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Repellency activity of essential oil on thai local plants against american cockroach (*Periplaneta americana* L.; Blattidae: Blattodea)

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Abstract The essential oils derived from Thai local plants, *Cymbopogon citratus* (lemon grass), *Cymbopogon nardus* (citronella grass) and *Syzygium aromaticum* (clove) were evaluated for repellent activity against adult american cockroach (*Periplaneta americana* L.) in the laboratory of the Plant Production Technology Section, Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang (KMITL), Bangkok, Thailand. All of the essential oils in ethyl alcohol showed higher percent repellency (81-100%) against *P. americana* than all of the essential oils in soybean oil (66-84% repellency). The essential oil from *C. citratus* in ethyl alcohol exhibited the highest repellency (100%) among the tested repellents and naphthalene (83% repellency). This study indicates the potential of *C. citratus* oil to be used as an alternative in developing and producing repellents as an effective measure used in controlling and eradicating *P. americana*.

Keywords: herbal essential oils, repellency, *Periplaneta Americana.*

Introduction

The american cockroach, *Periplaneta americana* L.: are an obnoxious and filthy domestic pest found in tropical countries around the world. Cockroaches are a high priority among urban pests because they are aesthetically unappealing, transmit diseases, and damage stored products and household goods (Borror *et al.*,1989; Chompoosri *et al.*, 2004; Khan *et al.*, 2011a). Cockroaches, although not usually the most significant transmitter of disease, but play a supplementary role in some allergy related diseases as well as the spreading of diseases such as: cholera, leprosy, dysentery, diarrheal diseases and the plague. Additionally, Cockroaches carry filth and pathogens on their legs and body and contaminate food on contact (Sriwichai *et al.*, 2002;

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Manzoor *et al.,* 2012; Rahman and Akter, 2006; Soonwera and Sainonsee, 2007). Currently, control of cockroach populations is dependent upon continued applications of residual insecticides, such as pyrethroids, organophosphate, organochlorine and carbamates and stomach poisons, such as hydramethylnon and sulfluramid (Khan *et al.,* 2011b; Tunaz *et al.,* 2009). Although effective, their repeated use may have undesirable side effects, such as the disruption of natural biological control system and the development of resistance. Therefore, these problems have highlighted the need for the development of new types of selective cockroach control alternative. Research regarding insect repellents derived from plant extracts is need to find alternative that are safer but still effective and some plant species contain insecticidal or repellent substance.

Isman, (2006) also reported that plant essential oils and their constituents have been suggested as potential alternatives to currently used insects control agents largely because they constitute a potential source of bioactive chemicals that have been perceived by the general public as relatively safe and pose less risk to the environment, with minimal impacts to human. Essential oils from *Citrus hystrix, Cymbopogon citratus* Stapf, *Mentha aruensis* and *Eucalyptus* spp. showed repellency against *P. americana*. *Cyperus rotundus* oil and *Illicium verum* oil revealed repellented activity against *B. germanica* (Chang and Ahn, 2001; Chang *et al*., 2012). The present study attempted to evaluate the repellent efficacy of herbal essential oil on Thai local plants (*C. citratus*, *C. nardus* and *S. aromaticum*) against *P. americana* adult under laboratory conditions.

Materials and methods

Test cockroaches

P. americana eggs were obtained from The National Institute of Health, Department of Medical Sciences, Ministry of Public Health, Thailand. The cockroaches were reared in Entomology and Environment laboratory, Plant Production Technology Section, Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang (KMITL). Nymphs and adult of *P. americana* were fed on dog pellets in glass jars (22.5 cm diameter x 35 cm) at 32.50±1.25ºc , 64.50±3.50 %RH and 12h:12h light : dark cycle. *P. americana* adult (aged 8 months) was employed for toxicity test under laboratory conditions.

Plant materials and Herbal essential oils

The three species of plants (*Cymbopogon citratus*, *Cymbopogon nardus* and *Syzygium aromaticum*) were identified, authenticated and submitted at Plant Production Technology Section, Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang (KMITL), Thailand. Each plant material was extracted for essential oils by water distillation. All essential oil was dissolved in ethyl alcohol and were kept at room temperature before testing. (Table 1).

Table 1. List of herbal essential oil on Thai local plants, part used, location and active ingredient of herbal essential oils tested in this study

Scientific name, Family	Plant part	Location	Therapeutic property
Cymbopogon citratus (DC.) Stapf., Graminae	Stem	Nakonratchasima, Thailand	Analgesic, antifungal, antiseptic, antiviral, bactericidal, febrifuge and insecticide
Cymbopogon nardus L., Graminae	Stem	Nakonratchasima, Thailand	Antiseptic, bactericidal, parasitic, deodorant, diaphoretic, parasitic, tonic and insecticide
Syzygium aromaticum Merr et Perry., Myrtaceae	Flower	Chumphon, Thailand	Antifungal,antimicrobial, antiseptic, anti-inflam-matory and bactericidal

Repellency test

Before application of the repellents, A plastic box (18.5x26x10.5 cm, with the top open) was employed in the repellent test. All four walls of the box were smeared with Vaseline to prevent escape of cockroaches. A piece of filter paper (Whatman NO.1, 18.5x26 cm) was marked to divide into 2 equal parts (treated and control area), and was placed at the bottom of the box. 2 ml of herbal essential oils were applied on the treated area and 2 ml of water were applied on the control area. naphthalene, the control standard, is solid. Each set of containers of food and drink for the cockroaches was placed at both sides of the box (treated and control area). Five adults of the *P. american* aged 8 months, were released into the center point of filter paper on the box. The repellency was observed after 24 hours under laboratory conditions. Each experiment was repeated ten times. Lastly, the repellency against the cockroaches was calculated for each test (Li and Ho, 2003) following this formula:

I= (NS – NC)/(NS+NC)
PC= [1- (NS)/(NS+NC)]x100%
PS= 100% - PC

Where:
I: excess proportion index
PC: Percentage repellency (i.e. percentage of animals trapped in control test chamber)
PS: Percentage attractancy (i.e. percentage of insects trapped in essential oils test chamber)
NS: number of insects trapped in the essential oil test chamber
NC: number of insects trapped in the control test chamber

A negative value of I indicates a repellency effect, whereas a positive value indicates an attraction, and zero values a neutral response.

Statistical analysis

The mean number of cockroaches in test and control cups were analyzed using a paired *t*-test. One-way analysis of variance (ANOVA) were used for the hatching percentage to determine significant treatment differences by SPSS for Windows (version 16.0). All levels of statistical significance were determined at $P<0.05$.

Results and discussions

The herbal essential oils, from *C. citratus* oil, *C. nardus* oil and *S. aromaticum* oil in ethyl alcohol at 10% concentrations against *P. americana*, were compared with naphthalene, as shown in Table 2. The optimal mean number of cockroaches observed with *C. citratus* oil, showed 0.0±0.0 cockroaches per box. Followed by *S. aromaticum* oil and *C. nardus* oil which showed 0.1±0.3 and 0.5±0.7 cockroaches per box, respectively. Furthermore, the highest percentage of effective repellency (PC%) against cockroaches was *C. citratus* oil, showing 100% repellency. Followed by *S. aromaticum* oil and *C. nardus* oil which showed 90 and 81% repellency, respectively. The highest percentage of effective attractancy (PS%) was *C. nardus* oil showing 19% attractancy towards cockroaches. The index of reaction (I) of herbal essential oils when being compared with the control, ranged from -1.00 for *C. citratus* oil, -0.63 for *C. nardus* oil and -0.80 for *S. aromaticum* oil, respectively.

The herbal essential oils from *C. citratus* oil, *C. nardus* oil and *S. aromaticum* oil in soybean oil at 10% concentrations against *P. americana*, were compared with naphthalene, as shown in Table 3. The optimal mean

number of cockroaches observed with *C. nardus* oil, showed 0.8±1.7 cockroaches per box. Followed by *S. aromaticum* oil and *C. citratus* oil which showed 1.6±1.9 and 1.7±1.9 cockroaches per box, respectively. Furthermore, the highest percentage of effective repellency (PC%) against cockroaches was *C. nardus* oil showing 84% repellency. Followed by *S. aromaticum* oil and *C. citratus* oil which showed 68 and 66% repellency, respectively. The highest percentage of effective attractancy (PS%) was *C. citratus* oil showing 34% attractancy against cockroaches. The index of reaction (I) of herbal essential oils when being compared with the control, ranged from -0.32 for *C. citratus* oil, -0.68 for *C. nardus* oil and -0.36 for *S. aromaticum* oil, respectively.

As described earlier, chemically controlled are a common method of *P. americana* control. However, it has been limited by several factors: the development of natural resistance by *P. americana* and the negative impact on human health. Thus, this study has revealed that the essential oil derived from *C. citratus* oil in ethyl alcohol showed higher percent repellency against *P. americana.* Similarly, Manzoor *et al.*, 2012 found that essential oil from *C. citratus* showed the most effective repellency (100%) against american cockroaches, (*P. americana*) after 24 hours. Phuakbuakhao and Soonwera, (2010) reported *C. citrates* revealed repellent activity *P. americana* adults. However, *C. citratus* oils repellent and toxic against household insect pests. Sritabutra *et al.*, 2011 reported that the volatile oil from lemon grass (*C. citratus*) showed strong repellent action against *Aedes aegypti* and *Anopheles dirus*, and could prevent mosquito bites for up to 98 min.

Phasomkusolsil and Soonwera (2012) reported that the essential oil from *C. citratus* oil with a concentration of 0.21 mg/cm^2 exhibited a high repellency (100%, 98% and 98%) against three mosquitoes species: *Ae. aegypti*, *An. dirus* and *Cx. quinquefasciatus*. Moreover, Kumar *et al*. (2013) found that the main components of *C. citratus* contains citral which was the most toxic against *M. domestica* larvae, with LC_{50} of 0.002 µl/cm^2 (contact toxicity assay) and LC_{50} of 3.3 µl/L (fumigation assay).

In Thailand, *C. citratus* oil is a popular medicinal herb, which comprises of a wide range of purposes. Citral, the major aromatic constituent of *C. citratus* oil, has been reported to have a variety of different applications, as an antimicrobial, anti-inflammatory and sedative (Negrelle and Gomes, 2007). Furthermore, these essential oils have developed to be repellent products against cockroaches. However, the solvent will be synergized with essential oil, to effect *P. americana* for repellency activity. These results could encourage the search for new active natural compounds, offering an alternative to synthetic repellents from other Thai indigenous plants.

Table 2. The repellency/ attractant/ neutral of herbal essential oils on Thai local plants in ethyl alcohol against *Periplaneta americana* adult

Herbal essential oils	Number of cockroaches±SD				
	Tested	Control	I	PC%	PS%
C. citratus oil	0.0±0.0*	3.4±1.6	-1.00	100.0	0.0
C. nardus oil	0.5±0.7*	2.9±1.3	-0.63	81.0	19.0
S. aromaticum oil	0.1±0.3*	3.3±1.8	-0.80	90.0	10.0
ethyl alcohol (negative control)	2.6±2.3	1.9±2.2	0.15	43.0	58.0
naphthalene (positive control)	0.4±0.8*	2.6±1.8	-0.67	83.0	17.0

*Significant differences between tested and control by paired *t*-test ($P< 0.05$)
**The I ranges from -1 to +1; the positive index (+) indicated that test solutions were attractants; the negative index values (-) indicated that the test solutions were deterrents
PC = Effective Repellency; *PS* = Effective Attractancy

Table 3. The repellency/ attractant/ neutral of herbal essential oils on Thai local plants in soybean oil against *Periplaneta americana* adult

Herbal essential oils	Number of cockroaches±SD				
	Tested	Control	I	PC%	PS%
C. citratus oil	1.7±1.9	3.3±1.9	-0.32	66.0	34.0
C. nardus oil	0.8±1.7*	4.2±1.7	-0.68	84.0	16.0
S. aromaticum oil	1.6±1.9	3.4±1.9	-0.36	68.0	32.0
soybean oil (negative control)	0.4±0.7*	4.6±0.7	-0.84	92.0	8.0
naphthalene (positive control)	0.8±1.5*	4.2±0.0	-0.68	84.0	16.0

*Significant differences between tested and control by paired *t*-test ($P< 0.05$)
**The I ranges from -1 to +1; the positive index (+) indicated that test solutions were attractants; the negative index values (-) indicated that the test solutions were deterrents
PC = Effective Repellency; *PS* = Effective Attractancy

Conclusion

All herbal essential oils were proved to have insecticidal effect against adult *P. americana* under laboratory conditions. Especially, *C. citratus* oil showed the highest repellency against of *P. americana* adult.

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