*Journal of the American Mosquito Control Association*, 12(2):293–294, 1996


# EVALUATION OF THE EFFICACY OF 3% CITRONELLA CANDLES AND 5% CITRONELLA INCENSE FOR PROTECTION AGAINST FIELD POPULATIONS OF *AEDES* MOSQUITOES

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ABSTRACT. We assessed the efficacy of 3% citronella candles and 5% citronella incense in protecting subjects from bites of *Aedes* spp. under field conditions. The study was conducted in a deciduous woodlot in Guelph, Ontario, Canada from July 26 to August 10, 1995. Eight subjects, dressed identically, were assigned to one of 8 positions on a grid within the study area. Two citronella candles, 2 citronella incense, 2 plain unscented candles, or no candles (i.e., nontreated controls) were assigned to 2 positions on the grid each evening. Subjects conducted 5-min biting counts at each position and performed 16 biting counts per evening. On average, subjects received 6.2 ± 0.4, 8.2 ± 0.5, 8.2 ± 0.4, and 10.8 ± 0.5 bites/5 min at positions with citronella candles, citronella incense, plain candles, and no candles, respectively. Although significantly fewer bites were received by subjects at positions with citronella candles and incense than at nontreated locations, the overall reduction in bites provided by the citronella candles and incense was only 42.3 and 24.2%, respectively.

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. However, with the exception of unpublished data cited in Curtis (1986) that suggested that citronella candles do not appreciably reduce the biting rates of mosquitoes, quantitative studies of the repellency provided by citronella-based candles or incense are lacking. The purpose of this study was to assess the efficacy of commercially available 3% citronella candles and 5% citronella incense to protect people from bites of *Aedes* spp. mosquitoes under field conditions.

The study was conducted in a deciduous woodlot in Guelph, Ontario (43°45′N, 80°20′W). This woodlot, which is surrounded by large snowmelt pools where large numbers of immature *Aedes* spp. develop has been described previously (Surgeoner and Heal 1992, Heal et al. 1995). Eight subjects (4 ♀♀; 4 ♂♂) were used in this study, which was conducted on 8 nights (July 28, 31 and August 1, 2, 7, 8, 9, 10, 1995). An additional person timed biting counts and recorded weather conditions. The subjects wore headnets, white cotton gloves, and green coveralls with the sleeves rolled up to the elbows. They were not allowed to wear repellent.

Biting counts were initiated by 1900 h each night. The subjects were assigned to one of 8 positions on a grid within the study area at the beginning of the evening and rotated through all 8 positions twice each night. Positions were separated by at least 10 m. Each treatment was placed at 2 positions on the grid each evening. The treatments were citronella candles, citronella incense, plain unscented candles, and no candles (i.e., nontreated controls). Two citronella candles, 2 plain candles, or 2 citronella incense were placed at each treated position on top of 35-cm plastic stands 1 m apart. A plastic lawn chair was placed between the plastic stands and subjects conducted biting counts while seated on the lawn chairs. Treatments were assigned to positions on the grid such that each treatment was at each position twice during the 8-night evaluation.

Biting counts were made during 5-min periods at each position. The subjects aspirated all of the mosquitoes biting both exposed forearms into 150-ml clear plastic vials. The subjects recorded the number of mosquitoes captured and then moved to the next position on the grid. Thus, subjects made 4 biting counts at each treatment, each night. Mosquitoes collected were pooled each night and 30/night were randomly selected and identified using keys of Wood et al. (1979). Ambient temperature, relative humidity, wind speed, and wind direction within the study site were recorded at ≈30 min intervals during the biting counts.

The data were analyzed using a 4-factor analysis of variance with subject, treatment, position on the grid, and night as the independent variables. Because the number of mosquitoes collected per 5-min biting count varied widely between subjects, and the variance was correlated with the mean, these data were $\log_{10}$ transformed prior to the analysis. Subject, position on the grid, and night were random variables and treatment was a fixed variable. The analyses were completed using Statistical Analysis Systems

Table 1. Mean number ± SE of mosquitoes collected per 5-min biting count ($n$ = 128) at positions with 3% citronella candles, 5% citronella incense, plain candles, or nontreated controls.

| Parameter | Treatment | | | |
|---|---|---|---|---|
| | Citronella candles | Citronella incense | Plain candle | No treatment |
| Mean ± SE[1] | 6.2 ± 0.4A | 8.2 ± 0.5B | 8.2 ± 0.4B | 10.8 ± 0.5C |
| Percent reduction[2] | 42.3 | 24.2 | 23.1 | — |

[1] Means followed by the same letter are not different at $P < 0.05$; Student–Newman–Keuls test.
[2] Percent reduction calculated as: [(no. biting subjects at nontreated positions − no. biting at treated positions)/(no. biting at nontreated positions)] × 100.

version 6.04 (SAS Institute Inc., Cary, NC). Percent reduction in the number of bites provided by each treatment was also calculated as: [(no. biting subjects at nontreated positions − no. biting at treated positions)/(no. biting at nontreated positions)] × 100.

Each night 800–1,300 mosquitoes were collected. Ten mosquito species were identified from 240 individuals subsampled throughout the study. The species and percent composition were: *Aedes euedes* Howard, Dyar and Knab (59.2%), *Ae. vexans* (Meigen) (12.5%), *Ae. fitchii* (Felt and Young) (11.2%), *Ae. trivittatus* (Coquillett) (10.4%), *Ae. excrucians* (Walker) (2.5%), *Ae. canadensis* (Theobald) (2.1%), *Ae. stimulans* (Walker) (0.8%), *Ae. implicatus* Vockeroth (0.4%), *Coquillettidia perturbans* (Walker) (0.4%), and *Anopheles quadrimaculatus* Say (0.4%). Ambient air temperatures ranged from 19 to 26°C during biting count evaluations. Wind was less than 5 km/h during all nights except for <30 min on August 1 when gusts up to 8 km/h were recorded. Regardless of the wind direction, the subjects were always exposed to the smoke of at least one candle or incense. Light rain fell for <10 min on August 1; however, it did not rain on any other evening. None of the meteorological parameters measured would have deterred host-seeking activity by mosquitoes and therefore did not affect the results obtained.

Subjects received significantly fewer bites ($P < 0.001$) at positions with citronella candles compared with the other 3 treatments (Table 1). Significantly more mosquitoes ($P < 0.001$) were collected at nontreated positions than ones with citronella incense and plain candles and biting counts did not differ significantly ($P > 0.5$) between these 2 treatments (Table 1). Although significantly fewer mosquitoes were collected at treated positions compared with nontreated ones, the overall percent reduction provided by the citronella candles, citronella incense, and plain candles was only 42.3, 24.2, and 23.1%, respectively. Surprisingly, plain candles reduced the biting activity of mosquitoes, presumably because the light, heat, carbon dioxide, and moisture produced drew mosquitoes away from the subjects. 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%.

As in previous studies with woodsmoke (Snow et al. 1987), citronella candles or incense were ineffective for reducing the biting pressure of mosquitoes, and their use by the general public should be discouraged. Although one manufacturer (S.C. Johnson & Son, Limited, Brantford, Ontario) specified that the candles should be placed ≈45 cm apart, for practical and safety reasons we spaced the candles and incense 1 m apart. In general the directions for use of these products are vague or nonexistent and consumers are not explicitly told how many candles must be used to produce adequate levels of protection from mosquitoes. Increasing the number of candles or incense per unit area may have increased the efficacy of these products; however, it is unlikely that consumers would tolerate the excessive amounts of smoke and odor that would have to be generated to produce this effect.

We thank the Ontario Ministry of Agriculture and Food and Rural Affairs for continued infrastructural support. We also thank the subjects who participated in this study.

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