Ability of Field Populations of *Coptotermes* spp., *Reticulitermes flavipes*, and *Mastotermes darwiniensis* (Isoptera: Rhinotermitidae; Mastotermitidae) to Damage Plastic Cable Sheathings

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ABSTRACT A comparative field study was conducted to evaluate the ability of subterranean termites to damage a set of four different plastic materials (cable sheathings) exposed below- and above-ground. Eight pest species from six countries were included, viz., *Coptotermes formosanus* (Shiraki) in China, Japan, and the United States; *Coptotermes gestroi* (Wasmann) in Thailand and Malaysia; *Coptotermes curvignathus* (Holmgren) and *Coptotermes kalshoveni* (Kemner) in Malaysia; *Coptotermes acinaciformis* (Froggatt) with two forms of the species complex and *Mastotermes darwiniensis* (Froggatt) in Australia; and *Reticulitermes flavipes* (Kollar) in the United States. Termite species were separated into four tiers relative to decreasing ability to damage plastics. The first tier, most damaging, included *C. acinaciformis*, mound-building form, and *M. darwiniensis*, both from tropical Australia. The second tier included *C. acinaciformis*, tree-nesting form, from temperate Australia and *C. kalshoveni* from Southeast Asia. The third tier included *C. curvignathus* and *C. gestroi* from Southeast Asia and C. *formosanus* from China, Japan, and the United States, whereas the fourth tier included only *R. flavipes*, which caused no damage. A consequence of these results is that plastics considered resistant to termite damage in some locations will not be so in others because of differences in the termite fauna, for example, resistant plastics from the United States and Japan will require further testing in Southeast Asia and Australia. However, plastics considered resistant in Australia will be resistant in all other locations.

KEY WORDS subterranean termites, *Coptotermes*, plastic cable sheathings, nylon 12, polyethylene

Subterranean termites are able to damage a wide range of materials, including several plastic products (Gay and Wetherly 1962, 1969; Becker 1963; Beal et al. 1973; Beal and Bultman 1978; Unger 1978; Unger and Unger 1984). Susceptibility of plastic materials varies with their chemical structure, hardness, and surface finish (Becker 1976, Watson et al. 1984).Results may also differ between termite species (Beal et al. 1973, Beal and Bultman 1978, Watson et al. 1984). Recently, Lenz et al. (2012) reported that in a 6-yr field trial, Australian *Coptotermes acinaciformis* (Froggatt) was more destructive to medium-density polyethylene cable sheathing compared with termite fauna at sites in Thailand and the United States, and according to a separate shorter-term trial, also more destructive than termites in Malaysia and Japan.

The issue of differences between termite species in their ability to damage plastics warrants a more comprehensive evaluation and has significant practical implications. A given material may be assessed in one country as termite-resistant, whereas in another country with a different termite fauna, the same material may be termite-susceptible. Some countries have experienced major problems with termite damage to underground communication and power cables, dating to when such cables were first laid, such as Australia from 1911, and thus have a long history of testing cable sheathing for termite resistance (Ruddel 1985).

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Table 1. Types of plastics exposed to termite attack

Plastics[a]	Low-density polyethylene	Medium-density polyethylene	Development product polyamide-based	Polyamide 12 (Nylon 12)
Code	LDPE	MDPE	DPPA	PA 12
Brand name	Lotrene FB3003	Finathene 3208	Rilsamid TCP	Rilsamid
Manufacturer	QAPCO	Total Petro-chemicals	Arkema	Arkema
Density (g/cm^3)	0.92	0.938	1.05	1.01
Shore D hardness	55	60	67	72

[a] All samples provided by Arkema Japan, Kyoto.

Other countries have little or no such history, for example, the United States (Kofoid 1946, Krishna and Weesner 1969, Pearce 1997), presumably because the termite faunas have little or no ability to damage cables.

Polymers have no food value for termites. Hence, the standard practice for assessments of their termite resistance in the field involves offering polymer samples that are in intimate contact with a highly palatable timber (bait wood) to aggregate termites at the site and keep them in contact with experimental samples for a sustained period (Lenz et al. 1992). As a rule, samples are inspected at annual intervals, and, at the same time, bait wood is replaced as samples are reinstalled. These procedures are based on the assumption that termites, once they have located the bait wood and materials, will remain active around the samples for a prolonged period. Hence, the samples will be exposed to high termite pressure for much of the year. In practice, however, this is seldom the case. The period of high termite activity may, at least in the tropics and subtropics, as our observations in northern Australia, Southeast Asia, and the southern United States indicate, last for only 2–3 mo, sufficient time for termites to consume the bait wood. Once the bait wood is consumed, the economically important wood-feeding target species will typically abandon the site. For the remaining 9–10 mo of the year, samples may have no further or only limited contact with termites, except, perhaps, with less aggressive species, which may feed only on wood remnants and carton material left behind by the more aggressive target species.

Here we report a comparison of the ability of termites to damage a set of four plastic materials (cable sheathings) exposed belowground and aboveground against several key pest species of termites, notably *Coptotermes formosanus* (Shiraki) in China, Japan, and the United States; five additional species of *Coptotermes* in Thailand, Malaysia, and Australia; *Mastotermes darwiniensis* (Froggatt) in Australia; and *Reticulitermes flavipes* (Kollar) in the United States. The Australian *C. acinaciformis* occurs in several forms across the continent. The southern tree-nesting form (*C. acinaciformis* T) and a northern mound-building form (*C. acinaciformis* M) were included in the trial and treated as separate species (as indicated by Lo et al. 2006, T.A.E., unpublished data).

Materials and Methods

Experimental Plastics. Four plastics in the form of cable sheathings (hollow tubes) were evaluated: low-density polyethylene (LDPE), medium-density polyethylene (MDPE), development product polyamide-based (DPPA), and polyamide 12, also known as Nylon 12 (PA12) (Table 1). Based on previous laboratory results with Australian *C. acinaciformis* M, these materials are ranked as follows: highly susceptible (LDPE), susceptible (MDPE), limited susceptibility/resistant (DPPA), and resistant (PA12) (Watson et al. 1984, M.L., unpublished data).

Samples of each material, all 0.9 cm outside diameter with a 0.1-cm-thick plastic sleeve, were cut into 20-cm lengths. These lengths were capped at each end with a metal dome nut; thus, only the ability of termites to attack the smooth sheathing surface was evaluated. Samples received a shallow surface scratch of ≈10 cm length to simulate possible damage to the surface of a cable during installation (Ruddel 1985, Boes et al. 1992), which could provide a vantage point for termite attack.

Plastic cable sleeves did not contain an actual cable section inside for practical and logistics reasons. Several decades of field assessments by Commonwealth Scientific and Industrial Research Organization Entomology (Australia) of sections of entire cables or of just the plastic sleeves found no differences in termite response. The amount of food (bait wood) that is offered together with the samples determines the level of interest by termites in the samples.

Field Sites. Trials were conducted in Australia (two sites), southern China, Malaysia, Thailand, and southern United States (four sites). Details of locations, climate, habitat, and target species of termite for each site as well as additional details on methodology are provided in Table 2.

Methods of Exposure. Two belowground methods for exposing the samples to termite pressure, described in detail earlier, were used (Lenz et al. 1992, 2012). Samples were offered to termites together with bait wood 1) within shallow trenches at all sites, except Malaysia, and 2) inside buried containers in Malaysia as well as at one site in Australia (Table 2). A limited number of samples were also exposed to termites in southern United States by using 3) the aboveground method of exposure, as described in Creffield et al. (2013) (Table 2).

Table 2. Location, climate, and habitat of field sites, target species of termite, exposure method, and interval between replacement of bait wood for the belowground (trench; container) and aboveground (stainless-steel container) exposure method over 12 mo

Location	Coordinates	Climate (avg annual rainfall)	Habitat	Target termite	Method of exposure	Wood replacement interval, months	No. of colonies/ replicates per colony
Australia							
Griffith, NSW	32.9° S, 146.2° E	Dry (410 mm) subtropical	Eucalypt woodland	*C. acinaciformis* T	Trench	3,12	3/5
					Container	12	3/5
Darwin, NT	12.6° S, 131.3° E	Wet/dry (1730 mm) tropical	Eucalypt woodland	*C. acinaciformis* M, *M. darwini*ensis	Trench	3,12	3/5
					Trench	3,12	3/5
Southeast Asia							
Phuket, Thailand	8° N, 98.4° E	Wet (2,240 mm) tropical	Mixed tree plantation	*C. gestroi*	Trench	4	3/5
Penang, Malaysia	5.4° N, 100.3° E	Wet (2,670 mm) tropical	Rainforest	*C. gestroi*	Container	3	1/5
				C. curvignathus	Container	3	1/5
				C. kalshoveni	Container	3	1/5
China							
Guangzhou, GD	23.2° N, 113° E	Wet (1980 mm) tropical	Mixed tree plantation	*C. formosanus*	Trench	3,12	4/5
Japan							
Kagoshima Pref.	31° N, 130.4° E	Wet (1650 mm) subtropical	Pine forest	*C. formosanus*	Trench	6,12	3/5
United States							
Stennis Space Ctr./	30.4° N, 89.6° W	Wet (1650 mm)	Pine forest/	*C. formosanus*	Trench	4,12	2/5
McNeill, MS	30.6° N, 89.6° W	subtropical	grassland	*C. formosanus*	Trench	4,12	3/5
Lake Charles, LA	30.2° N, 93.2° W		Mixed tree plantation	*C. formosanus*	Steel container	NA	1/3
New Orleans, LA	30° N, 90° W		Suburban parkland	*C. formosanus*	Trench	4,12	3/5
Gulfport, MS	30.6° N, 89.1° W		Pine forest	*R. flavipes*	Trench	4,12	3/5

1) The bottoms of 10-cm-deep by 30-cm-wide by 1.3-m-long trenches were lined with strips of a palatable *Pinus* spp. (10-cm wide by 0.5-cm thick). Samples were placed horizontally on top of the strips and perpendicular to the long axis of the trench, and contiguously parallel with each other and in random linear sequence. Each sample was sandwiched between two *Pinus radiata* David Don rectangular bait wood stakes (2.5 by 5.0 by 20.0 cm). This arrangement was covered with another layer of pine strips, followed by heavy-gauge wire mesh with 0.6-cm-square openings to protect samples against mechanical damage from digging tools when the trenches were opened for inspection. Trenches were then backfilled with soil up to the level of the surrounding soil surface.
2) Site conditions in Penang, Malaysia, necessitated placement of samples inside containers rather than in trenches (Lenz et al. 2012). Plastic rectangular boxes (40 by 30 by 15 cm) with a removable lid were filled with boards of rubber wood (*Hevea brasiliensis* Müller Argoviensis), and samples were positioned horizontally at random among the wood. In Griffith, Southeast Australia, samples were installed not only in trenches, but also for comparison inside steel drums (32 cm in height by 30 cm in diameter) with a flat lid. Samples were installed vertically at random between boards of *Eucalyptus regnans* Ferdinand von Mueller.

All containers had several termite entry holes through their base and sides, and were buried to a depth such that their lids were flush with the soil surface. Lids were covered with a plastic sheet and ≈5-cm-thick layer of soil.

3) At McNeill, MS, and Lake Charles, LA, samples were placed in rectangular stainless steel exposure containers designed for assessing aboveground resistance of materials to termite damage (Creffield et al. 2013; Table 2). Termites were first aggregated in stacks of bait wood placed just below the soil surface. Once large numbers of termites were present in the bait wood, a further layer of bait wood was offered and a stainless-steel container was placed on top of the bait wood stack. Plastic samples together with additional bait wood were positioned inside the container on top of a stainless-steel grid floor (25 by 25 mm^2 apertures) located 80 mm above the base of the container. Hence, samples had no direct contact with the soil but could be readily reached by termites.

Reinstallation and Inspection of Samples. Belowground trials lasted 12 mo. Samples were removed, cleaned, and reinstalled according to the same original methodology. However, new bait wood was added every 3–6 mo, depending on the site, for the duration of the study period (Table 2). This procedure was developed based on the experience that termites will deplete the bait wood supply within a few months. Resupplying bait wood is essential to maintain the presence of termites in proximity to the samples for the full exposure period. Termites often “plaster” nonwoody surfaces that they do not damage or have

Table 3. Rating system for damage to plastic samples

Damage rating	Abbreviation	Definition
Nondamaged	OK	No damage
Nibbled	N[a]/SN[b]	Surface roughened or pitted very shallowly (≤0.3 mm pit depth), and only in a few, restricted regions ≤5 mm^2 (≤1% surface area of sample)
Attacked	A[a]/SA[b]	Surface shallowly or deeply pitted (>0.3 mm pit depth) over extensive areas (>5 mm^2), but sheathing not penetrated
Destroyed	D[a]/SD[b]	Sheathing penetrated so that inner parts of the cable are exposed

[a] N, A, D, damage on smooth surface of samples.
[b] SN, SA, SD, damage along scratch line.

ceased damaging with a layer of building material (fecal material and soil). Hence, once the samples are plastered by termites, further direct contact with the sample surfaces during the remaining duration of a trial is precluded. The process of presenting termites repeatedly with new bait wood and using samples with clean fully accessible surfaces results in a realized termite exposure period that is equivalent to 2–4 yr in traditional methodologies where only a single supply of bait wood, lasting just a few months, is provided for the entire 12-mo trial. The aboveground trial was terminated when termites had consumed all of the bait wood, usually within ≤3 mo (Creffield et al. 2013).

Samples were inspected for damage only after completion of the trial. The entire surface area of each sample was cleaned and examined by eye. Any damaged areas were further evaluated under a microscope at 12- to 60-fold magnification. Four damage categories were assigned separately to the smooth surface area and to the scratch line (Table 3). Only the most severe damage rating, on the surface and along the scratch line of each sample, was used in the analyses.

Data Analysis. Data (number of cable samples in each damage rating) were analyzed by using a four-factor general linear model (GLM), with plastic type (four levels: LDPE, MDPE, DPPA, and PA12), species (eight levels: *C. acinaciformis* T, *C. acinaciformis* M, *Coptotermes curvignathus* (Holmgren), *C. formosanus*, *Coptotermes gestroi* (Wasmann), *Coptotermes kalshoveni* (Kemner), *M. darwiniensis*, and *R. flavipes*), method of exposure (two levels: trench and container), and wood replacement (three levels: annual, quarterly, and aboveground samples) as the factors. The interaction for plastic × species was included; however, those for method of exposure and wood replacement interval were not, as these were not used for all species. Differences between levels within each treatment were compared by using post hoc pairwise comparisons (Sokal and Rohlf 1995, SYSTAT v. 9.0 1998).

Differences for location were investigated for four species: *C. acinaciformis* M and T, *C. formosanus*, and *C. gestroi*. A separate analysis was conducted for each species, as not all methods of exposure or wood replacement regimen were installed in each location. The analysis for *C. acinaciformis* and *C. formosanus* used three factors: location, plastic type, and wood replacement, plus interaction for location × wood and plastic × wood were included for *C. acinaciformis*. The analysis for *C. gestroi* used two factors: location and plastic type, plus the interaction location × plastic type.

Results

The total number of samples contacted by termites and their damage ratings are listed in Table 4. Proportions of samples in each damage rating category for each plastic type averaged across species are shown in Fig. 1. Proportions for each species averaged across plastics are shown in Fig. 2, whereas damage proportions among plastics and species are shown in Fig. 3.

LDPE sustained the highest levels of damage, whereas PA12 sustained the least. LDPE and MDPE had 'D' and 'SD' damage ratings, whereas DPPA and PA12 did not. DPPA sustained a small number (3 of 285) of 'A' and 'SA' damage ratings, whereas PA12 sustained few (15 of 285) 'N' and 'SN,' the least severe damage ratings other than nondamaged.

The four-factor GLM analysis for all species ($N = 76$ colonies with 1,172 samples for all analyses; Table 5) had relatively high levels of explained variation ($r^2 = 0.727–0.886$) and up to three of the treatments were significant. The patterns were similar for samples rated nondamaged (OK) or nibbled ($N = \pm SN$). There were significant differences in damage between plastic types (in general, LDPE with low proportion of samples remaining without damage or just nibbled and PA12 with a high proportion of samples without damage and just a few nibbled) and species (in general, *R. flavipes* unable to damage, and *C. acinaciformis* M and *M. darwiniensis* causing more damage), whereas wood replacement interval (most frequent wood replacement or 3 mo) had a low impact, and method of placement did not have any impact (samples in trenches were damaged similarly to those in containers). The interaction terms were not significant.

The patterns were similar for samples rated attacked (A, SA) and destroyed (D, SD). There were significant differences in damage between plastic types (in general, LDPE was highly susceptible to damage and PA12 was far more resistant) and species (in general, *R. flavipes* had a low ability to damage samples, and *C. kalshoveni*, *C. acinaciformis* M, and *M. darwiniensis* had a high ability). Neither wood replacement nor method of placement was significant. The interaction terms were significant, as LDPE sustained D or SD ratings by only two species.

Thus, termite species could be separated into four tiers relative to inflicting decreasing damage to plastic

Table 4. Number of plastic samples assessed and their damage ratings installed against eight termite species in trenches or containers in Asia, Australia, and the United States

Species, location	Plastic type[a]	Total	Damage rating[b]			
Method			OK	N + SN	A + SA	D + SD
C. acinaciformis, tree-nesting form, temperate Australia						
Trench	LDPE	30	18	0 + 0	1 + 1	
	MDPE	29	24	5 + 0		
	DPPA	30	25	5 + 0		
	PA12	30	25	5 + 0		
Container	LDPE	15	8	6 + 0	1 + 0	
	MDPE	15	10	5 + 0		
	DPPA	15	10	5 + 0		
	PA12	15	15			
C. acinaciformis, mound-building form, tropical Australia						
Trench	LDPE	29	7	4 + 2	1 + 1	12 + 2
	MDPE	29	15	0 + 4	0 + 1	9 + 0
	DPPA	29	10	5 + 12	0 + 2	
	PA12	29	24	0 + 5		
C. curvignathus, Southeast Asia						
Container	LDPE	5	4	0 + 1		
	MDPE	5	4	0 + 1		
	DPPA	5	3	0 + 2		
	PA12	5	5			
C. formosanus, China, Japan, United States						
Trench	LDPE	115	104	5 + 6		
	MDPE	114	113	0 + 1		
	DPPA	115	115			
	PA12	115	115			
Container	LDPE	6	1	0 + 5		
	MDPE	6	1	0 + 5		
	DPPA	6	2	0 + 4		
	PA12	6	6			
C. gestroi, Southeast Asia						
Container	LDPE	20	15	5		
	MDPE	20	20			
	DPPA	20	20			
	PA12	20	20			
C. kalshoveni, Southeast Asia						
Container	LDPE	5	2	2 + 0	0 + 1	
	MDPE	5	5			
	DPPA	5	4		1 + 0	
	PA12	5	4	0 + 1		
M. darwiniensis, tropical Australia						
Trench	LDPE	30	4	3 + 9	1 + 2	9 + 2
	MDPE	30	14	3 + 8	0 + 3	0 + 2
	DPPA	30	17	0 + 13		
	PA12	30	26	0 + 4		
R. flavipes, United States						
Trench	LDPE	30	30			
	MDPE	30	30			
	DPPA	30	30			
	PA12	30	30			

[a] Plastic type: low-density polyethylene (LDPE); medium-density polyethylene (MDPE); development product polyamide-based (DPPA); polyamide 12 (nylon 12) (PA12).

[b] Damage ratings (Table 3). Some zeros for 'Damage Ratings' omitted for clarity.

samples. The first tier, most damaging, included *C. acinaciformis* M and *M. darwiniensis*, both from tropical Australia. These were the only species that caused D or SD ratings. The second tier was composed of *C. acinaciformis* T from temperate Australia and *C. kalshoveni* from Southeast Asia, both caused some damage of A and SA. The third tier included *C. curvignathus* and *C. gestroi* from Southeast Asia, as well as *C. formosanus* from China, Japan, and the United States, which caused some N and SN only. The fourth tier included only *R. flavipes* from the United States, which caused no damage to any of the plastic samples ('OK'; Table 3).

The three-factor GLM analysis for *C. acinaciformis* on nondamaged samples ($N = 20$ colonies, 300 samples; $r^2 = 0.850$) to test for differences between location found two significant factors: location (thus confirming the result for the previous analyses that treated *C. acinaciformis* M and *C. acinaciformis* T separately) and plastic type (LPDE most susceptible and PA12 least susceptible, as found before). Neither the wood replacement interval nor any interaction was significant (Table 6).

The three-factor GLM analysis for *C. formosanus* on nondamaged samples ($N = 24$ colonies, 512 samples; $r^2 = 0.751$) to test for differences between location

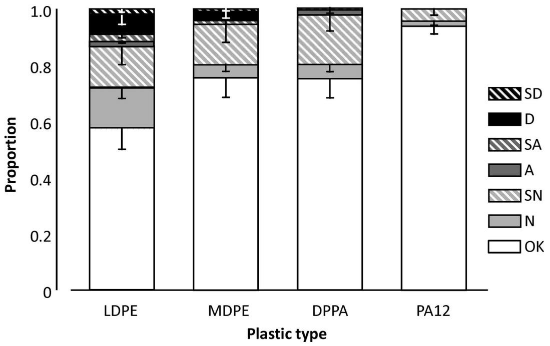

Fig. 1. Damage (a) to each type of plastic (b) averaged across all species of termite. (a) Damage ratings: OK, N, SN, A, SA, D, and SD (Table 3). Same sequence as Table 3. (b) Type of plastic (see Table 1): LDPE, low-density polyethylene; MDPE, medium-density polyethylene; DPPA, development product polyamide-based; PA12, polyamide 12 (Nylon 12).

found two significant factors: plastic type (LDPE most susceptible, and PA12 least susceptible, as found before) and wood replacement interval (3 mo, most damage).

Locations were not significantly different (Table 6). The two-factor GLM analysis for *C. gestroi* on non-damaged samples ($N = 8$ colonies, 80 samples; $r^2 = 0.903$) to test for differences between location found only the interaction significantly different (Table 6). Note the lower number of replicates in Penang (Table 2), suggesting this result may be an anomaly.

Discussion

Two distinct patterns in the data emerged, for plastic type and for species. For plastic type, low-density polyethylene clearly exhibited least resistance to damage by termites. MDPE and DPPA showed intermediate resistance, and PA12 (Nylon 12) exhibited the greatest resistance.

For species, *C. acinaciformis* M and *M. darwiniensis* caused the most damage. *C. acinaciformis* T and *C. kalshoveni* caused less damage, but more than *C. curvignathus*, *C. formosanus*, and *C. gestroi*, whereas *R. flavipes* caused no damage.

In this context, it is interesting that Malaysian *C. kalshoveni* has shown higher wood consumption rates in the laboratory, possibly showing higher persistency for remaining at a feeding site, compared with *C. gestroi* (Yeah and Lee 2007). This behavior could be a contributing factor in explaining the differences in the damage ratings between these two Malaysian species. However, field wood consumption rates of bait wood did not differ between *C. formosanus* and *C. acinaciformis* (Creffield et al. 2013), indicating that differences in damage ratings between species are not just because of differences in consumption rates.

With more data available for *C. formosanus* and *C. gestroi*, in economic terms among the world's most significant termite pest species (Sornnuwat 1996, Lee 2002, Kirton and Brown 2005, Lee et al. 2007, Scheffrahn and Su 2008, Su and Scheffrahn 2010), we can confirm earlier results that they have a more limited ability to damage plastics compared with *C. acinaciformis* and *M. darwiniensis* from Australia and *C. kalshoveni* from Malaysia (Lenz et al. 2012), at least under the conditions of this trial. Costa–Leonardo et al. (1999) mention that *C. gestroi* (formerly called *Coptotermes havilandi*) does cause damage to electric cables. However, the type of plastic sheathing was not stated. Hence, this could well be referring to soft house-wiring insulation.

In specific laboratory trials that exposed plastic samples to entire colonies, *C. formosanus* caused minor damage ("slight nibbling") to samples of different plastics (Tsunoda et al. 2010). These results indicate that to be valid, statements on the economic impact of termite pests must be considered at the species level, as strong differences can be evident both within and between genera, and even within widely recognized species that may actually represent a complex of species as we now know in the case of *C. acinaciformis.* In addition, statements should be specific to the types of material under consideration. This point is also supported by the fact that *C. formosanus* has recently been shown to have a greater tolerance to low doses of two

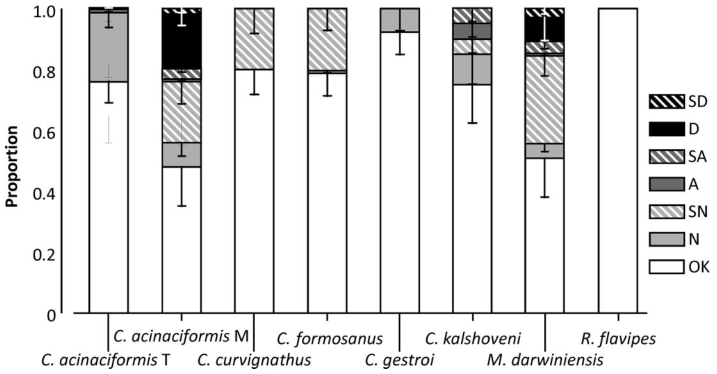

Fig. 2. Damage (a) to plastic samples caused by each species of termite averaged over all types of plastic. (a) Damage ratings (Table 3).

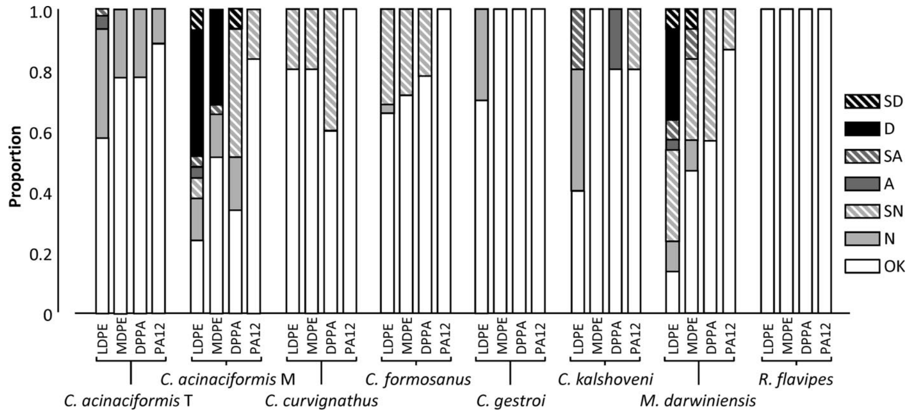

Fig. 3. Proportion of samples of each type of plastic with damage ratings for each species of termite (a). (a) Type of plastic (Table 1) and damage ratings (Table 3).

pyrethroids, compared with *C. acinaciformis* (Creffield et al. 2013).

Wood replacement interval was found only to have an effect for lower damage ratings (OK and N across all species), and the method of placement was found to have no effect for any comparison. The within-species analyses that included direct comparisons of *C. acinaciformis* T and *C. formosanus* found no effect. These two species were not the most damaging (second tier and third tier, respectively). Therefore, it is possible that the more damaging species may have caused different levels of damage with differing placement methods and bait wood replacement frequency.

Within the 12-mo test duration, we could not demonstrate with our group of species an effect of the combination of repeated bait wood replacement while at the same time exposing clean sample surfaces to termites on damage ratings. However, it is obvious that such an intensive ("accelerated") termite exposure trial would give far more weight to the results concerning the ability or inability of a given species to damage the materials compared with conventional methods. Furthermore, the complete destruction of each offering of bait wood and recontact with sample surfaces, as indicated by a new layer of plastering on them, most notably in the trials in three countries with *C. formosanus,* highlighted the intense termite presence around the samples. With our methodologies, one can more accurately evaluate the capability, or lack thereof, of a given species to inflict damage to

Table 5. Results of GLM comparisons: Proportion of plastic samples across damage ratings for plastic type, termite species, method of exposure, and wood replacement interval

Damage rating (r^2)	Factor	F	P	Pairwise comparisons[a]
OK (0.835)	Plastic	11.642	<0.001	(LDPE {MDPE) [DPPA} PA12]
	Species	12.156	<0.001	(Rf Cc [Cf Cg Ck CaT) CaM Md]
	Method	0.069	0.795	NS
	Wood[b]	14.458	<0.001	3 < (4, 6, 12)
	Plastic × species	1.201	0.302	NS
N + SN (0.727)	Plastic	3.232	0.032	(LDPE MDPE DPPA) > PA12
	Species	3.490	0.005	Rf < (Cc Cf Cg Ck CaT CaM Md)
	Method	0.112	0.739	NS
	Wood	12.193	<0.001	3 < (4, 6, 12)
	Plastic × species	0.896	0.596	NS
A + SA (0.729)	Plastic	6.272	0.001	(LDPE DPPA) > (MDPE PA12)
	Species	6.128	<0.001	(Rf Cc Cf Cg [CaT CaM Md) Ck]
	Method	0.040	0.821	NS
	Wood	0.730	0.426	NS
	Plastic × species	2.365	<0.001	Only 4 spp. + 3 plastics with A + SA
D + SD (0.886)	Plastic	12.968	<0.001	(LDPE DPPA) > (MDPE PA12)
	Species	14.609	<0.001	(Rf Cc Cf Cg Ck CaT [Md) CaM]
	Method	0.052	0.821	NS
	Wood	0.949	0.426	NS
	Plastic × species	7.270	<0.001	Only 2 spp. + 2 plastics with D + SD

[a] Significant differences ($P < 0.05$) in Bonferroni-corrected, post hoc pairwise comparisons are indicated with signs and brackets; those abbreviations within identically shaped brackets are not significantly different (plastics; species); those abbreviations within brackets located to the right indicate most resistant samples (plastics), and to the left least ability to damage samples by termite species. Species abbreviations: CaT, *Coptotermes acinaciformis* tree-nesting form; CaM, *C. acinaciformis* mound-building form; Cc, *C. curvignathus;* Cf, *C. formosanus;* Cg, *C. gestroi;* Ck, *C. kalshoveni;* Md, *M. darwiniensis;* Rf, *R. flavipes.*

[b] Wood replacement interval = months.

Table 6. Results of the GLM-comparing proportion of nondamaged plastic samples (rated 'OK') for *C. acinaciformis* (tree-nesting and mound-building form), *C. formosanus* (China, Japan, United States), and *C. gestroi* (Malaysia, Thailand) against location, plastic types, and wood replacement

Species (r^2)	Factor	*F*	*P*	Pairwise comparisons
C. acinaciformis (0.850)	Location	16.587	0.002	Tree-nesting > mound-building
	Plastic	9.882	0.001	LDPE < MDPE < DPPA < PA12
	Wood	1.938	0.186	NS
	Location × plastic	2.113	0.152	NS
	Wood × plastic	0.689	0.663	NS
C. formosanus (0.727)	Location	0.039	0.846	NS
	Plastic	3.344	0.044	(LDPE MDPE [DPPA) PA12]
	Wood	20.552	<0.001	3 < (4, 6)
C. gestroi (0.903)	Location	1.000	0.391	NS
	Plastic	9.000	0.052	NS
	Location × plastic	13.500	0.032	Malaysia < Thailand, only for LDPE

Significant differences ($P < 0.05$) in Bonferroni-corrected, post hoc pairwise comparisons are expressed as in Table 5.

these or other materials that may be exposed to termite attack.

The main focus of this study was to compare the response of different species of *Coptotermes* among the most important termite pests of wood and wood products (Creffield et al. 2013). *R. flavipes* and *M. darwiniensis* were included because they are frequently used in assessments of termite resistance of materials. At the sites in Thailand and Malaysia, *Macrotermes, Odontotermes,* and *Microtermes* (Macrotermitidae) were also present and could be found at times feeding on the bait wood. However, all the evidence indicated that whatever damage was inflicted on the plastic samples could be attributed only to *Coptotermes,* confirming earlier results at the same sites (Lenz et al. 2012).

At this stage we cannot say why Australian termites (*C. acinaciformis* M and T, and *M. darwiniensis*) damage plastic samples far more readily than any other species investigated. In the case of *M. darwiniensis,* larger mandible size could be a factor in its success of damaging plastics and a wider range of materials than any other termite species (Gay and Callaby 1970), just as some of the larger ground-dwelling beetle larvae can leave deep marks on even harder samples with their substantial mandibles. However, the species of *Coptotermes* are too similar to each other. Factors other than "mandible size," for example, attraction or repellency of components of plastics, may underlie the difference in behavior between *C. acinaciformis* and its congeners.

Our results demonstrate that materials tested and determined as termite-resistant in one country or location may not be resistant elsewhere. Specifically, materials considered termite-resistant based on assessments against *R. flavipes* in the United States will need to be reassessed in all other locations. Similarly, materials considered resistant to *C. formosanus* will need to be reassessed in Southeast Asia and Australia, and those considered resistant in Southeast Asia will need to be reevaluated for use in Australia. In contrast, materials considered resistant in Australia will likely be resistant in other locations. Of course, there are many other locations and genera of pest species that were not considered in this study. Consequently, the ability of South American and African termites and Macrotermitidae, in general, to damage plastic cable sheathings remains to be determined.

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