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Potential Use of Botanical Termiticide

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ABSTRACT

Termite is one of the most dangerous wood destroying insects and life crop plantations. Termites are commonly controlled using synthetic chemicals which can cause environmental hazzards. However, there are various environmentally methods for controlling termites, including the use of plant extracts and essential oils derived from plants such as orange, clove, and citronella oils. Orange oil has been used quite intensed in the USA, though many questioned concerning the long lasting effect of the oil. The paper is aimed to present general view on the potential use of botanical termiticides and its possible strategy to develop. Various kinds of termites can be found in different ecosystems in Indonesia, such as urban forest trees, plantations, and soils. Synthetic termiticides can be applied as whole treatment and localized treatment. Although the whole treatment is more expensive, but it is more effective because it uses fumigants such as chemicals (sulfuryl fluoride and methyl bromide) or heat. However, these chemicals are known to be ozon depletors. In contrary, the localized treatment is cheaper, but it is less effective and require repetead aplications. The key success in all treatment of termites in any structures is early detection of termite infestation such as signs of damage wood, fecal pellets, and discarded wings. Various plant extracts and essential oils show termiticide activities against different kinds of termites comparable to synthetic termiticide. For example, a formulated botanical pesticide containing clove and citronella oils is effective against dry-wood termite (*Cryptotermes cynocephalus*). Application of 5% of the formula kill the termite and protect the treated wood almost complete (score 9,8 out of 10) indicating that the formula is potential to be developed. This formula and other potential botanical termiticides need to be evaluated and improved to become more feasible both practically and economically. A main limitation for developing of botanical termiticides is its mass production and its price which can compete with the synthetic ones.

Keywords: Termite, essential oil, botanical termiticide

ABSTRAK

Potensi Antirayap Nabati

Rayap adalah salah satu serangga perusak kayu paling berbahaya dan juga dapat merusak pertanaman yang masih hidup. Umumnya rayap dikendalikan dengan menggunakan senyawa kimia sintetik yang dapat membahayakan lingkungan, padahal ada cara-cara cara pengendalian rayap yang ramah lingkungan, termasuk penggunaan ekstrak dan minyak atsiri berasal dari tanaman, seperti minyak kulit jeruk (orange oil), minyak cengkeh dan minyak serai wangi. Formula anti rayap dari minyak kulit jeruk sudah dijual di Amerika Serikat, walaupun masih ada kontroversi tentang keefektifannya jangka panjang. Tulisan ini menguraikan kemajuan perkembangan pestisida nabati anti rayap dan strategi pengembangannya. Berbagai jenis rayap ditemukan pada beragam ekosistem di Indonesia, seperti tanaman hutan kota, tanaman perkebunan, dan tanah. Anti rayap sintetik dapat diaplikasikan secara menyeluruh atau secara lokal. Walaupun aplikasi secara menyeluruh lebih mahal biayanya, tetapi lebih efektif, karena menggunakan senyawa kimia fumigan seperti sulfuril fluorida dan methyl bromida atau uap panas. Sayangnya, bahan-bahan kimia tersebut dapat merusak lapisan ozon. Sebaliknya, aplikasi secara lokal lebih murah tetapi kurang efektif dan memerlukan aplikasi ulang. Salah satu kunci keberhasilan pengendalian rayap adalah mendeteksi gejala rayap secara dini, misalnya adanya kerusakan pada kayu, bubuk halus dari kayu yang rusak, dan ditemukannya potongan sayap rayap dewasa. Beragam ekstrak tanaman dan minyak atsiri anti rayap menunjukkan sifat anti rayap yang baik sebanding dengan senyawa anti rayap sintetik. Misalnya, salah satu formula anti rayap berbahan baku minyak cengkeh dan serai wangi menunjukkan dapat mematikan rayap kayu kering (*Cryptotermes cynocephalus*). Aplikasi 5% formula pada kayu dapat melindungi kayu hampir sempurna (skor 9,8 dari maksimal skor 10). Hasil ini mengindikasikan bahwa formula anti rayap nabati tersebut berpotensi untuk

dikembangkan lebih lanjut. Formula tersebut dan beberapa anti rayap nabati potensial lainnya perlu diuji dan diperbaiki sehingga layak baik secara praktis maupun ekonomi. Kendala utama pengembangan anti rayap nabati adalah produksi masal dan harga yang kompetitif terhadap anti rayap sintetik.

Kata kunci: Rayap, minyak atsiri, anti rayap nabati.

INTRODUCTION

Termite is one of the most damaging insects not only on wooded constructions, but also in agricultural crops and forstry trees. Economic loss due to termites in terms of expenditures for damage, repair, and preventative treatment costs on wooden structures in the USA exceed of 2 billion dollar US annualy (Clausen and Yang, 2008; UNEP/FAO, 2000). In China, economic losses from termites exceed $ 1 billion US each year and tens of thousands of tons of pesticides have been applied in the 13 provinces of southern China (UNEP/FAO, 2000). In Indonesia, economic losses due to termites in wooden structures is increasing from year to year. For example, in 1995 total damage due to termites was estimated Rp. 1,6 triliun, increased to 1,89 in 1999, and in 2000 was around 2,8 triliun (Rachmawati *in* Sumarni, 2005). This figure is getting higher and higher since wood quality used in most housings and manufactures in big cities tend to be lower qualified. Economic loss on agriculture crops by termites is not well documented, although reports showed that termites attack various crops, such as cereals, pusle crops, oil crops, sugarcane, vegetable, fruit trees, and horticulture crops (UNEP/FAO, 2000).

More than 2,600 species of termites, have been described but fewer than 185 are considered pests (UNEP/FAO, 2000). . In Indonesia, there are around 200 species of termites, but only 5 species of the most important, such as *Coptotermes curvignathus*, *Coptotermes traviani*, *Macrotermes gilvus*, *Microtermes insperatus* and *Cryptotermes cynocephalus* (Rudi, 2002) (Figure 1). Primada *et al.* (2003) surveyed the richness of termite at campus of Indonesian University in Depok; they found 6 species of termites that were most frequent and scatterely found in the campus areas i.e. *Coptotermes curvignathus*, *Macrotermes gilvus*, *M. insperatus*, *Schedohinotermes javanicus*, *Odontotermes grandiceps* and *O. javanicus*. Information of the types of termites on agriculture ecosystem in Indonesia is rare, but few repotrs confirmed the wide spread of termites in various ecological systems (Table 1). In other countries, UNEP/FAO (2000) listed several important termites such as *Anacanthothermes* and *Hodotermes* (*Hodotermitidae*), *Neotermes* (*Kalotermitidae*), *Captotermes*, *Heterotermes* and *Psammotermes* (*Rhinotermitidae*), *Amitermes*, *Ancistrotermes*, *Cornitermes*, *Macrotermes*, *Microcerotermes*, *Microtermes*, *Odontotermes*, *Procotermes* and *Syntertermes* (*Termitidae*).

The paper is aimed to present general view on the progress on herbal termiticidal research findings in Indonesia.

Table 1. List of termite species reported in various parts of Indonesia

Species	Habitat/host	Location	Reference
Coptotermes. curvignathus, *Macroterme gilvus*, *Macrotermes. insperatus*, *Schedohinotermes javanicus*, *Odontotermes grandiceps* and *Odontotermes javanicus*	Urban forest trees of the University of Indonesia Campus	Jakarta	Primada *et al.* (2003)
Macrotermes gilvus	Forest tree (*Melaleuca leucadendron)*	Purwakarta, West Java	Natawiria *et al* *in* Hardi and Kurniawan (2007)
Coptotermes curvignathus	Palm oil	North Sumatra	Darma-Bakti (2004)
Nasutitermes metangensis, Odontotermes sarawakensis, Globitermes sulphureus, Macrotermes carbonarius, Schedorhinocetermes javanicus	Urban forest trees of the Andalas University Campus	West Sumatra	Suin (1992)
Coptotermes, Glyptotermes, Macrotermes and *Cryptotermes*	Village soil area	Suku Mapur, Bangka	Susanti *et al* (2010)

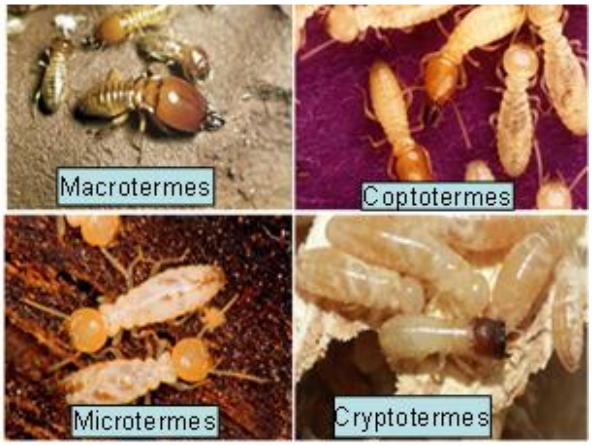

Figure 1. Four most important of termites (Source: http://www.solusiantirayap.com/info-rayap)

BIOLOGY OF TERMITES

Termites live in the colony; consist of the queen (the largest individual) which lays eggs, a king, and soldiers which have a large head with powerful jaws (Figure 2). There are four distinct groups of termites, i.e. damp wood, dry wood, subterranean, and arboreal/mound builders. Damp wood termites live and feed in very moist wood, especially stumps and fallen trees on the forest floor. Dry wood termites live in the wood. Subterranean termites live and breed in soil, trees or other above ground. Mound builders live in high construction buildings (UNEP/FAO, 2000).

Mashek and Quarles (2005) briefly described the biology of dry wood termites. There are two kinds of termites, i.e. subterranean and drywood. The subterranean termites included *Reticulitermes* and *Coptotermes*. They live all times in the ground and forage in wood beneath and above ground. Subterranean termites make tunnels to commute between soil underground and structures above ground. In the underground, they usually make a big collonies of 50,000 size to a few million workers. On the contrary, dry wood termites have smaller collonies, less than 1,000 workers. Important species of dry wood termites are *Cryptotermes* and *Incisitermes*. Dry wood termites live their entire life cycle inside of wood, except when become swarning (flying termites). A typical colony of dry wood termites takes about 4 years to mature.

Figure 2. Queen, King and Workers of termite (Photo: Dr. Barbara L. Thorne *in* UNEP/ FAO, 2000).

PROGRESS ON TERMITE CONTROL METHODS

History of termite control

Termiticide can be applied as whole treatment and localized treatment. Both treatments have advantageous and disadvantageous (Mashek and Quarles, 2008; Lewis, 2002). The whole treatment applied simultaneuosly on all infestations, accesible and inaccesible (hiding termites), in a structure is very effective to control termites. Commonly, the whole treatment uses fumigants such as

Table 2. List of synthetic termiticides approved by the Australian Government (The Environmental Health Directorate, Department of Health, Australia, 2006)

Active ingredient	Chemical group	Usage	Toxicity to humans	Lifespan (years)
Bifenthrin	Pyrethroid	Pre- and post construction	Medium to high toxicity	3-10
Chlorpyrifos	Organophosphorus	Pre- and post construction	Medium to high toxicity	5
Imidacloprid	Neonicotinoid	Post construction	Low to medium toxicity	3
Fipronil	Phenylpyrazole	Post construction	Low to medium toxicity	Not known
Arsenic trioxide	Arsenic	Post construction	High to very toxict, carcinogenic	Not known
Triflumuron		Insect growth regulator. Post construction	Low to medium toxicity	Not known
Permethrin	Pyrethroid	Treatment of tree and tree stumps	Low to medium toxicity	Not known
Hexaflumuron	Benzoyl urea	Insect growth regulator. Bait matrix system	Low toxicity	Not known
Chlorfluazuron	Benzoyl phenyl urea	Insect development inhibitor. Bait matrix system	Low toxicity	Not known

chemicals (sulfuryl fluoride and methyl bromide) or heat. The chemicals are known to be ozon depletors, means dangerous to envirnment. However, the whole treatment is more expensive. In its application, the whole treatment needs installing of tarpaulin (water-proof cloth), the structures (housing) must be vacated and all important facilities must be covered with protective bags. On the contrary, localized treatment is more restrictive to certain areas such as single board or small group of boards. Localized treatment can use chemicals (aerosol pyrethrum and liquid pyrethroids) or non chemicals (heat, microwave, high voltage electric current, wood replacement, etc.). Although it is cheaper, the localized treatment is less effective (13-100% effective) compared with the whole treatment, and may cause damage to structures especially if using drill holes to inject either liquid or dust termiticides into the wood strcuctures. In addition, in the localized treatment, substances must be contacted with termites, therefore it requoires re-treaments if new investation of termites from underground tunnels are visible.

Synthetic Termiticide

Conventional methods for controlling termites are largely based on using synthetic termiticides. The Environmental Health Directorate, Department of Health, Australia (2006) listed several approved synthetic pesticides for termites (Tabel 2). These termiticides are recommended for pre-construction barrier treatments in new buildings and for perimeter barrier treatment around existing buildings, as well as in and around buildings. In Indonesia, for preserving woods, synthetic chemicals used are based on copper chromium boron (CCB), fluor chrome arsenate phenol (FCAP), copper chromium fluor (CCF) (Rudi, 2002). These termiticides are toxict to humans and environment. Therefore, studies on finding alternative termiticides, such as botanical termiticides which environmentally friendly are necessary.

Botanical Termiticide

Several plants have been tested to exhibit termiticide activities, either in laboratory experiments or in field studies (Table 3). Using filter paper test, Jembere *et al.* (2005) evaluated plant extracts such as milletia (*Milletia ferruginea*), croton (*Croton macrostachys*), neem (*Azadiracta indica*), and datura (*Datura stramonium*) on *Macrotermes* sp. From all the plant extracts, milletia seed extract (10%) was toxic to the termite comparable to the synthetic insecticide, chlorpyrifos. Croton bark extract at 25% also toxic to the termite, whereas datura fruit and neem seed extracts were toxic only at higher dosage (40%). Serite *et al.* (1991) found that a methanol extract of *Citrus netsudaidai* seed effectively deterred nymphs of *Reticuliteranes* *speratus* termites; limonoids (i.e. obacunone, nomilin and limonin) are identified as the active principles of the extract. Ahmed *et al.* (2006) show that leaf and seed extract of *Whitania somnifera*, *Croton tiglium* and *Hydgrophilla auriculata* were not only toxic to *Microtermes obesi* with LD 50 ranged 4.31% and 2.98% in 6 days, but also repelled termite from making further tunnels in the treated soils. Hardi and Kurniawan showed that 2% leaf extract of *Cymbopogon nardus* was toxict against *Macrotermes gilvus.*

Besides plant extracts, clove bud and garlic oils are toxic against Japanese termite (*Reticulitermes speratus* Kolbe) (Park and Shin, 2005), patchouly oil against *Coptotermes formosanus* (Betty *et al*., 2003), Fumigant toxocity of essential oils i.e rosemary (10 µl) and lemon grass (10 µl) per 553 cm3 air caused 100% mortality after 24 hr in a coated container. In wooden surface test, geranium, lemongrass and tea tree oils caused 95-100% mortality due to their fumigant activities of the oils (Clausen and Yang, 2008). Recently, Mashek and Quarles (2008) stated that orange oil formula is effective in controlling dry wood termites either by contact and fumigant action. Orange oil is obtained by steam destillation. It contains 95% d-limonene. Active mechanism of the oil is by disolving chitinaceous exoskeleton of dry wood termites living in a hollow inside wood galleries. Furthermore, they stated that the key success of controlling termites is early recognizing of signs of termite investation, such as damage wood, flying termites, discarded wings, and fecal pellets. They experiences indicated that orange oil should be injected into the wood with the volume of 3% of the total wood volume. Field efficacy of the orange oil formula such as XT-2000 can be judged from less frequency of customer calls after treatment. One company of orange oil services showed that within last 9 years, the number of buildings treated with orange oils were 15,000 structures, and only 5-15% consumer call backs were reported, indicating that the orange oil is effective as termiticide.

Research studies in Indonesia showed that several botanical pesticides promising as termiticides are neem seed (*Azadirachta indica*), jeringau rhizome (*Acorus calamus*), custard apple seed (*Annona squamosa*), and bengkuang seed (*Pachyryzus erosus*.) (Sumarni, 2005). Other study by Sari *et al.* (2004) indicated that termicidal activity from resin of *Shorea javanica* was attributed to n-hexane and diethyl ether soluble compounds such as friedelin, vulgarol B, junipen, and secondamar.

Recently, a formulated essential oil has been developed as termiticide. The formula contains a mixture of clove and citronella essential oils in form of emulsion. Bioactivity of the formula to dry wood termite (*Cryprotermes cynocephalus*) showed that at 5% formulation it killed 100% termites in laboratory condition and protected treated wood almost complete (score

Table 3. Various plant materials show termiticide activities against termites

Type of plant	Efficacy	Reference
Milletia (*Milletia ferruginea*) seed extract (10%)	Toxict to *Macrotermes* sp; comparable to chlorpyrifos	Jembere *et al.* (2005)
Croton (*Croton macrostachys*) bark 25%	Toxict to *Macrotermes* sp	Jembere *et al.* (2005)
Datura fruit and neem seed extracts 40%	Toxict to *Macrotermes* sp.	Jembere *et al.* (2005)
Citrus netsudaidai methanol extract	*Reticuliteranes speratus*	Serite *et al.* (1991)
Aglaia odorata 0.5% and *Piper retrofractum* 1%	Toxict to *C. curvignathus*	Puspita-Sari (2008)
Pogostemon cablin	Repellency and toxict to *Coptotermes formosanus*	Betty *et al.* (2003)
Plant extracts of bintaro *(Carbera odollam)* and kecubung (*Brugmansia candida*) 4%	Toxict to *Coptotermes* sp.	Tarmadi *et al.* (2007)
Kirinyuh (*Eupatorium odoratum*) leaf ethanol extract 2.5%	*Coptotermes* sp	Hadi (2008)
Sirsak powder 6g/topless bottle	*Coptotermes* sp	Simanjuntak *et al.* (2007)
Shorea leprosula and *S. javanica* gums chloroform and petroleum ether extracts 5%	*Kelotermitidae termite*	Setiawati *et al.* (2001)
Acacia auriculiformis bark (ethyl ether fraxtion 4%)	Anti feedant to *C. curvignathus*	Yanti (2008)

9,8 of 10) (Atmadja *et al*., 2009). Preliminary application of the formula at 5% concentration injected into floor with sign of termite house or sprayed on termite galeries on wood delayed further termite colonization. Frequent inspections are needed to reaplication of the formula solution since the formula only killed termite by contact and temporary repelence. In addition, a field observation of the repellency of the formula against soil termite invested on living crop plants such as *Mentha arvensis* indicated that aplication of 2-5% formula by drenching around the roots expelled termite from feeding the root plant. However, aplication at 4-5% indicated phytotoxicity effect on the plant (Supriadi, unpublished result).

The recent finding indicated that essential oils of Indonesian origin are promising to be developed as termiticide. More essential oils need to be evaluated as termiticides because Indonesia is rich in essential oil producing plants. Indonesia produced 40 kinds of essential oils though only 13 of them have been reached significant market volumes, such as patchouli, clove, citronella, nutmeg, vetiver, and kananga oils (Rizal and Djazuli, 2006). However, Indonesian essential oil export was still low i.e. US$ 47, 2 in 2004.

STRATEGY OF TERMITE CONTROL

Termite control strategy has been intensively focused on wood structures than on forest or agriculture crops. For forest trees and agriculture crops, the control strategy is similar, including soil and seed treatments. Soil treatment may be used low toxicity synthetic termiticides such as chlorpyrifos, imidacloprid and fipronil, as well as baiting (UNEP/FAO, 2000). Alternate control methods are also been developed, such as:

- Selecting low-risk sites, such as avoiding peat swamps areas which is rich in *Coptotermes curvignathus*.
- Local specific types of crops
- Resistant tree species
- Reduction of mechanical damage
- Maintenance of plant vigour by adopting standard operational procedure for crop management, especially under stress conditions (water or nutrient stress, deprived of sufficient light)
- Sanitation by regular of nests inspection and removal, as well as removal of affected branches/trees.
- Increasing biodiversity of natural enemies such as ants
- Inter-planting with resistant plant

A number of novel methods of termite control have been recently introduced, or may be introduced in the future, such as genetic engineering plant resistant, biological control using *Metarhizium anisopliae*) fungus and entomopathogenic nematode (eg. *Heterorhabditis* sp.), baiting systems using chitin synthesis inhibitors, as well as soil and seed treatments.

Practical recomendations to avaoid termite investations in housings are close inspection and application of anti termite chemicals during constructions, making perimeter boundries between housing and halaman by clearing all possible enter points of termites such as cutting off roots and branches, clearing up all unused wood materials and wood debries, red, reducing soil humidity due to leacking of water pipes and water logging irrigation, and also consult expert specialist (Imam Santoso; an urban pest control specialist; http://www.margonda.com/Jendela/mewaspadai-bahaya-serangan-rayap.html).

Key of success in all treatment of termites in any structures is early detection of any termite infestations. Various signs of termite investations can be examined, including damage wood, fecal pellets, and discarded wings (Figure 3). To be effective in detecting termite infestation, various tools have been developed including acoustic detector, X-ray, borescoupe, infrared, microwave, laser, and trained dogs. But the most effective one is by experience instructures (Mashek and Quarles, 2008).

Control of termite infestations on wood structures can be made by brushing or spraying of wood surface with termicides, whereas for soil infestations can be drenched. Aplications must be repeated several times until no sign of infestation is seen.

Figure 3. Signs of termite infestation: Adult died and discard wings (*top*), fecal pellet (*centre*), and damage wood (*bottom*)

Termiticide applications on pre-construction site is essential if building is intended to be constructed in endemic termite areas. All structures of wood must be made from preserved woods.

FURTHER RESEARCH AND DEVELOPMENT

1. Field testing of botanical termiticides for their technical, economical and safety evaluations.
2. Search more plant extracts and essential oils as termiticide.

CONCLUSIONS

1. Various termites are found in various ecological conditions and has caused significant damage to wood constructions and crop plants world wide.
2. Termite control methods are still based on using synthetic chemicals wich are not environmentally safe
3. Different plant extracts and essential oils have been shown to have potential as termiticide and need further development for their practical, economical and safety evaluations.

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