Bioactivity of Indonesian mahogany, *Toona sureni* (Blume) (Meliaceae), against the red flour beetle, *Tribolium castaneum* (Coleoptera, Tenebrionidae)

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ABSTRACT. Bioactivity of Indonesian mahogany, *Toona sureni* (Blume) (Meliaceae), against the red flour beetle, *Tribolium castaneum* (Coleoptera, Tenebrionidae). The insecticidal activity of *Toona sureni* (Blume) Merr. was evaluated considering repellency, mortality and progeny production of F_1 adults of *Tribolium castaneum* (Herbst, 1797) (Coleoptera, Tenebrionidae). Dried extract of seeds of *T. sureni* was dissolved in acetone to prepare solution of various concentrations (0.5, 1.0, 2.5 and 5.0%). To test for repellency, the insects were exposed to treated filter paper. Mortality of larvae, pupae and adults was evaluated by the treatment of spraying the insects with different concentrations of *T. sureni* extract. Residual effect of the extract was also evaluated considering the production of progeny of F_1 adults. The highest repellency (93.30%) of *T. castaneum* occurred at the highest concentration (5.0% suspension of *T. sureni*); while the lowest (0.0%) repellency occurred at 0.5% suspension after 1 day of treatment. The highest mortality against adults (86.71%), larvae (88.32%) and pupae (85%) occurred at 5% suspension at 8 days after application. There was a negative correlation between the concentrations of *T. sureni* and the production of F_1 adult's progeny of *T. castaneum*. The highest number of progeny (147) of *T. castaneum* occurred in the control at 7 days after treatment; and the lowest number of progeny (43) occurred at 5.0% concentration in 1 day after treatment. The results show that *T. sureni* is toxic to *T. castaneum* and has the potential to control all stages of this insect in stored wheat.

KEYWORDS. Insect mortality; plant extract; repellency; residual effect; stored wheat.

RESUMO. Bioatividade do mogno da Indonésia, *Toona sureni* (Blume) (Meliaceae), contra o besouro-das-farinhas, *Tribolium castaneum* (Coleoptera, Tenebrionidae). A atividade inseticida de *Toona sureni* (Blume) Merr. foi avaliada considerando repelência, mortalidade e a produção de progênie de adultos F_1 de *Tribolium castaneum* (Herbst, 1797) (Coleoptera, Tenebrionidae). Extrato seco de sementes de *T. sureni* foi dissolvido em acetona, para preparar soluções de várias concentrações (0,5; 1,0; 2,5 e 5,0%). Para testar a repelência, os insetos foram expostos a papel de filtro tratado. A mortalidade de larvas, pupas e adultos foi avaliada pulverizando os insetos com diferentes concentrações do extrato de *T. sureni*. O efeito residual do extrato também foi avaliado pela produção de progênie dos adultos F_1. A maior repelência (93,30%) de *T. castaneum* ocorreu na maior concentração (5,0% suspensão de *T. sureni*); enquanto que a mais baixa repelência (0%) ocorreu na suspensão de 0,5% em um dia após o tratamento. A mortalidade mais elevada de adultos (86,71%), larvas (88,32%) e de pupas (85%) ocorreu com a suspensão a 5%, aos oito dias após a aplicação. Houve uma correlação negativa entre a concentração das suspensões de *T. sureni* e a produção de progênie de *T. castaneum*. O maior número de progênie (147) foi produzido na testemunha aos sete dias após o tratamento; enquanto o menor número de progênie (43) foi na suspensão de 5,0% no primeiro dia após o tratamento. Os resultados demostram que *T. sureni* é tóxico para *T. castaneum* e tem potencial para ser usado no controle de todos os estágios deste inseto em trigo armazenado.

PALAVRAS-CHAVE. Efeito residual; extrato de plantas; mortalidade de insetos; repelência; trigo armazenado.

Stored products of agricultural and animal origin are attacked by more than 600 species of beetle pests, 70 species of moths and about 355 species of mites causing quantitative and qualitative losses and insect contamination in food commodities is an important quality control problem of concern for food industries (Rajendran & Sriranjini 2008). Plant extracts contain compounds that show ovicidal, repellent, antifeedant, sterilization and toxic effects in insects (Isman 2006). The toxicity may be by contact, ingestion or through fumigant action. Focus on the vapour or fumigant toxicity of essential oils of plants and their constituents has sharpened since the 1980s. There are many reviews dealing with the use of plant products in general, against insect pests of stored products (Weaver & Subramanyam 2000; Isman 2006), specifically on essential oils (Singh & Upadhyay 1993; Regnault-Roger 1997) and others only on monoterpenoids (Coats *et al.* 1991).

The red flour beetle, *Tribolium castaneum* (Herbst., 1797) (Coleoptera, Tenebrionidae), is a serious pest of stored cereals in tropical and subtropical regions of the world. It is generally found in granaries, mills and warehouses, feeding on wheat flour, rice flour, and other processed cereals. Since it is not a secondary pest, larva nor adult generally damage sound grains, but they feed on kernels already broken or damaged by other pests (Apert 1987). The presence of the red flour beetle in stored foods directly affects both the quantity and quality of the commodity (Mondal 1994). Synthetic insecticides have been successfully used to protect stored grains from insect infestations, but their indiscriminate and massive use have created serious problems such as hazards to the environment including human health and toxic to non-target organisms (Sighamony *et al.* 1986), residues in food grains (Fishwick 1988), environmental pollution (Wright *et al.* 1993), and development of resistant strains (Zettler & Cuperus 1990). Finding safe alternatives to synthetic insecticides to protect stored grains and grain products from insect infestations are highly desirable.

The Indonesian mahogany, *Toona sureni* (Blume) Merr. (1917) (Meliaceae), is a medium-sized to fairly large tree, up to 40–60 m tall and diameter up to 100 cm (300 cm in mountainous areas) with dark brown young branches. The trunk is branchless for up to 25 m; bark is usually fissured and flaky, whitish, grayish brown or pale brown, scented when cut. It is a genus of six species of trees in the mahogany family Meliaceae, native from eastern China to south India, Southeast Asia and northern Australia. *Toona australis* and *T. ciliata* are important timber trees, providing a valuable hardwood used for furniture, ornamental panelling, shipbuilding, etc. Some authorities treat these two as the same species, under the name *T. ciliata*. *Toona sinensis* is of interest as by far the most cold-tolerant species in the Meliaceae, native in China as far north as 40°N in the Beijing area. It is the only member of the family that can be cultivated successfully in northern Europe, where it is planted as an ornamental tree in parks and avenues (biosphere.biologydaily.com/biology/Toona*)*.

An alternative eco-friendly strategy for the management of noxious insect pests has been searched to reduce harmful effects of chemical insecticides. The appropriate use of botanical pesticides can play a significant role in sustainable crop protection by providing a stable pest management program. Natural products are well known to have a range of useful biological properties against insect pests (Arthur 1996). The effectiveness of many botanical oils against stored grain insects has already been demonstrated (Dunkel & Sears 1998). Many types of spices and herbs are known to possess anti-insect activities especially in the form of essential oils (Tripathi *et al.* 1999). Also, it may be possible to use botanical extracts, edible oil and/or develop environmental manipulation strategies for effective insect control (Zewar 1993; Xie *et al.* 1995). Different types of plant preparations such as powders, solvent extracts, essential oils and whole plants are being investigated for their insecticidal activity including their action as fumigants, repellents, antifeedants, antiovipositions and insect growth regulators (Isman 2000; Negahban & Moharramipour 2007). Higher plants are a rich source of novel natural substances that can be used to develop environmental safe methods for insect control (Jbilou *et al.* 2006).

Modern-day crop protection is based on integrated pest management, which includes all the available techniques in a compatible manner along with judicious use of different agrochemicals. Therefore, for successful establishment of *Toona sureni* (Blume) Merr. (Meliaceae) and to reduce insecticidal load in IPM program, the role of this plant extract is very important. Keeping this view, the present study was conducted to evaluate repellency, mortality and production of progeny by F_1 adults of *T. castaneum* to *T. sureni* seed extracts on stored cracked wheat.

MATERIAL AND METHODS

Study site. The experiment was conducted in the Key Laboratory of Natural Pesticide and Chemical Biology of the Ministry of Education, South China Agricultural University (SCAU), Wushan Road, Guangzhou 510642, PR China. It was carried out under laboratory conditions at 26 ± 2°C, 70 ± 10% relative humidity (r.h.) in continuous dark room.

Insect. The red flour beetle, *Tribolium castaneum*, was obtained from the Key Laboratory of Natural Pesticide and Chemical Biology of the Ministry of Education, South China Agricultural University, Guangzhou, PR China, where the insects were reared at 26 ± 2°C and r.h. 65–70% in continuous dark condition. One hundred adults of both sexes were obtained from the stock culture and transferred to glass jars 500 g of wheat with standard food medium (wheat flour: dry yeast = 19:1). After five weeks of oviposition, the adults were removed by sieving the grains with a sieve of 2 mm mesh. The beetles (7-day-old) that subsequently emerged were used for the different bioassays.

Plant extract. The seeds of Indonesian mahogany, *T. sureni,* were obtained from the Department of Plant Protection, Faculty of Agriculture, Bogor Agricultural University, Bogor, Indonesia. The seeds were dried naturally on laboratory benches at room temperature (23 ± 2°C) for 10 days and subsequently artificially dried an oven at 40°C for six hours. The seeds were powdered using an electric grinder. One hundred grams of the seed powder was dissolved separately in 300 ml of methanol. The mixtures were mixed for 30 min and left to stand for 72 hrs and shacked several times at certain intervals. The extract of the seeds of Indonesian mahogany was concentrated using a rotary evaporator at maximum temperature of 45°C and finally a hard brownish extract was obtained. The extract was stored in tightly corked bottles in a refrigerator before use. Portions of this dried extract were dissolved in acetone to prepare solutions of various concentrations (0.5, 1.0, 2.5 and 5.0%) for the bioassays.

Repellency Test. It was conducted according to the method of Talukder & Howes (1994). Filter papers (Whatman®, Grade 40:8 μm) were cut in half, and 1 ml solution of each concentration was applied to each half uniformly with a pipette. The treated halves were air-dried and attached with the untreated half with a cello-tape at the middle in such a way that attachment did not interfere with the free movement of insect from one half to the other. Each filter paper was then placed in a Petri dish and 10 adult beetles (7-day-old) were released at the centre of each filter paper and covered with a lid. The Petri dishes were kept in an incubator (26 ± 2°C, 70 ± 10% r.h. in continuous dark condition). There were six replicates for each treatment. The data were expressed as percentage of repulsion (R) that was calculated using the formula of McDonald *et al.* (1970): R = 2 × (C – 50); where, C is the percentage of insects present in the control half. Positive values expressed repellency and negative values attractancy. The average values were then categorized according to McDonald *et al.*, 1970 (Table I).

Table I. Classification of % repulsion according to McDonald *et al.* (1970).

Class	% Repulsion
0	>0.01 to 0.1
I	0.1 to 20
II	20.1 to 40
III	40.1 to 60
IV	60.1 to 80
V	80.1 to 100

Mortality test. Ten adults (3–6 day old, not sexed) were released in a Petri dish with 20 g of half broken wheat. The insects were sprayed using hand sprayer with 2 ml solution of each concentration of *T. sureni* extract and the Petri dishes were covered with parafilm. The solvent (acetone) was used as control. The Petri dishes were kept in an incubator at 26 ± 2°C and r.h. 65–70% in continuous dark condition. There were six replicates for each treatment. Adult mortality was recorded after 8 days spraying treatments were performed. The same procedure was used for larval (30-day-old) and pupal (5-day-old) instars. Insects are presumed dead if they did not move when touched with a pin.

Progeny production test. To determine the effect on F_1 progeny production, 20 g of half broken wheat were treated with each concentration of the extract. The treated wheat was air dried and kept in Petri dishes. Ten adults of *T. castaneum* of both sexes were confined in each Petri dish at 1, 3, 5 and 7 days after treatment; and the Petri dishes were covered with parafilm. The Petri dishes were incubated at 26 ± 2°C and r.h. 65–70% in continuous dark condition for 7 days to evaluate mortality. The solvent was used as control. There were six replicates for each treatment. The numbers of adult's F1 progeny were counted from 25 days and it was continued up to 40 days of insect confinement.

Statistical analysis. The whole study was repeated three times with freshly prepared *T. sureni* suspension. Abbott's formula was used to correct the control mortality (Abbott 1925). Then the mortality data was submitted to analysis of variance (ANOVA). Data of repellency of *T. castaneum* were subjected to 2-way ANOVA between doses of *T. sureni* and exposure time (day). Data regarding F_1 adult's progeny of *T. castaneum* were also subjected to 2-way ANOVA between doses of *T. sureni* and exposure time (day). Data for percent mortality of *T. castaneum* was analyzed with one-way ANOVA. The statistical analyses were performed using the Proc GLM procedure of SAS (SAS Institute 2001). Means were separated using Least Significant Difference (LSD) test at 5% level of significance.

RESULTS

The repellency *of T. castaneum was* significantly different between concentrations of *T. sureni* and the control (F = 72.88, d.f. = 11, 71; P < 0.0001), as shown on Table II. The highest repellency (93.30%) presented by the insects occurred at 5.0% concentration of *T. sureni* after 1 day of exposure; while the lowest repellency (0.0%) occurred at 0.5% concentration after 3 days of exposure (Table II).

All stages of *T. castaneum* were significantly affected by *T. sureni* concentrations for all variables: mortality of adult (F = 51.56, d.f. = 4, 29; P < 0.0001); mortality of larva (F = 84.57, d.f. = 4, 29; P < 0.0001); and mortality of pupa (F = 61.53, d.f. = 4, 29; P < 0.0001) compared with their respective controls (Fig. 1). The results also demonstrated that the highest mortality of adult (86.7%), larva (88.3%) and pupa (85%) occurred at 5% concentration of *T. sureni* at 8 days post-application (Fig. 1).

The number of progeny produced by F_1 adults *of T. castaneum* was inversely affected by concentrations of *T. sureni* (Table III). The interaction of the factors viz. treatment and exposure time (day) was significantly different in the numbers of F_1 adult's progeny (F = 991.59, d.f. = 19, 119; P < 0.0001) *of T. castaneum* compared with their respective controls (Table III). There was a negative correlation between treatments and the numbers of progeny. The result demonstrated that the highest number of progeny (147) occurred for the control for 7 days of exposure of *T. sureni*; and the lowest number of progeny (43) occurred for 5.0% suspension for 1 day of exposure of *T. sureni* (Table III).

Table II. Mean ± SE repellency (%) of *Tribolium castaneum* (n = 60) on wheat under different concentrations (%) of *Toona sureni* compared with control.

Treatment	Exposure time			Mean[1]	Repellency Class[2]
	1 day	2 days	3 days		
0.5	13.32 ± 4.21 a	10.00 ± 4.52 a	0.0 ± 0.0 a	7.82 ± 4.34 a	I
1.0	36.70 ± 3.32 bc	23.31 ± 3.37 bc	6.71 ± 4.23 bc	22.24 ± 3.91 bc	II
2.5	46.71 ± 4.29 bc	30.00 ± 4.56 bc	16.71 ± 3.34 bc	31.11 ± 4.23 bc	II
5.0	93.30 ± 3.35 c	85.00 ± 3.45 c	70.00 ± 3.71 c	82.81 ± 3.11 c	V

[1]Means with the same letter within a column are not significantly different (LSD-test; P < 0.05).
[2]The mean values were categorized in repellency classes according to McDonald *et al.* (1970).

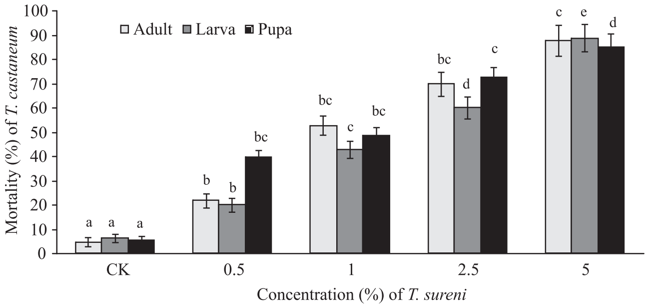

Fig. 1. Mean ± SE mortality (%) of adult, larva and pupa of *Tribolium castaneum* (n = 60) on wheat at different concentrations (%) of *Toona sureni* compared with control. Means with the same letter within same stage (adult, larva and pupa) of *T. castaneum* are not significantly different.

Table III. Mean ± SE the numbers of F_1 adults' progeny of *Tribolium castaneum* (n = 60) on wheat applying different concentrations (%) of *Toona sureni* compared with control (acetone only).

Treatment	Residual time			
	1 day	3 days	5 days	7 days
CK	142 ± 1.09 a	143 ± 0.78 a	144 ± 1.72 a	147 ± 0.96 a
0.5	89 ± 0.71 b	92 ± 0.76 bc	100 ± 1.35 bc	100 ± 1.44 b
1.0	73 ± 0.75 c	82 ± 0.79 bc	83 ± 1.20 bc	93 ± 0.95 bc
2.5	52 ± 0.79 cd	62 ± 0.83 bc	72 ± 0.99 bc	82 ± 1.38 c
5.0	43 ± 0.84 d	51 ± 0.88 c	62 ± 0.92 c	63 ± 0.79 d

Means with the same letter within a column are not significantly different (LSD-test; $P < 0.05$).

DISCUSSION

The toxicity of essential oils to stored-product insects is influenced by the chemical composition of the oil, which in turn depends on the source, season and ecological conditions, method of extraction, time of extraction and plant part used (Don-Pedro 1996; Lee *et al.* 2001). Essential oils and their components have been tested in small vials (5–100 ml) or chambers (100–3400 ml) or in Petri dishes of different sizes, so far against 20 coleopteran species, four lepidopterans and a liposcelid (Rajendran & Sriranjini 2008). The most common target insects were the adults of the rust-red flour beetle, *T. castaneum*, the rice weevil, *Sitophilus oryzae* (L.), the maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) and the lesser grain borer, *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae). Bruchids such as the dried bean beetle, *Acanthoscelides obtectus* (Say), the cowpea beetle, *Callosobruchus maculatus* (F.) and adzuki bean weevil, *Callosobruchus chinensis* (L.) (Coleoptera: Bruchidae) have also been given considerable attention (Rajendran & Sriranjini 2008). *Acanthoscelides obtectus* was highly susceptible to the essential oils of *L. hybrida*, *R. officinalis* and *Origanum majorana* L. (Regnault-Roger 1997). It has also been reported that SEM76 and ZP51, essential oils from plants belonging to Lamiaceae, were relatively effective against several stored product insects (Shaaya *et al.* 1991, 1997).

Repellents, feeding deterrents, and insecticides of natural origin are rational alternatives to synthetic insecticides. These compounds are naturally produced in many plants and play a vital role as resistance factors in plant defense systems. Crude extracts of *T. sureni* seeds have been shown here to have strong repellency, moderate feeding deterrence, and direct contact toxicity to *T. castaneum* in all stage in its life cycle. Products from several plant parts have been demonstrated to act as repellents, toxicants and antifeedants against a number of coleopterans that attack stored products (Raja *et al.* 2001; Tapondjou *et al.* 2002; Saroukolai *et al.* 2010). The effectiveness of neem, *Azadirachta indica* A. Juss (Meliaceae) seed extracts on larvae and adults of different strains of *T. castaneum* was investigated by Khanom & Khalequzzaman (2000). The leaf extract of *Polygonum hydropiper* (Polygonaceae) and *Annona squamosa* (Annonaceae) was effective against the larvae of *T. castaneum* (Hussain *et al.* 1995); *Artemmisia vulgaris* against the larvae of *T. castaneum* and *S. zeamais* (Ferrolino & Padolino 1995); and *Aphanamixis polystachya* (Wall & Parker) against the larvae of *T. castaneum* (Talukder & Howse 1993, 1994).

The efficacy of *T. sureni* extract as grain protecting against the red flour beetle was demonstrated by the data of progeny. The lowest number of progeny has emerged when F_1 adults were exposed to 5% suspension of *T. sureni* extract and increased with the extract concentration. Ground leaves, bark and seeds of *A. polystrachya* provided protection for wheat flour by reducing F_1 progeny of *T. castaneum* (Talukder & Howse 1995). The present study is also supported by findings of Rahman *et al.* (2007) who investigated the insecticidal activity of ethanol extract of *Macaranga postulate* (Euphorbiaceae) against *S. oryzae*. Singh & Singh (1991) screened 31 essential oils from different botanical sources against the house fly, *Musca domestica* L. (Diptera: Muscidae), and reported repellent and insecticidal activities against this species. The repellent, deterrent and biological effects of some plant materials against stored product insects have been studied by other researchers (Tripathi *et al.* 2002; Kim *et al.* 2003).

In conclusion, *T. sureni* seed extracts showed strong repellency against the red flour beetle, increasing proportionally with the increase of concentration of the extract. It is toxic to all stages of *T. castaneum* and reduces progeny production. Therefore, we conclude that seed extract of *T. sureni* is potentially useful to control *T. castaneum*; however, studies concerning the chemical analysis of the active compounds and the mechanisms involved in the action, besides the methods for large scale application should be accomplished.

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