Proceedings of the Tenth International Conference on Urban Pests
Rubén Bueno-Marí, Tomas Montalvo, and Wm. H Robinson (editors) 2022
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RELIABLE LABORATORY TRIAL FOR TESTING INNOVATIVE ANTI-TERMITE BARRIERS

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Abstract Assessing physical barrier on the basis of a laboratory test is an important step on the product development, as those barriers have to remain efficient towards subterranean termites as long as the building is in service. This becomes more challenging when the anti-termite barrier has to resist against different termites with distinct foraging strategies and/or aggressiveness. This work is presenting a laboratory trial that could be considered as a first step in an anti-termite barrier development. The laboratory test was set up with different barriers and is including *Coptotermes gestroi* (Wasmann) or *Reticulitermes flavipes* (Kollar) (ex. *santonensis* De Feytaud). To improve the test robustness with *R. flavipes*, far less aggressive and virulent, the barriers were punctured in order to allow primers for termite attack. This method, including a large number of termites (600 workers per test device) was shown discriminant especially for *R. flavipes* presenting a lower attack level compared to *C. gestroi*. It was reproducible and reliable to assess the barrier performances and could be considered as a first step evaluation.

Key words *Reticulitermes flavipes, Coptotermes gestroi*, termite management, anti-termite barrier assessment

INTRODUCTION

Termites are ubiquitous social insects and essential members of the soil ecosystem by providing many benefits in terms of breakdown and recycling of organic matters. In return, termites are a huge threat for wooden commodities and do generate considerable economical losses. Due to climate change and environmental degradation, together with global trade, a significant global expansion of termites is predicted along with the economic losses due to their activities (Buczkowski and Bertelsmeier, 2017; Govorushko, 2019). On the other hand, wood, as a renewable bio-based material, sees its use increasing in the building sector due to its ability to stock carbon as well as its high-level technological characteristics. Regulations and environmental concerns in the wood protection industry are making non-biocidal anti-termite barriers serious candidates for termite management. They are non-invasive systems, excluding subterranean termites from the buildings, protecting the structure, fittings and contents (Grace, 2006; Ahmed and French, 2008). Developing such barriers is challenging as they must remain efficient as long as the building service life, and sometimes towards different subterranean termites. The aim of this work was to develop a laboratory method to evaluate the efficacy of physical barrier against both the very aggressive *C. gestroi* and the less virulent *R. flavipes* (Lewis, 1997; Li et al, 2010), both found on French territory, overseas and metropolitan respectively (Zaremski and Fouquet, 2009). The method was adapted to comply with both termite species, in order to improve its robustness.

MATERIALS AND METHODS

Four physical barriers were tested, none of them containing insecticidal active ingredients: (A) a 100% bio-based polyamide film, (B) an ultra-high molecular weight polyethylene film, (C) a polyethylene film, which is the matrix without insecticide for the TERMIFILM® (Messaoudi et al., 2016), (D) a mesh made of bi-component multi-filament polyester yarn which has sheath end core part each filament, the grid pattern presenting holes of 0.63 mm^2.

Each barrier was cut into 6 cm^2 samples with no preferential side. The barriers were tested (i) as they were (undamaged) for both termite species, (ii) with 4 small holes of 0.5 or 0.7 mm, drilled using 25G and 22G needles respectively for *R. flavipes* only (Figure 1). The holes were bored at the corners of a 1cm^2 square, at the center of each sample. Barrier D, being already a mesh, was used only in its original form.

The barriers were placed in between glass tubes (5 cm height and diameter), as presented in Figure 2. In the control devices, the barrier was replaced by a thermoplastic film (Parafilm®, Sigma). A pine (*Pinus sylvestris*, L.) sapwood bait of dimensions 15 x 25 x 25 mm^3 (L, R, T), covered by wet Fontainebleau sand (4 vol sand /1 vol deionized water), was placed in the lower tube. On the upper tube, were introduced on the humid floral foam 600 termite workers, added with 6 nymphs and 6 soldiers for *R. flavipes*, and 60 soldiers for *C. gestroi*. Both termite types are collected from breeding boxes, *R. flavipes* being originally collected in Saint Trojan forest, Oléron Island, and *C. gestroi* on La Réunion Island (France). The proportions between the casts within the breeding box populations were kept for the test groups. Each modality (barrier/intact or drilled), as well as controls, were tested in four replicates. The test devices were kept 8 weeks: (i) at 27°C, 75% Relative Humidity for *R. flavipes,* (ii) at tropical ambient conditions (La Réunion island) for *C. gestroi*. They were observed and watered twice a week. At the end of the test, the devices are disentangled, the survival rate of the termites is calculated, a visual rating is given to each Pine bait (based on the visual assessment of the EN117) (EN117, 2013).

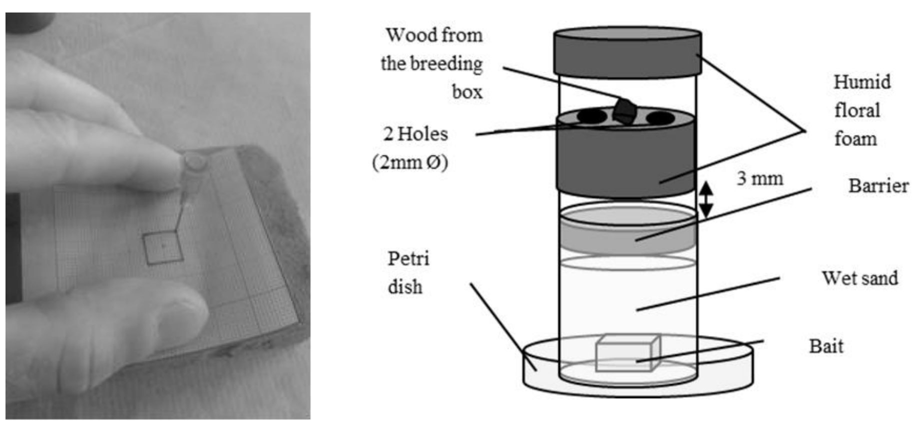

Figure 1,2. Film drilling, scheme of the test device.

RESULTS AND DISCUSSION

The results obtained for *C. gestroi* and *R. flavipes* are given in Table 1 and 2 respectively. For all control samples, the Parafilm® was damaged in many places, the bait was reached and presented a severe attack, and the survival of the termites was above 50%. These criteria validate our test in terms of sufficient termite feeding pressure and termite virulence, the required level of termite activity being achieved (Ewart and Rawlinson, 2000). As expected, *C. gestroi* were aggressive enough to degrade 1 sample out of 4, for the barrier D consisting of a specific type of mesh, confirming then their damage abilities (Chouvenc et al., 2016). Barrier D remained untouched by *R. flavipes*. For this last termite species, it seemed interesting to add

4 small holes, as primers to facilitate termite attack, to overcome their destructive disparity with *C. gestroi* and reproduce a potential mechanical problem on the barrier over the time when *in-situ* below a building.

Table 1. Performances of two physical barriers towards *C. gestroi* (*No attack, **Severe attack)

Barrier	Treatment	Barrier observation	Pine bait Visual rating	Termite survival rate Average (%)
A	-	No degradation, no material removal from the film	0*	26%
D	-	For 3 samples: No degradation, no material removal from the film	0	32%
		For 1 sample: Degradation of the grid	4**	50%
Control	8 samples	Degradation of the Parafilm® used as a control barrier, crossing of the film	4	Higher than 50%

The 4 barriers presented different behaviours. The barrier A was not degraded by any termites, the barrier B was not degraded even when drilled, they can therefore be considered as potential candidates for further development. The film C, which is a matrix remained intact when used undamaged (table 2). In the case of the drilled samples, some were heavily damaged and the bait was reached. The holes acted as primer aperture but are not initially large enough to let the termite go through, being smaller that the head or the mandibule sizes (Su et al., 1991). The termites took the opportunity of these failures in the film for further degradation.

This method set up to test the performance of different barriers was shown to be an adequate and discriminant method for *R. flavipes*, when the barrier is drilled. The holes made on the barrier are only indented to be primer failures. The termites do still have to degrade the barrier around those holes or anywhere else to go through. Indeed, in the field/on site, some “pioneers” *Reticulitermes* workers explore systematically in every direction in search for food. These workers initiate a foraging process by covering each direction of the foraging territory (Reinhard et al., 1997). Thus, the drilled holes are a privileged foraging point, a weak part of the barrier. Once the pioneer workers have crossed the barrier, workers will be attracted by the recruitment trail along with the volatiles from the wood. In this case, if the barrier is not performant enough, the termites can go through the barrier down to the bait.

Moreover, the large number of termites used seems an adequate group size (Thorne et al., 2010) and brought sufficient biological pressure to make the difference between the controls and tested barriers. The survival rate (above 50%) and the severe attack needed on the bait have been largely experienced in European standardized methods where a non-choice test is applied (such as EN117, 2013). Here, these validity criteria were easily reached for the controls, meaning that the termite population chosen could feed and survive on the volume of the bait for the 8 weeks, for both termite species.

CONCLUSION

In conclusion, the laboratory methods developed are adequate to evaluate the potentialities of materials as physical anti-termite barriers, with different subterranean termites (CIRAD, 2016; ORLAT, 2016). The methods were easy to perform, reliable and reproducible, and can be a first step to further development. They were also proved to be reliable with physico-chemical barriers.

Table 2. Performances of the physical barriers towards *R. flavipes* (*No attack, **Severe attack)

Barrier	Treatment	Barrier observation	Pine bait Visual rating	Termite survival rate (%)
A	-	No degradation, no material removal from the film, nibbling signs on few samples	0*	0
	4 holes 0.5 mm Ø	No degradation even around the holes, no material removal from the film, nibbling signs on few samples	0	0
	4 holes, 0.7 mm Ø		0	0
B	-	No degradation, no material removal from the film	0	0
	4 holes 0.5 mm Ø	No degradation even around the holes, no material removal from the film	0	0
	4 holes 0.7 mm Ø		0	0
C	-	No degradation, no material removal from the film	0	0
	4 holes 0.5 mm Ø	2 samples: No degradation even around the holes, no material removal from the film	0	0
		1 sample: material removal, attempt of tunneling through the barrier	0	0
		1 sample: one of the 4 holes enlarged, crossing of the barrier	4**	30.7
	4 holes 0.7 mm Ø	1 sample: one of the 4 holes enlarged, but no crossing of the barrier	0	0
		3 samples: 1 or 2 holes enlarged, crossing of the barrier	4	62.8, 31.2 and 38.2 for the 3 samples respectively
D	-	No degradation, no material removal from the film	0	0
Control	16 samples	Degradation of the Parafilm® used as a control barrier, crossing of the film	4	Higher than 50%

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