-min landing rate count at positions with Fragrance A (65% +enantiomer of linalool with 35% -enantiomer of linalool) candles, unscented tea candles, Fragrance B ((racemic linalool=35% -enantiomer of linalool with 65% +enantiomer of linalool) candles, and Off® Citronella candles.

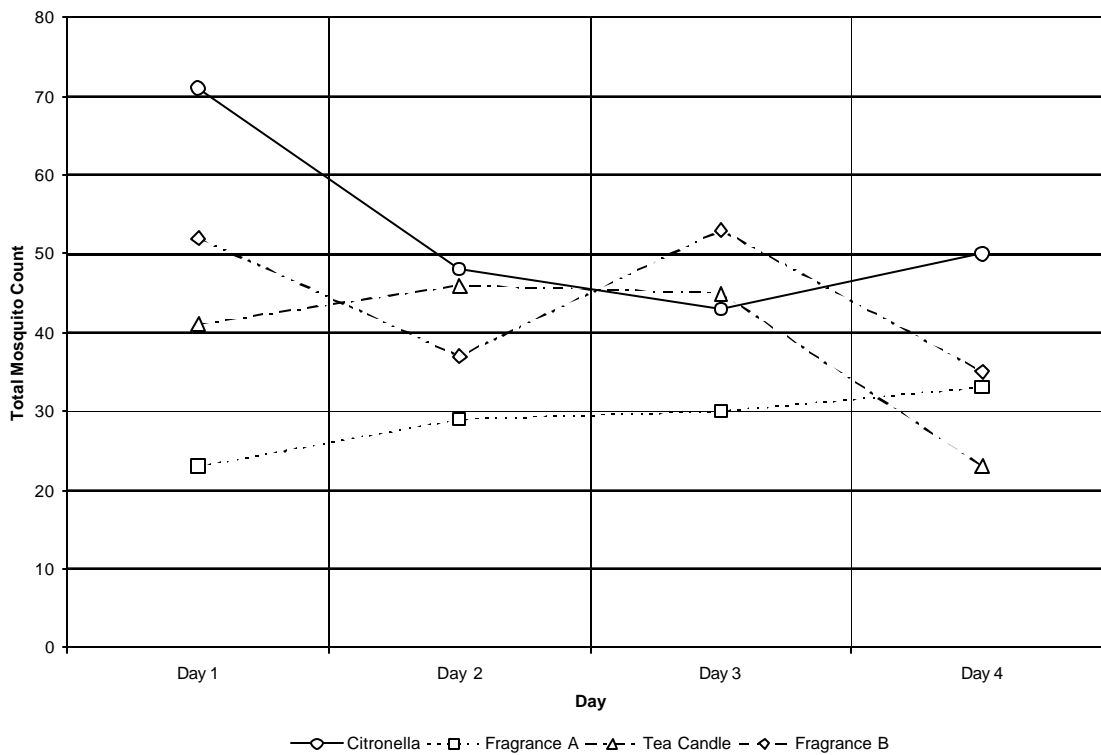
<i>Rank</i>	<i>Treatment</i>	<i>Total Collection</i>	<i>Mean Day Collection</i>	<i>Mean Subject Collection</i>
<i>1</i>	Fragrance A	115	28.75	7.19

2	Tea Candle	155	38.75	9.69
3	Fragrance B	177	44.25	11.06
4	Citronella	212	53	13.25

Table 4. T-test comparison of mean number of mosquitoes collected per 10-min landing rate count at positions with Fragrance A (65% +enantiomer of linalool with 35% -enantiomer of linalool) candles, unscented tea candles, Fragrance B ((racemic linalool=35% -enantiomer of linalool with 65% +enantiomer of linalool) candles, and Off® Citronella candles.

Comparison	Difference	90% Confidence Interval	Lower Limit %	Upper Limit %
Tea Candle - Fragrance A	-40	7.50	-30.64625586	-20.97
Tea Candle - Fragrance B	22	7.50	9.353744135	19.03
Tea Candle - Citronella	57	7.50	31.9343893	41.61

Graph 1. Comparison of mosquito landing rates in 10 min periods in treatment locations over 4 days.



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