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OPINION

Cucumber vs Ants: a Case Against the Myth of the Uses of Plant Extracts in Insect Pest Management

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Abstract

An accumulation of questionable scientific reports on the use of natural plant extracts to control household pest insects, using biologically irrelevant experimental designs and extremely high concentrations, has resulted in a publication bias: "promising" studies claiming readily available plants can repel various insects, including social insects, despite no usable data to judge cost-effectiveness or sustainability in a realistic situation. The Internet provides a further torrent of untested claims, generating a background noise of misinformation. An example is the belief that cucumbers are "natural" ant repellent, widely reported in such informal literature, despite no direct evidence for or against this claim. We tested this popular assertion using peel extracts of cucumber and the related bitter melon as olfactory and gustatory repellents against ants. Extracts of both fruit peels in water, methanol, or hexane were statistically significant but effectively weak gustatory repellents. Aqueous cucumber peel extract has a significant but mild olfactory repellent effect: about half of the ants were repelled relative to none in a control. While the myth may have a grain of truth to it, as cucumber does have a mild but detectable effect on ants in an artificial setup, its potential impact on keeping ants out of a treated perimeter would be extremely short-lived and not cost-effective. Superior ant management strategies are currently available. The promotion of "natural" products must be rooted in scientific evidence of a successful and cost-effective implementation prospect.

Introduction

Chemophobia or chemonoia, meaning a fear of "chemicals", combined with the "appeal to nature" fallacy, or the false idea that a "natural" chemical is inherently safer than a synthetic chemical, are significant drivers of the growing demand for "natural" and food-based alternatives to products such as medicine, cosmetics, and pesticides (Francl, 2013; Shelomi, 2020). While non-chemical therapies and pesticides certainly have applications in medicine and integrated pest management respectively, the demand for "natural" chemicals and rejection of anything seen as "artificial" can lead to people rejecting safe and effective products in favor of alternatives lacking in safety or proven effectiveness but often higher in price, and thus suffering needlessly (Johnson et al., 2017). Using chemophobia to market a product that is not cost-effective is itself a negative, as it involves profiting from logical fallacies and misinformation, or at worst committing fraud by making false statements. Insisting that all claims be supported by evidence is a solid ethical position, and one can apply the scientific method to confirm or reject "hypotheses" promoted by the natural products industry. This "mythbusting" (Zavrel, 2016) can expose ineffective remedies as unethical placebos, but also can reveal genuine effects of compounds that can be further investigated, as has happened for several safe and effective pharmaceuticals derived from plant-based chemical remedies. A good example is the mosquito repellent para-Menthane-3,8-diol (PMD), derived from lemon eucalyptus (*Corymbia citriodora* (Hook.) ssp. *citriodora*) and endorsed by the Centers for Disease Control and Prevention (CDC) as similarly effective as DEET (CDC, 2019). [It is worth noting that "natural" oil of lemon eucalyptus is *not* an effective

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repellent, and that PMD is considered *less* safe than DEET, having more documented side effects and stronger restrictions on its use (CDC, 2019; Shelomi, 2020).]

The difference between science and pseudoscience lies in the rigor and replicability of the relevant work. Demonstrating PMD's effectiveness required years of research from multiple groups around the world using appropriate, standardized repellency testing protocols (Carroll & Loye, 2006). Unfortunately, too frequently one sees papers published in legitimate or predatory scientific journals concluding that a product is "very promising," but with methodological flaws such as impractically high concentrations or biologically irrelevant experiment designs that render the results meaningless. Individuals involved in promoting a certain product (or denigrating a competitor) can thus misuse scientific publications to provide a veneer of academic respectability to what is otherwise pseudoscience (Weigmann, 2018). In pest management this problem manifests as scientists taking any plant or food readily available to them and testing its effects against a pest, often in field-unrealistic concentrations with low sample sizes and confined laboratory experiments, and concluding that this "home remedy" formulation is useful, without any safety testing, any effort to identify the compounds responsible for the effect, and how to scale it in a cost-effective implementation. Examples include a study on 41 essential oils that claimed eight of them were 100% effective, but only following "a peculiar formulation to fix them on the human skin" (Amer & Mehlhorn, 2006); and a study that claimed a common seaweed kills mosquitoes, but only when mixed with a lethal dose of insecticide (Prasanna Kumar et al., 2012). Such research is abundant yet unhelpful and rarely leads to a cost-effective product, meaning a product that is safe, effective, and long-lasting to the point that it is worth using.

The target of study in this paper is the popular myth that cucumber (*Cucumis sativus* L.) repels ants. A quick Internet search reveals over a million hits promoting cucumber as a "natural" ant repellent. Methods of control include leaving slices or peels of cucumber anywhere in the home one wants ants to avoid, using an extract of cucumber in water or another "natural" chemical solvent, or purchasing an expensive cucumber-based "natural" product. The same search also reveals YouTube videos of ants devouring cucumbers without trouble, so clearly ants are not completely put off by cucumber. Some online sources state "bitter cucumber" is a better repellent: we could not identify what plant "bitter cucumber" could exactly relate to, but suspect it refers to a Cucurbitaceae plant, bitter melon (*Momordica charantia* L.)

Like most such claims, the scientific evidence for cucumber as repellent is scant, though the possibility that certain Cucurbitaceae contain a compound that, at a high concentration or in a purified form, repels ants is non-zero. A report from 1982 testing an "old wives' tale" that cucumbers repel cockroaches found that, while whole cucumbers did nothing, sliced cucumber repelled roaches 80% of the time, and the active ingredient, trans-2-nonenal, repels roaches 100% of the time (Maugh, 1982). The same researchers identified two more chemicals inside cucumbers, (E,Z)-2,6-nonadien-1-al and (E)-2-nonen-1-al, that repel cockroaches (Scriven & Meloan, 1984). The active moiety of these molecules can be applied to make even more potent synthetic compounds, like diisopropyl ether and 5,5-dimethyl-3-ene-butyrolactone, that are much more effective repellents. The author noted, however, that these compounds are all highly volatile (Maugh, 1982): it is likely that cucumber's repellency effect wears off quickly, at which point it becomes a slice of rotting food that would only serve to attract more pests. The only evidence of cucumbers explicitly repelling ants in the "scientific" literature are two poor-quality studies from 2013 and 2014 by the same researcher published in predatory journals, which we are ethically dis-inclined to cite in order to combat the scourge of predatory publishing (Clark & Smith, 2015; Kurt, 2018).

In the spirit of mythbusting, we thus tested the hypotheses that cucumber and bitter melon can function as gustatory and/or olfactory repellents for applicable solutions against ant infestations.

Material and Methods

Our methods are all derived from published bioassay literature, albeit of varying quality and relevance to ants, yet nonetheless with sufficient citations to justify publication. Whole, raw cucumbers and white bitter melon were purchased from a grocery store in Taipei, washed thoroughly, and the peel grated off. To make aqueous solutions, 20 g of either grated peel were added to 100 mL of reverse-osmosis purified water and extracted for 24 hours at 4°C. These extracts were sterilized of any microbes by filtering through Millex® GP filter units with 0.22 μm pore-size Millipore Express® PES membranes. To produce other extracts, 20 g of peel were sequentially extracted in 100 mL each of analytical grade hexane, isopropanol, and methanol for 24 hours each at -20°C. Extracts were centrifuged to eliminate solid particles.

Ants were trapped from around the National Taiwan University Entomology Museum building using a bait of canned tuna, fructose syrup, and rolled oats. The ants were identified morphologically as the invasive *Pheidole megacephala* (Fabricius) (Wetterer, 2007). Worker ants were collected into a 50 mL centrifuge tube just before use. Each individual ant was used once, then killed by freezing. Only the minor worker ants were used. Major worker ants (soldiers) were not used.

Experiments were performed in 55 mm diameter plastic petri dishes, the sides of which had been painted with Fluon® to keep the ants from escaping. The methods are modified from those used to test responses to chemicals in *Drosophila* (Monte et al., 1989). To test for gustatory repellency, a circle of cardstock that can fit inside the dish is cut in half. One half is dipped quickly in the extract, the other as a control dipped in the solvent. The two halves are placed in the dish and allowed to air dry, and twenty ants placed in the center of the dish with a paintbrush. To control for visual cues, a box is placed over the petri dishes to block out the light. After 15 minutes, the box was lifted and the number of ants standing on the control or extract paper was recorded. For each plant-solvent combination, a total of 10 replicates was run. The samples with the most significant gustatory response were tested for olfactory response. In those tests, each dish contained two hole-punches of cardstock placed equidistant from either end of the petri dish, one wetted with 20 µL of extract and the other with the control solvent. Twenty ants were released in the center, and a box used to block visual cues. After 15 minutes, the number of ants in each half of the arena was recorded.

For statistical analysis, a response index (RI) (Monte et al., 1989; Amer & Mehlhorn, 2006) was calculated from the number of ants on the control (C) and extract (E) side using this equation: $RI=(E-C)/(E+C)$. The mean RI over all replicates was recorded as the strength of the effect: a strongly attractant substance has an RI of 1, a strongly repellent substance has an RI of -1, and a completely neutral substance has an RI of 0. The number of insects on the E and C sides over all replicates for each solvent was compared using a two-tailed, two-sample, paired t-test, which estimates the statistical significance of the repellency (ie: how often or how reliably a repellent effect can be observed). Two-tailed tests are more conservative but allow for the possibility of an attractant effect. The same test was also used to compare the effects of cucumber to bitter melon with the same solvent.

Results

The results are summarized in Table 1. T-tests comparing the results of gustatory tests for cucumber and bitter melon in each of the four extracts showed no significant difference in their effect ($p > 0.1$). The extracts in water and in hexane had weak ($-0.4 < RI < -0.2$) but significant ($p < 0.01$) repellent effects, and extracts in methanol had very weak ($-0.2 < RI < -0.1$) but significant ($p < 0.01$) repellent effects. Extracts in isopropanol showed no effect ($0 < RI < 0.2$, $p>0.1$). For water and hexane only, we performed olfactory testing. Bitter melon extracts and cucumber in hexane had no effect ($p > 0.05$). Only aqueous extract of cucumber had a statistically significant effect ($p < 0.001$), with an RI of -0.544, meaning on average 77% of ants were found on the side of the petri dish with the control water disk, compared to the 50% expected in a negative control

Discussion

The results suggest that cucumber may indeed repel some ants, slightly, sometimes. More accurately, the results show that a purified extract of Taiwanese *C. sativus* peel in dihydrogen monoxide (“water”) repelled a slim majority of *Pheidole megacephala* workers harvested from a single colony from one half of a confined container to another, with an effect lasting at least 15 minutes. We found no significant differences between the gustatory repellency of bitter melon and cucumber, and no olfactory repellency for bitter melon at all: whatever the online sources regarding “bitter cucumber” are talking about, it is not *Momordica charantia*.

The results suggest cucumber is not a particularly powerful way to repel ants, as some ants were always present on or near cucumber extract disks or papers. We also cannot tell from the data how long the effect lasts, how far the effect spreads, or what concentration of volatiles is needed for maximum effect. Isolating the compound[s] responsible may provide interesting results: it is unlikely to be trans-2-nonenol, (E)-2-nonen-1-al, or (E, Z)-2, 6-nonadien-1-al (Scriven & Meloan, 1984), as those are insoluble in water. That said, because the observed effect is still weak, adding such an analytical chemistry component to this study would serve mostly to make it appear more publishable and appease chemistry-minded reviewers.

Table 1. Results of Gustatory and Olfactory Repellency Tests of Cucumber and Bitter Melon Extracts on *Pheidole megacephala* (Fabricius).

Fruit	Solvent	Gustatory			Olfactory		
		Mean RI	p-value	Result	Mean RI	p-value	Result
Cucumber	Water	-0.284	0.007	weak repellent	-0.544	<0.001	half repellent
	Hexane	-0.400	0.019	weak repellent	0.205	0.194	no effect
	Isopropanol	0.207	0.421	no effect			
	Methanol	-0.165	0.014	very weak repellent			
Bitter Melon	Water	-0.356	0.001	weak repellent	-0.21	0.100	no effect
	Hexane	-0.342	0.003	weak repellent	-0.156	0.221	no effect
	Isopropanol	0.003	0.501	no effect			
	Methanol	-0.172	0.023	very weak repellent			

Data is based on 10 replicates for each assay with 20 ants per replicate. No olfactory experiments were done for isopropanol or methanol extracts. p-values are based on a two-tailed, two-sample t-test. RI = Response Index.

To summarize, while this research did find "statistically significant" effects of cucumber peel extract on ants, it does not at all suggest cucumber is a good or even promising repellent. The extract did not approach 100% repellency, even after only 15 minutes of time, while typically repellents are measured in terms of hours of absolute repellency (RI of -1.0). Cucumber extract cannot be considered a cost-effective repellent, both because of its low efficacy and because cucumber provides much higher value as a food. Cucumber-based products marketed as "natural" repellents [and likely priced accordingly] are almost certainly a waste of money, unless they have been adulterated with actual repellents. Fresh cucumber as recommended by the Internet would likely be even less effective: the bulk of the cucumber is not particularly aromatic but is rich in nutrients that worker ants would eagerly take back to their colonies. Spreading ant food around places where ants congregate does not seem like an effective strategy for ant management. There are better uses for cucumbers and better solutions for ant control.

Indeed, the very idea of an "ant repellent," natural or otherwise, was misguided from the start: it is a marketing gimmick for "natural" product pushers, but was never a cost-effective pest management tool. Repellents are valuable for temporary personal protection against pests that cannot be easily eradicated, such as against mosquitoes when hiking in a natural forest. However, pests that can infest households or in sensitive field setups (crops, recreational areas, pastures, etc.), repellency is simply impractical. Repellents eventually wear off, and then the pests will return. For cost-effective control of household insects such as ants or cockroaches, the simple preventive action of keeping potential food items out of access can prevent or limit infestation levels, and insecticides that have demonstrated their efficacy and sustainability can be used thoughtfully to mitigate pest problems. One of the most common solutions used for ant control at home is a mixture of borates (borax or boric acid) with bait such as sugar, which the workers will take back to share with the colony, causing significant population reduction, while using a extremely small quantity of active ingredient. Unlike cucumber, borates are both safe and effective, with plenty of peer-reviewed and rigorous publications supporting their use (Klotz et al., 1998; Gore & Schal, 2004), with the marketing bonus of also being "natural," for anyone who still values that term.

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Authors' Contributions

MS: conceptualization, methodology, writing and revision
BJQ and LTH: methodology, investigation.

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