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Abstract
Some ecotypes of the honey bee, Apis mellifera L., show excessive levels of colony defense that have occasionally resulted in human and animal deaths. In cases where death has occurred, the victim, animal or human, has often been confined or panicked into an area from which it cannot escape. Our study was done to evaluate the use of repellents to reduce the severity of the stinging during accidental disturbances of excessively defensive colonies. Three mosquito repellents (diethyl-meta-toluamide, 2-ethyl-1,3-hexandiol, and dimethyl phthalate) and 2 odiferous compounds known to be repellent to honey bees (benzaldehyde and menthol) were tested in European (Texas) and Africanized (Mexico) apiaries by victims in protective clothing. When sprayed as an aerosol at the defending worker bees, all the compounds significantly reduced the number of bees around the victim and the number of stings in a patch of suede exposed during the test. DEET was consistently the most effective repellent. A number of materials could be developed as repellents for emergency use by individuals that are at high risk of encountering wild honey bee colonies in the course of their daily activity.

Keywords
Apis melliferam, repellents, colony defense, diethyl-meta-toluamide, menthol, stinging

Disciplines
Entomology | Systems Biology | Toxicology | Weed Science

Comments
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Use of Insect Repellents for Dispersing Defending Honey Bees (Hymenoptera: Apidae)

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ABSTRACT Some ecotypes of the honey bee, Apis mellifera L., show excessive levels of colony defense that have occasionally resulted in human and animal deaths. In cases where death has occurred, the victim, animal or human, has often been confined or panicked into an area from which it cannot escape. Our study was done to evaluate the use of repellents to reduce the severity of the stinging during accidental disturbances of excessively defensive colonies. Three mosquito repellents (diethyl-meta-toluamide, 2-ethyl-1,3-hexanediol, and dimethyl phthalate) and 2 odiferous compounds known to be repellent to honey bees (benzaldehyde and menthol) were tested in European (Texas) and Africanized (Mexico) apiaries by victims in protective clothing. When sprayed as an aerosol at the defending worker bees, all the compounds significantly reduced the number of bees around the victim and the number of stings in a patch of suede exposed during the test. DEET was consistently the most effective repellent. A number of materials could be developed as repellents for emergency use by individuals that are at high risk of encountering wild honey bee colonies in the course of their daily activity.

KEY WORDS Apis mellifera, repellents, colony defense, diethyl-meta-toluamide, menthol, stinging
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levels of seas where stung into where bees, all number effective use by sense of their menthol, through much of Texas, and Mexico, and stinging incidents, 1 death (Taylor and Rinderer 1991), we began research to reduce the number of stings by defense. Collins (1991) conducted a preliminary study on a number of compounds for their testing. We in- duced, several com- mercially available mosquito repellents—diethyl-meta-toluamide (DEET, McCabe et al. 1954), 2-ethyl-1,3-hexanediol (Granett and Haynes 1945, King 1954), and dimethyl phthlate (King 1954)—and 2 beekeeping products—benzaldehyde (oil of bitter almond, Townsend 1963) and menthol (Wilson and Collins 1989). We purchased all materials except benzal from Aldrich (Milwaukee, WI). Menthol crystals were obtained from Mann Lake Bee Supply (Hackensack, MN). All of the repellents were diluted to 15% by volume (by weight for menthol) in mineral oil. Controls of mineral oil alone and no spray were included in the experimental design. The liquids were dispersed with compressed-air aerosol cans (Sure Shot Atomizer Sprayer, Milwaukee Sprayer, Milwaukee, WI).

In experiment 1, we used only European honey bee colonies of several commercial stocks in Wes- laco, TX; experiment 2 was done in Tapachula, Chiapas, Mexico. Africanized honey bees had been present in that area for 5 yr before the experiment. Samples of worker bees were collected from each colony in the Tapachula apiary and identified by morphometric analysis (Daly and Balling 1978, Rinderer et al. 1983). Eleven colonies were Afri-
Fig. 3. Photographic series taken during a trial sequence with Africanized honey bees. Number of bees in air around the victim is representative of a mean response. (a) before treatment, (b) while repellent was sprayed, (c) while a suede target is waved, column A, no spray; B, DEET.

canized, 2 were Africanized with evidence of introgression of European genes, 2 were European with evidence of introgression of African genes, and 1 was European. All colonies in the apiary where testing was done were disturbed by vigorous pounding on hives, opening covers, and brushing bees from the entrance.

For each replicate of the experiment, 3 people wearing white, hooded coveralls with facial screening (standard beekeeper protective equipment) walked (1 at a time) among the disturbed colonies and attracted numerous defending bees. They then stood in front of a white backdrop (183 by 198 cm). Two black-and-white photographs were taken of the experimenter's back and the flying bees. The experimenter then sprayed the test compound around his/her upper body for 10 s. An average of 46.3 ml of oil-repellent mixture was used during the 10 s. At 5 and 10 s after the beginning of spraying, photographs were taken. After the spray, a
number of bees in air was sprayed, (c)

disturbed colonies (100 cm²) was waved slowly in
front of the experimenter for 15 s at head height. Photographs were taken at 10 and 15 s after the
waving began. The number of flying bees in the
area defined by the backdrop were counted from
the negatives. The stings left in the suede patch
were also counted.

For a complete replicate, each of the 3 experi­
menters did the test sequence with each of the 5
chemicals and 2 controls. All experimenter-chemi­
cal combinations were done in different random
order for each replicate. Two replicates were com­
pleted per day. Experiment 1 (Texas) was done on
September 1991. Day 4 of experiment 2 was de­

ted because of drastically reduced numbers of
bees with stings, because of their vigorous stinging
on days 1-3. Thus, each compound was tested 24
times in experiment 1 and 18 times in experiment
2. In experiment 1, the coveralls were washed each
evening to remove any residues from the day's
tests. No facilities were available for washing the
coveralls during experiment 2.

Because of missing data, results were analyzed
with a general linear models procedure for unbal­
anced analysis of variance (ANOVA) (SAS Institute
1988). The variables were day, replicate nested
within day, chemical, by day, coverall, and
chemical by coverall. The final analysis for
each response variable was repeated without the
nonsignificant effects included in the model. Type
III partial sums of squares were used. Pairwise
comparisons of the least squares means were made
by t-test.

**Results and Discussion**

**Effect of Chemical.** The levels of activity of de­
defending workers before the test materials were
sprayed were not significantly different by chemi­
cal (European honey bee F = 0.27, df = 6, P
> 0.952; Africanized honey bees F = 1.06, df = 6, P
> 0.394) (Fig. 1), that is, the testing began with
similar numbers of bees in the air around the ex­
perimenter for all treatments. The numbers of
bees in the air around the experimenter during
spraying (European honey bee F = 5.28, df = 6, P
< 0.0001; Africanized honey bees F = 38.94, df
= 6, P < 0.0001) and presentation of the suede
patch (European honey bee F = 5.37, df = 6, P
< 0.0001; Africanized honey bees F = 18.41, df
= 6, P < 0.0001), and the numbers of stings in the
patch (European bees F = 8.45, df = 6, P
< 0.0001; Africanized bees F = 13.94, df = 6, P
< 0.0001) were all reduced by the use of an aerosol

![Fig. 4. Mean number of bees in the air from each of the timed photographs taken during the trial sequence.](image)

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**Table 1. Intensity of defense by pursuing A. mellifera workers when aerial repellent sprays were used**

<table>
<thead>
<tr>
<th>Stage of test</th>
<th>Mean no. bees in the air*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
</tr>
<tr>
<td></td>
<td>Rep 1</td>
</tr>
<tr>
<td>European bees</td>
<td></td>
</tr>
<tr>
<td>Before treatment</td>
<td>24.8a</td>
</tr>
<tr>
<td>During treatment</td>
<td>10.6c</td>
</tr>
<tr>
<td>After treatment, moving target</td>
<td>7.9g</td>
</tr>
<tr>
<td>Africanized bees</td>
<td></td>
</tr>
<tr>
<td>Before treatment</td>
<td>170.7j</td>
</tr>
<tr>
<td>During treatment</td>
<td>105.6m</td>
</tr>
<tr>
<td>After treatment, moving target</td>
<td>126.7n</td>
</tr>
</tbody>
</table>

Means in the same row followed by the same letters are not significantly different (P > 0.01; least squares means [SAS Institute 1988]). Rep, replicate.

* Number in parentheses (%) is the fraction of bees remaining during treatment or target presentation (after treatment), expressed as a percentage of the numbers before treatment.
spray (Figs. 1 and 2). The control in which nothing was sprayed at the defending workers resulted in significantly more bees and more stings than did any of the spray treatments. Spraying mineral oil alone had some effect in reducing the number of bees in the air and number of stings; however, this treatment was numerically less effective than the repellents. DEET was consistently the most effective material used. Representative photographs from a control (nothing) and a repellent (DEET) test are shown in Fig. 3 (experiment 2).

**Effect of Bee Type.** The Africanized colonies in Chiapas had a more intensive response to the disturbances by the experimenters than did the European colonies in Texas (Fig. 4; see also y-axis scales in Fig. 1, and Fig. 3). In both cases, the repellents (especially DEET) reduced the number of bees in the air to <50 after 10 s. Even with the reduced stinging when repellents were used, the Africanized honey bees stung the suede much more often than did European honey bees.

Other differences in the pattern of defensive response by the 2 bee types were apparent when the time frame of the experiments was examined. The Africanized apiary always had a large number of bees in the air to day 4 (replicates) (F = 4.44, df = 3, P < 0.0055) and across the 3 d of the experiment (F = 43.36, df = 2, P < 0.0001) (Table 2). A greater proportion of bees were driven off by the spray during later tests and fewer returned to sting the patches when they were presented. Day 4 of the test with these bees was canceled because of the lack of sufficient defending workers that were still stinging.

In contrast, bees from the European apiary responded to disturbance of their colonies with more bees flying on test days 2, 3, and 4 and the 2nd replicate of day 1. However, the numbers of defenders had decreased by the 2nd replicate on days 2, 3, and 4 (Table 1). The percentage of bees present during spray and target waving was also somewhat greater on days 3 and 4. The level of defensive behavior by Africanized honey bees generally decreased from day to day with continued disturbance; with European bees, defensive behavior increased, at least for the 1st event of a day.

In experiment 2 with Africanized honey bees, we noted a significant interaction (F = 1.97, df = 12, P < 0.036) of chemical-by-day for the number of bees in the air during spraying. With Africanized honey bees, DEET and benzaldehyde were always effective at repelling bees. The other compounds were less effective when bees were most defensive (that is, day 1, Table 3).

**Effect of Person.** In both of the experiments, 1 person consistently brought more defending bees from the apiary (experiment 1, F = 9.52, df = 2, P < 0.0002; experiment 2, F = 9.94, df = 2, P < 0.0001; Table 4). This was not the same person for experiment 1 as for experiment 2. The differences may be attributable to odors or cleanliness of the coverall, or to differences in the behavior of the person; that is, some of the experimenters were more effective in stopping the bees than others.

| Table 2. Rates of stinging by defending *A. mellifera* after repellent sprays were used |
|---------------------------------|------------------|------------------|------------------|------------------|
| **Bee ecotype**                | **Mean no. stings in suede target** |
|                                | Rep 1 | Rep 2 | Rep 1 | Rep 2 | Rep 1 | Rep 2 | Rep 1 | Rep 2 |
| European                       | 16.3a | 9.2a  | 2.5b  | 6.3b  | 15.6a | 9.0a  | 16.6a | 13.6a |
| Africanized                    | 87.5c | 64.8d | 56.2e | 38.3f | 25.3f | 19.9f | —     | —     |

Means in the same row followed by the same letter are not significantly different (P > 0.05; least squares means [SAS Institute 1988]).

| Table 3. Interaction of repellent and test day on the intensity of defense by Africanized honey bees during spraying of test material |
|---------------------------------|------------------|
| **Repellent**                   | **Mean no. bees in the air** |
|                                | Day 1 | Day 2 | Day 3 |
| DEET                            | 48.5ab | 35.7a | 41.0a |
| Benzaldehyde                    | 57.5ab | 35.6a | 39.4a |
| Menthol                         | 105.7bc | 35.9a | 47.0ab |
| Dimethyl phthalate              | 125.5c | 77.2ac | 56.6a |
| Ethyl hexandiol                 | 145.6c | 70.3ad | 52.2a |
| Mineral oil                     | 155.2c | 117.6cd | 77.3ad |
| Nothing                         | 257.3e | 306.4f | 256.4f |

Means within column or row followed by the same letter are not significantly different (P > 0.05; least squares means [SAS Institute 1988]).
Defensive bees means [SAS Institute 1989, p. 231].

The results of our study indicate that several compounds will disperse honey bees defending their colony when sprayed at the flying workers. The most effective of the materials tested was DEET. All of the repellents were effective against both Africanized and European honey bee workers. Within 5 s after spraying began, the bees started leaving the area around the victim. As long as the material was being sprayed, the bees continued to move away and stay away. When spraying stopped, however, some of the bees returned (Fig. 4).

These compounds were not tested immediately adjacent to the colonies harboring the defending bees. The experimenters walked at least 5 m from the colonies to do the test. We do not claim that spraying the repellents on a colony will abort the entire defensive event, as some critics (e.g., Schmidt and Spangler 1991) have implied. However, our results indicate that some materials, with proper development and labeling, could be made available as personal safety tools for persons at risk of encountering defensive honey bee colonies in the course of their daily activity.

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