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Analysis and Comparison of Safe Organic Ant Repellents

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ABSTRACT: Household ant invasion can cause both family health damages and financial losses. Professionally-used insecticides are not recommended for household usage because they can reduce human and animal health. Moreover, families lack knowledge on safe ant repellents because studies on organic ant repellents often showed inconsistent results. To provide concrete instruction on choosing safe organic ant repellents, this study investigated the topic in terms of the biochemistry of natural ant repellents that have been considered safe and effective, and provided a comparison among the repellents using a Y-tube olfactometer to determine the effectiveness of the ant repellents against two ant species. Spearmint, mint oil, and Chinese essential balm are shown to be effective ant repellents by using the plant alone or by mixing it with honey working as a bait. Although the choice of ants in the experiment does not represent all household-invasive ants, this study is still worth referencing for families plagued by ant invasions and for further studies on household ant control.

KEYWORDS: Animal Sciences; Other; Camponotus; Y-tube Olfactometer.

Introduction

Ant invasion, a notorious behavior of ant colonies of some species, including carpenter ants (Camponotus spp.), acrobat ants (Crematogaster spp.), and red imported fire ants (*Solenopsis invicta*), aiming for establishing new colonies or finding food and water sources, has been a common trouble in metropolitan and rural households.[1] Household ants spoil fresh food, transmit diseases, sting people (which can be life-threatening for people with anaphylactic reactions), and even damage electrical currents as some species are attracted by electrical fields.[2,3] They are also a great nuisance as it is unpleasant for most people to see masses of ants marching in their home.[3] These risks brought by invading ants result in increased health concerns and economic losses for the household. Professionally-used insecticides, albeit being the most effective agents in controlling ants, are not applicable to households, because they often negatively affect the health conditions of humans with their residual toxicity.[4-8]

It is known that the volatile odors of plants are effective in repelling ants, as the ants are naturally selected to be sensitive and respond to the chemical compounds in many plants.[9] Many herbs are common therapeutic agents and ingredients used in cuisines and thus can be easily obtained.[10-12] Even though the organic materials (which were selected in the experiment, see details in methodology) may induce allergic reactions and even be toxic when used inappropriately for certain individuals, they are safe for the majority without allergies to these products and can still be applied by following the correct instructions. Besides, there was more than one product proven effective by the following experiment (view details in results and discussion section), so alternative choices are given for people who are allergic to one particular material.[13-17] Therefore, these natural products are potentially safe organic choices for households to repel ants. However, previous studies mainly focused on the efficacy of one organic product in particular on repelling ants, but not on the effects of multiple potential ant-repelling products in comparison. Currently, organic options for household ant control are often related to the use of pepper, garlic, and vinegar. But these means have obvious drawbacks: pepper has irritating properties and can be dangerous for people with specific allergies; garlic has an unpleasant odor that lasts for hours; and vinegar may gradually erode objects if its application is not cleaned completely.[18-20] Therefore, finding safe organic ant repellent alternatives is important for controlling household ant invasions. This study tested the effects of nine organic insect-deterrents on repelling ants using Y-tube olfactometer and investigated the biochemical mechanisms of the plant-based ant repellents.

Materials and Methods

Ants:

Two species of carpenter ants, Japan carpenter ants (*Camponotus japonicus*) and sugar ants (*Camponotus nicobarensis*), were ordered as two separate colonies from a pet shop. These two species were chosen for two reasons. First, they are easily obtained and maintained, requiring limited space and efforts to raise as colonies, indoors. Second, these species are also considered household pests in tropical regions. Although household ants in non-tropical regions belong to different genera, the use of two species of *Camponotus* in the current study is still able to provide a reference regarding the effects of repellents on household ants.[21-23]

Y-tube olfactometer:

A Y-tube olfactometer with a base length of 5 cm, arm length of 5 cm, and internal diameter of 5 mm was used. This Y-shaped device enables thew volatile odor of tested material at each terminal of the arm to disperse to the fork junction of the tube.[24]

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Repellents:

According to previous studies on the efficacy of plant-based insect deterrents, the following easily-obtained materials were chosen to test their repelling effects on two ant species: citronella (*Cymbopogon nardus*), cinnamon (*Cinnamomum cassia*), spearmint (*Mentha spicata*), patchouli (*Pogostemon cablin*), clove (*Syzygium aromaticum*), ginger (*Zingiber officinale*), limonene, Chinese essential balm, and mint oil.[25-31] Citronella, cinnamon, patchouli, clove, and ginger were purchased from local groceries. Mint oil, Chinese essential balm, and limonene were purchased from household supply stores (the type of Chinese essential balm used was in liquid form with green coloration). Garlic (*Allium sativum*) and black pepper (*Piper nigrum*) were not examined here because of their unpleasant odor or irritating properties despite of their ant-repelling potentials and accessibility. Each repellent was placed at the terminal of one arm of the Y-tube olfactometer. The solid repellents (i.e., citronella, cinnamon, spearmint, patchouli, clove, and ginger) were ground into a powder first, and then 10 mg of each was applied in each trial (the powder was replaced after each trial). For the liquid repellents (i.e., limonene, Chinese essential balm, and mint oil), the volume of 50 μL was applied in each trial.

Stimulations for ant's movement:

Two stimulants, honey and strong light, were applied in the experimental arena to ensure the movement of tested ants. Honey, with the volume of 50 μL, was placed at the terminal of each arm to attract the ants at the base to move toward one of the two arms. A torch illuminating the base of the Y-tube also served to propel the ant to make a choice rather than to remain still at the base of the tube. The light stimulation method was modified based on the observation that *Camponotus* spp. tended to stay in the shade rather than under the sun. The room temperature throughout the experiment was held constant at 26 ºC, because *Camponotus* spp. are most sensitive and responsive to the odor of food (honey) under this temperature.[32,33]

Experimental design:

One ant was placed at the base of the Y-tube and allowed to choose between the arms with and without the repellent (Figure 1). Each ant was tested only once and replaced with a new individual without exposure to the experimental arena because ants' sensory system is able to remember recent odors and corresponding actions.[34] If the ant stayed in the arm without the repellent for 10 seconds, the tested repellent was regarded as effective, and vice versa. If the ant stayed still at the base of the arm for 2 minutes regardless of the stimulations of strong light and honey, the repellent was regarded as strongly volatile and powerful that even a tiny amount of its odorous particles could spread to the base of the tubes and discouraged the ant from moving forward. The effectiveness of each repellent was determined by the number of ants that made a particular choice: the more "no choice" and "repelled" occurred, the stronger the repellent was. Since the arms of the Y-tube are identical, the control group would only have to manifest that the ants would leave the base as the experimental design intends. However, the effect of the two propulsions for leaving the base, light and honey, has been well proven by prior research and experiments. Moreover, no other factors besides two propulsions and the repellent influence the choice of the ants. Therefore, a test with control group was not carried out. Still, it is necessary to stress that removing the control is only to be done with sufficient confirmation for the fundamental principle that the control intends to prove.

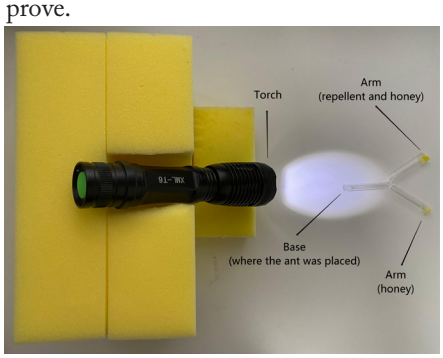

Figure 1: Experimental arena.

In the preliminary experiment, six *C. japonicus* and six *C. nicobarensis* were tested individually against nine repellent materials. The experiment was conducted without the stimulation of honey but with the stimulation of the light from the torch. The arena was also placed indoor with dim light to minimize the effect of vision (colors & shapes) on the ants' choices.

In the first formal experimental phase, the two ant species were divided into four separate groups (each with six ants) for each repellent tested to determine if starvation would force ants to make choices: starving (no food or water provision for 24 hours) *C. japonicus* (abbreviated as SCJ), full (just fed until the ants refused to eat or drink) *C. japonicus* (FCJ), starving *C. nicobarensis* (SCN), and full *C. nicobarensis* (FCN). The formal experiment was conducted with stimulations of both honey and strong light.

In the second formal experimental phase, the experiment was repeated with only SCJ and SCN groups, because there was a significantly smaller number of "no choice" for the starving groups than the full groups in the first formal experiment (see details in the Results and Discussion section), suggesting that ants were willing to make the greatest effort on choosing one of the two arms when they are starved. This starvation pre-treatment could ensure that ants choosing to stay at the base were indicative of the strong volatility of effective repellents, thus, the individual ant staying at the base without a choice was regarded as strongly repelled ones.

In the third formal experimental phase, because an inconsistency of test results (see details in the Results and Discussion section) of the Chinese essential balm existed – the Chinese essential balm was a powerful repellent in the preliminary experiment but not effective in the two formal experiments – additional experiments were conducted using essential balm with 12 ants in each group (SCJ and SCN). The apparatus of adding the liquid repellent was switched from a graduated cylinder (error of 0.1 mL) to an injector (error of 0.02 mL) because it was hypothesized that the result

inconsistency was due to the inaccuracy of the apparatus used for adding the essential balm.

Results and Discussion

The preliminary experiment without stimulation of honey or starvation treatment:

As shown in Figure 1, among the nine plant materials tested, mint oil, spearmint, limonene, and Chinese essential balm (represented as CEB) were the most powerful repellents against both *C. japonicus* (represented as CJ) and *C. nicobarensis* (represented as CN), intuitively having more blue columns (signs of effectiveness) over red (signs of no effect) than other repellents did. However, there were some oddities regarding the data collected: given that "no choice" results from the repellent being very potent thus discouraging the ant from even going to the fork junction of the Y-tube, it is not logical for a repellent with a minor odor like cloves to have the same effect as the repellent with strong odor like Chinese essential balm does. Through further investigation, the reason for this "no choice" phenomenon could be explained by the light illumination: the torch created a strong halo at the edge of its circle-shaped illumination and gradually lost battery power during the experiment; so, the edge of illumination was the strongest, and the illumination was unstable (Figure 1). Therefore, when the illumination was provided by the torch, the ants were discouraged from leaving the base because the unpleasantly strong light got intense when they approached the fork junction. The data collected from the choice of *C. nicobarensis* also corresponded with the observation that they were not attracted to illuminated environments during the ant colony maintenance phase. Therefore, a new torch with even illumination and sufficient power was selected. Honey, in addition, was used to further propel the ants to leave the Y-tube base. Further experiments were not carried out in the dim environment anymore. Although the reason for conducting the preliminary experiment in a dim environment was to avoid the interference of vision (color and shape of the repellent) on the choice of ants, the reflections of the Y-tube illuminated the repellent at the end of the arm after the stimulating torch was applied. Therefore, eliminating the vision interference factor was not applicable anymore.[35]

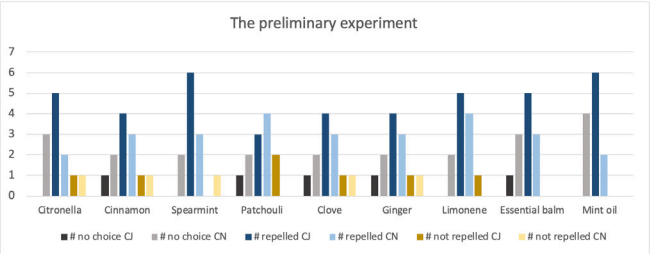

Figure 2: The efficacy of nine plant-based repellents against untreated *C. japonicus* and *C. nicobarensis* in the preliminary experiment.

The three formal experiments with stimulation of honey and starvation treatment:

After modifying the preliminary experimental method, results from the three formal experiments showed consistency in the effectiveness of spearmint and mint oil against both ant species with and without starvation treatment. Cinnamon, clove, and limonene also exhibited repellency against *C. nicobarensis* but not against *C. japonicus*, suggesting the differences in repellent sensitivity between ant species (see Figure 2 and Figure 3).

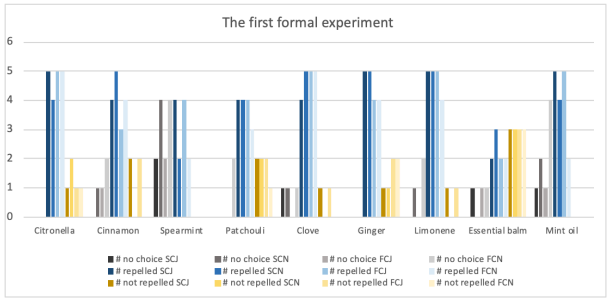

Figure 3: The first formal experiment: the efficacy of nine plant-based repellents against *C. japonicus* and *C. nicobarensis* with and without

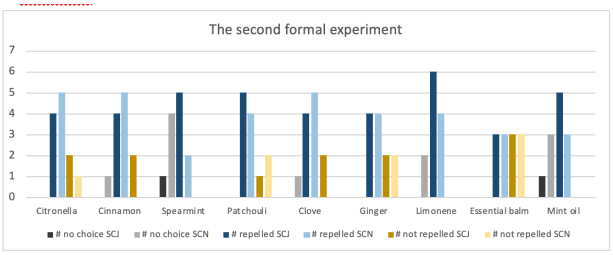

Figure 4: The second formal experiment: the efficacy of nine plant-based repellents against starved *C. japonicus* and *C. nicobarensis.*

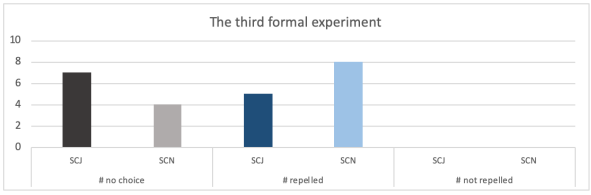

Figure 5: The third formal experiment: the efficacy of Chinese essential balm against starved *C. japonicus* and *C. nicobarensis.*

Chinese essential balm, which was a powerful ant repellent in the preliminary experiment (see Figure 1), was not consistently effective in the first or two formal experiment (see Figure 2 and Figure 3). Yet all ants that were "not repelled" by the essential balm died after eating the honey mixed with the essential balm, indicating the toxicity of essential balm. Thus, the third formal experiment was performed again for the Chinese essential balm only (see details in Methods section). As shown in Figures 4 and 5, the result differed from the first and second formal experiments: all tested *C. japonicus* and *C. nicobarensis* individuals were repelled by essential balm or had no choice (regarded as strongly repelled by essential balm, see details in Methods section).

There is a reasonable interpretation for this oddity. It was observed during the experiment that when ants chose the optimal position in the Y-tube to stay, they often exhibited tasting behavior on the honey and sometimes on the repellent as well. This seems strange because the ants can determine the odor via airborne particles to make a choice rather than by ingestion. However, the tasting behavior may happen because of the lure of honey. If ants tasted the honey in the arm with repellent, the ants tended to leave the arm immediately. For

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the essential oil, however, the ants were killed shortly after tasting. This explanation is somehow consistent with the Chinese essential balm's active ingredients: eugenol with LC_{50} value of 0.012 mg/cm^2 against carpenter ants, menthol with a significant influence on the foraging trails of ant colonies, and other components like eucalyptol and camphor, suggesting the effectiveness of essential balm in repelling and killing carpenter ants.[36-39] Indeed, facts mentioned above cannot be the definitive proof for my hypothesis as these testing on repellence was done via disturbing the foraging trail of a colony of ants, rather than single ants' choice in the present experiment.[40] The exact repellency of the Chinese essential balm as a whole against carpenter ants was therefore not obtained in the current study, meaning that before considering how to use the essential balm, we must first consider whether a colony of ants acts in the same way in front of essential balm or its bait as a single ant in the experiment.

If it is confirmed that a colony acts as single ants did in the experiment, the next step is to determine the lethal dose of Chinese essential balm. The Chinese essential balm should be powerful enough to kill the ants when they taste the mixture, while they should still allow the ants to approach. The current study showed that when the percent composition of essential balm in the mixture was 50% (50 μL of honey and 50 μL of essential balm), the ants were not killed immediately after tasting; when the percent concentration of essential balm in the mixture reached at 75%, the ants were killed instantly after tasting. However, since the lethal dose of essential balm and the effectiveness of essential balm on other ant pest species like *Coptotermes formosanus* are unclear, further investigations need to be done. In addition, essential balm evaporates quickly, so its persistence of toxicity used as ant bait also needs to be determined in future.

Advantages of Chinese essential balm and spearmint include their security for household application and effective repellence upon other insect pests, such as mosquitoes and flies, due to the menthol component. Also, essential balm can even relieve the discomfort from mosquitoes' bites.[41-44] However, as repellents, if not as bait, the essential balm and spearmint require further investigations as well: aside from testing whether the colony would be repelled by the repellents, ways of displaying the repellent require more study. The Chinese essential balm is highly volatile, so a thin, deep container would be required to achieve persistence of effect. Spearmint plant can be maintained indoor with sufficient light to provide repellence against ant pests: leaves at the bottom of the plant are often torn off to guarantee the growth of the plant, these leaves can be used to provide a repellent effect. Future studies also need to examine the repellent persistency of ground mint. If ground fresh mint fails to provide persistent repellence, other means, such as cutting the leaves in large pieces or slightly squashing the leaves, need to be examined.

Conclusion

The primary focus of future studies should be focused on essential balm and spearmint, as these two have the greatest prospect in application. Mint oil, another product that was proven effective in the study, is considered the essence extraction of mint plants, so the repellency of spearmint can be referred to mint oil, except that mint oil would require a container because of its volatility. While cinnamon, clove, and limonene were effective against only *C. nicobarensis*, they may not be the optimal choice for ant repellents because of limitation. At last, the verification of the repellent effect of the Chinese essential balm against a colony (rather than individual ants), amount of essential balm adequate for a bait, the effectiveness of spearmint plant alone as the repellent against a colony, and the universality of these two repellent materials, are worthy of future investigation.

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