# Natural durability of 8 tropical species suitable for round wood building: fungal and termites laboratory screening tests

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NATURAL DURABILTY OF GUYANESE WOODS

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## Abstract

Knowledge of the wood properties of tropical tree species is still relatively limited, making that timber exploitation focuses on a few abundant, large-diameter species. Very few is known about small diameter trees although they may be used, directly as round wood, in construction timber building. The aim of this work was to determine the wood natural durability of 8 candidate species for round-wood building in French Guiana ; *Oxandra askeckii*, *Goupia glabra*, *Lecythis persistens*, *Hymenopus heteromorphus*, *Pouteria bangii*, *Licania alba*, *Tachigali melinonii*, *Simarouba amara* and *Virola surinamensis* wood samples were exposed to white rots (European and tropical), brown rot (European) and European subterranean termites (using non-choice and multi-choice tests), in laboratory conditions by screening tests adapted from European standards.

Only two species were classified as durable against both fungi and termites: *Licania alba* and *Pouteria bangii,* meaning they can be used without treatment as building material under tropical or temperate climate. The other tested species were classified (1) as durable but with important difference observed between fungal and termite durability (*Goupia, Lecythis, Oxandra*), (2) moderately durable (*Hymenopus*), (3) or slightly durable to sensible (*Tachigali, Simarouba, Virola*), meaning actual European standards would not let use these last species in outdoor structure without protection, despite their vernacular use. However, they could be used in structure with appropriate protection systems (including wood protection and design protection systems). The results obtained on wood decay resistance bring crucial information to assess the valorization of these 8 tree species in the Guyanese construction market.

**Keywords:** French Guiana, Fungi, Natural durability, Round woods, Small-diameter woods, Termites.

## Introduction

The Guiana shield is one of the largest continuous areas of lowland tropical rainforest in the world. The forest cover reaches 8 million hectares in French Guiana (1/3 of the French forest) and shelters a unique biodiversity. Forestry operations are, therefore, subject to strict rules, designed to preserve the resilience of the ecosystem, maintain a high level of biodiversity and ensure the recovery of wood and carbon stocks. It is therefore essential to target the species to be harvested and optimize their processing in order to maximize the added value of the final products. Nowadays, about 90 vernacular timber species (ca. 250 botanical species), out of the 1800 species of trees inventoried in French Guyana, are considered as technologically relevant and therefore of potential commercial value (Guitet *et al.* 2014). Among this large tree diversity, less than 30 wood species were exploited over the last decades by the local wood industrial chain (Détienne *et al.* 1989; ITTO, 2019). Moreover, 4 timbers (*Louro vermelho*, *Basralocus*, *Mandioqueira* and *Pau roxo*) constitutes 75% of the volume harvested (PRFB, 2020). Local timber production thus only focuses on few abundant species (associated with long renewal period) and valorize only the old large-sized trees (with diameter superior to 50 cm). In a context of growing need for timber, such a production chain can no longer meet the demand while preserving the forest ecosystem. With wood demand expected to triple by 2030 (Houël *et al.* 2022; PRFB, 2020), it is therefore essential to broaden our knowledge about the potentialities of the Guyanese forest resource in order to identify new tree species of interest for timber production.

Small-diameter trees represent an abundant resource in the Amazonian rainforest (Sellan *et al.* 2023). This resource, unexploited, could constitute an interesting alternative for the construction sector. The most abundant species identified within the diversity of small-diameter trees (from 5 to 10 cm) are slow growing shade-tolerant species. They produce a dense wood (Ramananantoandro *et al.* 2016; Lehnebach *et al.* 2019), providing the material interesting mechanical performances, suitable for log building, as evidenced by traditional Palikurs constructions (Ogeron *et al.* 2018). Besides density and mechanics, the choice of the timber in the design of a wooden construction also strongly depends on natural durability, as the intended end-uses, (e.g. poles, framings, etc.) do not require the same durability performances (Pilgram 1983). Durability is one of the most important concerns related to the use of timber in construction, whatever the construction system used. Providing more information about this property, as well as other technological characteristics, can help in predicting service life, designing buildings, performance evaluation, and life cycle assessment of wood structures (Brischke *et al*. 2014). In addition, durability property is a good indicator of the activity of the secondary metabolite constituents and can provide useful leads for wood's valorisation through green chemistry applications (Royer *et al*. 2010; Perrot *et al*. 2018). In order to define the most adapted applications for small-diameter species, it is thus crucial to overcome the subsistent knowledge gap related to the natural resistance of such woods towards biological agents, as fungi and termites.

Natural durability is an inherent property of wood defined by its resistance against wood-destroying agents. It results from a combination of different parameters like chemical composition (mainly extractives compounds) and anatomical characteristics that are linked to the genetic determinants (Gouveia *et al.* 2021). The resistance of wood against destroying organisms is complex but can be assessed through a variety of test protocols, whether at a laboratory level or under field conditions (Kutnik *et al.* 2017). When investigating new species, a first approach may be to evaluate their resistance to specific organisms using reproducible and standardized laboratory-scale tests to allow comparison with more common species already used in construction.

The objective of this research work was to determine the durability of 8 selected Guyanese wood species with small diameter identified as abundant and under-valorized local resource, against European and tropical fungal strains and *Reticulitermes* termites, under laboratory conditions. This property is crucial to discuss the possible uses of these 8 timber species for local log building in the Guyanese construction market.

# Material & Methods

## Wood Species and Trees Selection

Eight Guyanese tree species were selected because of their rather homogeneous abundance on the whole French Guiana's territory (Jolivot et *al.* 2008), and their very slender and flawless morphology, answering the objective of providing a low-cost local building material (Table 1).

**[Table 1]**

The diameter distribution of the selected species, resulting from local inventories (https://paracou.cirad.fr/ and https://dataverse.cirad.fr/dataverse/paracou), is detailed in Fig. 1. The choice of the species studied results from a combination of different criteria, such as size at maturity, abundance in natural forests and the potential sylvicultural models of these species. Thus, 5 species were selected: *Hymenopus heteromorphus, Licania alba, Lecythis persistens, Oxandra asbeckii* and *Pouteria bangii*, whose size at maturity in natural stands does not exceed 30 cm in diameter (with the exception of *Licania*, i.e. 42 cm), which is the reason why the forestry sector has never been interested in harvesting them. However, for a given geometry, their high wood density suggests good mechanical performance for use as roundwood. These 5 species could complement the harvesting of large-sized timber tree in natural forests. *Goupia glabra* was also selected. It is a canopy species, which consequently reaches a much larger size at maturity, i.e. 62 cm. This long-lived, densely-wooded heliophilic species is already harvested by local logging when mature, but it is also very abundant in small diameter classes in moderately disturbed forests. It therefore accounts for a substantial proportion of the small-stem volumes resulting from forest clearing, and could be valorised as roundwood. The last two species selected were *Simarouba amara* and *Tachigali melinonii*. Unlike the others, they have light wood, but their vernacular uses suggest that they could be good candidates for the construction of temporary structures or emergency habitats for which low weight material with satisfactory mechanical performance and low resistance to rot is sufficient. In addition, *Simarouba* and *Tachigali* seem to be fairly resistant against insect attack compared to other wood species, during sawmill storage, for *example* However, their low density is one of the properties making their processing (except for the wood with high content of silica) and implementation relatively easy, as well as their impregnation with anti-fungal and anti-termite bio-treatments. According to Gerard *et al*. (2017,) *Simarouba amara* is classified in treatability class 1 (treatable), whereas *Tachigali sp.* can be classified until treatability class 3 (poorly treatable) according to the genus. It should be noted that *Simarouba amara*, *Tachigali melinonii* and *Goupia glabra*, due to their heliophilic temperament and high growth rates, could also be produced as roundwood through short-rotation planting or as a complement to longer-lasting plantations. Hereafter, species names are abbreviated by their genus names.

**[Figure 1]**

For termite and fungal resistance tests, an additional species, *Virola surinamensis*, known for its poor natural durability (Neves *et al*. 2002), has been added to be tested as virulence control.

Five trees per species were identified and collected near the Paracou experimental research station (https://paracou.cirad.fr/), in French Guyana (5°16'27N; 52°55'26W). This site is a “terra firme” natural forest belonging to the Caesalpiniaceae facies (Sabatier and Prevost 1989), a typical forest type of French Guiana. A total of 45 trees (5 per species) of 6-10 cm diameter were sampled, with the most cylindrical trunks and the longest useful lengths, in order to dedicate the whole tree to other characterization experiments required for round wood uses in building (drying, cracking, mechanical properties, durability field tests, etc).

## Preparation of natural durability tests samples

A 40 cm-long stem portion was collected from the lower part of each selected tree. Several wood pieces longitudinally oriented, 400 × 15 × 5 mm (L x R x T), were sawn from each stem portion. The pieces in the middle of the radial profile were selected in order to maximize heartwood proportion while avoiding the presence of juvenile wood. Finally, the pieces were longitudinally cut into 25 × 15 × 5 mm (L x R x T) test samples (Fig. 2).

**[Figure 2]**

To obtain a representative sampling of the exploitable wood, samples exhibiting peculiarities such as knots, slope grain or reaction wood were discarded (ISO 4471 1982). As the number of samples per tree is limited by the small size of the stem, natural durability screening tests (Bravery 1978; Salman *et al.* 2017), involving small-sized samples with reduced biological exposure durations, were preferred over European standards. In addition, as the objective was to assess the natural durability of the log as a whole, sapwood was not cleared from the samples. From each stem, 26 samples were randomly selected (Fig. 2): 18 samples to assess the fungal resistance (6 samples per fungus) and 8 samples to assess the termite resistance (5 samples for non-choice tests and 3 samples for choice tests).

## Resistance against fungal degradation by screening tests

The resistance against wood destroying rots was tested according to the guidelines of Bravery (1978), i.e. a screening tests adapted from EN 113-2 (2020) for the sample size and the fungal exposure duration.

Glass bottles of 720 ml volume were filled with 65 ml of sterile culture medium [malt extract (40 ± 0.5 g) (Quaron) and agar (20 ± 0.5 g) (Biomérieux) in deionized water (1 l)], inoculated with two small pieces (1x1 cm) of a 7-day-old culture mycelium of one brown rot [*Coniophora puteana (CP)* (Schumacher ex Fries) Karsten (BAM Ebw. 15)], one white rot [*Trametes versicolor* (TV) (L.) Lloyd (CTB 863A)], or one white tropical rot [*Pycnoporus sanguineus (PS)* (L.) Murrill, 1904] and then closed with carded cotton to enable air circulation. The inoculated glass bottles were stored for 2 weeks in a climatic chamber regulated at 22 ± 2 °C and 70 ± 5% Relative Humidity (RH) for *TV* and *CP*, or 27 ± 2 °C and RH > 75% for *PS*, until reaching the full colonization of the medium by the mycelium.

Surface sterilisation of the wood samples before decay resistance test was performed by UV radiations (20 minutes per face).

A batch of 10 samples per species was treated apart in order to calibrate the estimation of the theorical anhydrous mass of each species tested ($m_1$). This batch was stabilized (20 ± 2 °C and 65 ± 5 % RH) and weighed ($m_s$), then oven dried at 103 °C for 48 h and weighed ($m_a$). The theorical anhydrous mass ($m_1$) was calculated using the averaged stabilised mass to oven-dried mass ratio of the batch (k), according to Equation1 and Equation 2.

$$k = \frac{m_s}{m_a} \qquad (1)$$

$$m_1 = k * m_s \qquad (2)$$

The test samples (4 wood samples of the same species per inoculated glass bottles) were incubated for 8 weeks in a climatic chamber (22 ± 2 °C and 70 ± 5% RH for *CP* and *TV*; 27 ± 2 °C and RH > 75% for *PS*). Once the fungal exposure was completed, samples were carefully cleaned. All samples were then oven dried at 103 °C for 48 h and weighed ($m_2$). Degradation of each sample was assessed by computing the mass loss (ML %) as (Equation 3):

$$ML(\%) = \frac{m_1 - m_2}{m_1} \times 100 \qquad (3)$$

Pine sapwood and beech samples (12 replicates per fungal strain) were used as virulence controls (pine sapwood for *CP* and beech for the 3 fungal strains).

According to the median ML calculated per species, wood samples were sorted by durability class (Table 2).

**[Table 2]**

## Resistance to termites by screening tests

The Guianese wood species were exposed to subterranean termites (*Reticulitermes flavipes, ex. santonensis*) in non-choice and choice screening tests. Termites were collected from Oleron Island, France (Lat. 45° 49′ 5.9″ N; Long. −1° 13′ 47.8″ W). The colony was reared in a climatic chamber regulated at 27 ± 2 °C and RH > 75%.

Pine sapwood and *Virola* samples with dimensions of 25 × 15 × 5 mm (L × R × T) were also tested against termites as temperate and tropical virulence controls for choice and non-choice tests. As for the fungal decay tests, both tested and control samples were weighted and their moisture contents measured in order to determine their theoretical anhydrous mass ($m_3$) before termites exposure.

### Non-choice tests

The non-choice tests were carried out according to the main criteria of the EN 117 (2013), with some adjustment concerning the sample size and the termite exposure period. Five replicates (1 sample per tree) and 3 control samples were tested for each species, separately (Fig. 2). Each specimen was placed on a plastic mesh at the center of a 9-cm diameter Petri dish, containing 35 g of Fontainebleau wet sand (4 vol. of sand/1 vol. of deionized water). Considering the dimension of the samples to be tested, and according to the method used in previous studies (Afzal *et al.* 2017; Mohareb *et al.* 2017; Salman *et al.* 2017; Elaieb *et al.* 2020), 50 termite workers, one nymph and one soldier were then introduced into each test device. These test devices were placed for 4 weeks in a dark climatic chamber conditioned at 27 ± 2 °C and RH > 75%. Once a week water was added and termite behaviour was checked.

At the end of the exposure, the samples were removed, cleaned of sand and the termite survival rate was calculated. Sample degradations were given a visual rating according to the criteria of EN 117 (2013) (the criteria being adjusted to the sample size). Then, the samples were dried at 103 ± 2 °C to obtain their anhydrous mass after termite exposure ($m_4$), and their mass losses (ML %) were calculated similarly to Equation 3.

### Multi-choice tests

For the choice tests, 1 sample per species was placed on a plastic mesh around the center of a 14-cm diameter Petri dish, containing 150 g of Fontainebleau wet sand (4 vol. of sand/1 vol. of deionized water). The 8 Guyanese woods were exposed together to 250 termite workers, 5 nymphs and 5 soldiers, with and without *Virola* samples used as control and placed at the center of the Petri dish (Fig. 2). Both modalities were carried out to assess the impact of the presence of a non-durable wood in the multi-choice test devices.

Three replicates of each tested modality were carried out. In addition, two devices containing 8 samples of Pine sapwood or 8 samples of *Virola* were performed as controls. All the test devices were placed for 4 weeks in a dark climatic chamber conditioned at 27 ± 2 °C and RH > 75%. Termite survival rate, wood samples visual rating and mass loss were evaluated as for the non-choice tests.

# Results and Discussion

## Decay resistance

The average values of mass loss on *Pinus* and *Fagus* wood control samples (Table 3) are respectively above the thresholds required (EN 113-2 2020) hence validating the decay test.

**[Table 3]**

All the results for decay resistance test are presented in Fig. 3. For all tested species, a common pattern can be observed: tropical rot (*PS*) is the most virulent, leading to median mass losses ranging from 4.6% for *Pouteria* to 44% for *Virola*. In addition, temperate rots virulence appears lower for white rot (*TV*) than brown rot (*CP*) considering control species, but this pattern does not apply for all species tested.

**[Figure 3]**

*Goupia, Licania* and *Oxandra* median mass losses with tropical rot are about double those of the temperate rots. In this sense, it is therefore important to consider the biological risks of the concerned geographical area, by selecting the most discriminant fungal strain that may be encountered in the area where the wood will be used (EN 460 2023). *Lecythis, Licania, Oxandra* and *Pouteria* present the lowest degradation for all tested rots (Table 4).

According to their higher mass loss (ML), recorded with *Pycnoporus sanguineus*, *Pouteria* (ML = 4.6 %) is classified as highly durable (class 1), whereas *Licania* (ML = 6.2 %), *Oxandra* (ML = 7.3 %) and *Lecythis* (ML = 8.0 %) are classified as durable (class 2), meaning they can be used as indoor and outdoor building or joinery materials under tropical climate (until uses classes 3 or 4 under certain conditions), without any protection systems. Contrary to *Licania* and *Oxandra* that have been very little studied, the results obtained for *Lecythis* were expected since durability of this species has already been studied (Gerard *et al.* 2017). However, it should be pointed out that this species belongs to a complex gender gathering many species (with identification difficulties based on simple botanical criteria) having different durability classes [*L. persistens* is class 3 or 4 (Gerard *et al.* 2017) whereas *L. Pisonis* is class 1 or 2 (Comvalius L. B. 2001)].

*Goupia* and *Hymenopus* resulted in moderated degradations. Previous studies conducted in Guiana and Suriname also reported *Goupia* as moderately durable (Van Acker *et al.* 2000; Chudnoff 1984). Concerning *Hymenopus,* no data concerning the wood natural durability have been found within the scientific literature.

Finally, *Simarouba* and *Tachigali* appeared to be the most degraded species to the rots tested. *Simarouba*, as mentioned in the Tropical Atlas Timbers (Gerard *et al.* 2017), results as susceptible wood species. The Guyanese species tested as local control, *Virola,* was classified as susceptible and the most attacked species by the tropical rot (median ML = 44.0 %). This result confirms it could be, in that sense, a good marker of rot degradation intensity, in a tropical context. However, for temperate rots, and specifically considering only CP results, it appears that *Simarouba* (median ML = 28.5 %) could be more suitable as a control species than *Virola* in laboratory conditions (median ML = 18.6 %, less than the minimal value of 30 % required by the standard) for further decay tests. In other word, particular attention needs to be paid to the choice of the couple [control wood sample; Fungi type] to carry out decay resistance test on tropical wood species.

The median values of fungal mass losses (ML %) and associated durability classes of the 8 wood species tested, after 8 weeks exposure to *CP*, *TV* and *PS* are detailed in Table 4.

**[Table 4]**

## Resistance towards termites

### Non-choice tests

The results from termite resistance non-choice tests carried out on the selected small diameter round wood species are illustrated in Fig. 4. Visual rating and corresponding termite durability class according to the standards (EN 117 2013; EN 350 2016) are presented in Table 5.

The *Pinus* sapwood and *Virola* control samples were severely degraded (mass loss up to 12.47 ± 1.45 % and 10.93 ± 1.26 %, respectively) with a termite survival rate of 79.33 ± 5.03 % and 34.67 ± 9.24 %, respectively). Both set of control samples have a visual rating of 4 (susceptible to termites). The results from *Pinus* samples confirmed the high virulence of termites and the validity of the termite resistance tests according to the standards. Interestingly, *Virola* is also susceptible to termite, but present a lower termite survival rate than those obtain with *Pinus* sapwood. In this sense, a more appropriate wood species could be used for control samples during termite resistance tests in order to limit the termite mortality and thus better reach the requirements of the standards. It could also be envisaged to raise termites in the laboratory by giving them *Virola* as their main source of feed, enabling them to adapt their symbiotic system to this wood.

*Goupia*, *Licania* and *Pouteria* appeared to be durable against *Reticulitermes flavipes*, according to their visual rating of 1 (100 % of the five samples tested per species). The mass loss recorded for these three species (< 3.36 %) are similar. These results are concordant with previous studies. Comvalius (2001) has determined similar classification of these three wood species. However, a difference can be observed regarding the termite survival rate (TSR): *Pouteria* seems to be only repellent (TSR = 19.20 ± 20.52 %) when *Goupia* and *Licania,* appears to be little more toxic toward termites (TSR = 0.00 % and 0.40 ± 0.89 %, respectively).

**[Figure 4]**

**[Table 5]**

Weekly monitoring of the test devices, giving termite behavior information, comforts these results. For *Licania* samples (Fig. 5), we observed that all the termites were gathering on top of the wood sample, staying motionless, for the whole duration of the test until they all died. According to Haifig *et al*. (2015), "aggregation behaviour is a pattern found among most termites, characterized by high recruitment when a valuable resource is found", but in the present case, termites were very little active, hence suggesting that this behaviour was abnormal and unrelated to feeding. Furthermore, most of the individuals were found dead at the end of the experiment. Thus, their aggregation behaviour and death are very probably related to chemical wood compounds that acted as repellents. In addition, most of the wood species from the *Chrysobalanaceae* family, such as *Licania* (Wiemann 2010), are known to be very rich in silica which have high abrasive properties for cutting tools, but also for termite mandibles, which then acts as a digestibility reducer for the enzymatic digestion process of termite (Dhawan *et al*. 2007).

**[Figure 5]**

Pretty similar observations were obtained for *Goupia*. At the beginning of the test, all termites were attracted by the sample, gathering around it. Finally, they all died during the first week after eating (average ML = 3.5 %), proving the toxicity of this species. The anti-termite effect of these wood species could be due to the presence of some toxic or repellent extractive compounds whose properties could be used for the development of natural insecticides for the treatment of non-durable wood species (Rodrigues *et al*. 2011).

For *Pouteria* and *Oxandra*, the two species were less degraded than *Goupia* (Fig. 4) and the termites died slightly latter. *Pouteria* and *Licania* which gave here interesting resistance to termite attacks were also the most resistant to rot degradation. Past studies showed that chemical compounds that have been widely isolated from the extractives of *Pouteria* and *Licania* genus included phenolic acid, other phenolics non flavonoid, flavonoids, and terpenoids derivative

(Fitriansyah *et al.* 2021; Silva *et al.* 2012). According to this chemical composition, their extractives might thus be quite effective against both degradation agents (fungi and termites), making them as good candidates for log building applications without any treatment.

*Hymenopus*, *Lecythis*, and *Oxandra* were classified as moderately durable against *Reticulitermes flavipes*. They presented a low termite survival rate (< 2.00 %), a mass loss under 3.50 % (for *Lecythis)* and more than 10% of the tested samples for each wood species presented a visual rating of 2. The *Lecythis* genus gathers several species with sometimes very different properties than those of *Lecythis pisonis* (i.e., *Lecythis idatimon* or *Lecythis* which have a low natural durability) (Gérard *et al.* 2017). Great care must therefore be taken when identifying species within this genus, whose botanical identification is complex.

Finally, *Simarouba* and *Tachigali* showed the highest mass losses among the 8 tested species. Even if their mass losses (*Simarouba*: 4.89 ± 0.22 %, *Tachigali*: 8.03 ± 1.46 %) were lower than those of both control samples, they were also classified as non-durable toward termite attacks, due to their visual ratings (more than 50% of tested sample for each species rated 3 or 4). These finding are consistent with previous study underlining the sensitivity against termites of *Simarouba* and *Tachigali* (Gérard *et al.* 2017). Besides, Barbosa *et al.* (2007) used *Simarouba* as a "non-durable" control species and impregnation medium to test the resistance conferred by tropical wood extractives. However, in the same study the tested samples were exposed to a full colony of *Nasutitermes sp* for 8 weeks, which probably increased virulence towards the *Simarouba* samples used. Still, besides the high level of degradation recorded, it is also worth noting that all termites died after being in contact with *Simarouba* (TSR = 0 %). It is known that the *Simaroubaceae* family contains quassinoids, secondary metabolites responsible for a wide spectrum of biological activities including insecticides, antiparasites or herbicides (Alves *et al.* 2014). Finally, regarding *Tachigali*, the combination of high degree of degradation and low impact on termite survival (average TSR = 50.8 %, average visual rating = 3 and 4, and average ML = 8,03%), allow us to consider this species as a possible control species with *Virola* for termite tests.

These results need to be taken with caution. Indeed, the sampling does not really correspond to the one prescribed by the European standards, especially with regard to sample size, orientation and replicates resulting from the limitations caused by the specific geometry of the small-diameter sampled round woods. In addition, for these species characterized by non-differentiated wood, even if samples were cut in the middle of the radial profile of each tree, their extractives content and composition remain unknown.

Additional chemical analyses should be done to check that point. However, differences were observed between species indicating that these results provide a good overview of the natural durability of the selected species if used as roundwood.

### Multi-choice tests

The results from termite resistance multi-choice tests carried out on the 8 selected Guyanese small diameter round wood species are reported in Table 6.

The control devices demonstrated a good attractivity (majority of strong attacks recorded through visual rating) and a low termite resistance (*Virola*: TSR = 14.00 %; ML = 8.49 ± 5.56 %; *Pinus*: TSR = 87.6 %; ML = 8.1 %), validating their use as control. For all multi-choice test devices (with and without *Virola* samples), the termite survival was lower than 1.20 %. The regular test devices monitoring carried out during the whole test duration allowed to show that, for both modalities (with and without *Virola*), the termites were firstly attracted by *Goupia* sample.

**[Table 6]**

Fig. 6 illustrates the distribution of the mass consumed by the termites according to the wood species, and for all test modalities. After one week, termites preferred *Lecythis*, *Simarouba* and *Tachigali* samples in the absence of *Virola* sample. Concerning the test including *Virola* sample (Fig. 6), this one is clearly preferred and attacked by termites, compared to the others wood species, even if the *Simarouba* and *Tachigali* samples were also substantially degraded. According to the visual ratings presented in Table 6, the most susceptible species towards termites in multi-choice tests are *Simarouba*, and *Tachigali,* which agrees with the termite durability class determined through the non-choice tests.

**[Figure 6]**

Concerning *Pinus* and *Virola* control devices in tests (Fig. 6 in red), the average mass loss (%) after 4 weeks of exposure were 8.49 % and 8.10 %, respectively (Table 6).

Finally, the multi-choice test devices without *Virola* sample (in red) have a lower mass loss than multi-choice test devices with *Virola* sample (in blue). This result confirms that *Virola* is an attractive or palatable species for termites, and justify its used as control species.

The results from the average mass loss (Table 6) and the distribution of the mass consumed among the different wood species (Fig. 6) are consistent with those from the non-choice tests, showing that the less susceptible wood species toward termites are *Licania*, *Hymenopus*, and *Pouteria*.

## Durability classes of all wood species according to the different organisms

Table 7 summarizes the different durability classes of the 8 tested tropical round wood species concerning their resistance against Basidiomycete fungi (*Trametes versicolor* and *Coniophora puteana*, *Pycnoporus sanguineus* tropical strain) and subterranean termites (*Reticulitermes flavipes*).

Interestingly, *Licania* and *Pouteria* demonstrated high natural durability, with the lowest susceptibility toward both fungal and termite attacks. *Goupia* and *Oxandra* can be considered as intermediate cases since *Goupia* is durable considering termites attacks but sensitive to tropical rot, and *Oxandra* highly durable to durable for all rots but sensitive to termites. Something that can still be observed in wooden structures today in French Guiana, such as long-lived carbets (wooden shelters without walls, typical of Amerindian cultures), is that the posts sunk into the ground are made of very durable wood species such as *Vouacapoua* or *Minquartia spp.*, while the above-ground structure is made of wood species (*Annonaceae* and *Lecythidaceae*) that were a little less durable (Ogeron *et al*. 2018). Finally, *Hymenopus* and *Lecythis* are moderately durable while *Simarouba* and *Tachigali* are susceptible to attacks for both tests but evidence toxicity against *Reticulitermes flavipes* when it is tested in non-choice test.

However, these results provide an interesting overview of the natural durability of the selected species if used in round wood. To complete these results, it would be interesting to determine and analyze the chemical composition of each tested wood, in order to better identify their defense mechanism and understand the variability of their durability according to the different wood-destroying organisms (Carter and Camargo 1983).

**[Table 7]**

## Conclusion

According to fungal and termite tests, only *Pouteria* and *Licania* species have sufficient natural durability to be used as building material in ground contact under tropical climate without prior treatment.

*Goupia* is an interesting species: even though it is poorly durable against fungi, it performed well against termites, showing appetent and termicidal properties.

*Oxandra* and *Lecythis* result as durable against fungi and moderately durable against termites, meaning they need at least a termicidal treatment before any use as building material. Concerning *Lecythis* species, a high properties variability could be observed between the different genus. In this sense, it is very important to accurately identify the wood species in order to reach the desired durability level for the final use of wood.

Even if *Simarouba* is classified as poorly durable and sensible against termites, non-choice test indicated that it presents a certain termite toxicity. In this sense, *Simarouba* can be used in indoor conditions. In agreement with this statement, it's common to find *Simarouba* in the interior floors of old town houses in French Guiana. Finally, *Tachigali* results as poorly durable and sensible against termites, *such as Virola*, meaning they are not suitable as outdoor wooden material without prior treatment. Regarding treatment, their light microstructure could be one of the properties that would makes them more suitable for impregnation, contrary to dense wooded species such as *Oxandra* and *Lecythis*. If no treatment is applied, these light wood species could also be interesting for build light structures or temporary structures for emergency housing for example.

Ongoing field durability experiment will complement these results, in order to compare the results obtained in control conditions at laboratory scale to the performances achievable under real conditions of use, where complex phenomenon can occur, combining different fungal and termite attacks that can occur concomitantly in natural environment. This complementary study will allow to better evaluate and understand the natural durability of these 8 species in round wood in natural condition. To complete these studies, it would also be interesting to analyze and quantify the chemical compounds present in each species, in order to better understand the defense strategy developed by each species. Such chemical analyses could include a near-infrared spectroscopy survey allowing further durability classification within each species. The silica content is also an interesting parameter (very variable even at intra-specific scale) that could be measured and linked with termite feeding behavior.

Finally, the great diversity of Guyanese woods could be better valorized, based on sustainable and local uses of a resource to minimize imports and chemical treatments, if more information about their decay resistance was available. In that sense, this study can contribute to the identification of new valorization pathways for the abundant and non-valorized species tested here. More broadly, diversifying the species used in local constructions would help to limit the exploitation of the conventional commercial species, and to limit the opening of ever-deeper forest tracks to access to these resources.

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**Access to data**

The detailed data obtained through this study and presented in this article are available in the “CIRAD Dataverse Portail” with the following reference:

Leroy, Maëva; Candelier, Kévin; Damay, Jérémie; Bossu, Julie; Lehnebach, Romain; Thévenon, Marie-France; Beauchêne, Jacques; Clair, Bruno, 2023, "Replication Data for: Natural durability of 9 tropical species suitable for round wood timber building: fungi and termites laboratory screening tests.", https://doi.org/10.18167/DVN1/V3KS6Z, CIRAD Dataverse.

**Table 1. Genus, species and family name of the selected studied trees, their vernacular names (Molino 2022) in Creole and Bushinengue (Jaouen *et al.* 2022) and their pilot's name (ATIBT 2016).**

| Scientific name | Family | Creole name | Bushinengue name | Pilot name (ATIBT) |
|---|---|---|---|---|
| *Goupia glabra* Aubl., 1775 | Goupiaceae | Goupi, Bois caca | Kopi | Cupiuba |
| *Hymenopus heteromorphus* (Benth.) Sothers & Prance, 2016 *var. heteromorphus* | Chrysobalanaceae | Gaulette | Boliken koko | Grigri |
| *Lecythis persistens* Sagot, 1885 | Lecythidaceae | Mahot rouge | Lebi loabi | Sapucaia |
| *Licania alba* (Bernoulli) Cuatrec., 1964 | Chrysobalanaceae | Koko, Gaulette | Lebi koko | Grigri |
| *Oxandra asbeckii* (Pulle) R.E.Fr., 1931 | Annonaceae | **n.c.** | Muamba | Lancewood |
| *Pouteria bangii* (Rusby) T.D.Penn., 1990 | Sapotaceae | Balata pomme | Bakuman | **n.c.** |
| *Simarouba amara* Aubl., 1775 | Simaroubaceae | Simarouba, Acajou blanc | Asumaripa | Marupa |
| *Tachigali melinonii* (Harms) Zarucchi & Herend., 1993 | Fabaceae (Caesalpinioideae) | Cèdre Remi | Diaguidia | Tachi |
| *Virola surinamensis* (Rol. ex Rottb.) Warb., 1897 | Myristicaceae | Yayamadou marecage | **n.c.** | Virola |

*n.c.: not communicated*

**Table 2. Durability rating scale according to EN 113-2 (2020).**

| Durability class | Description | Median mass loss (%) |
|---|---|---|
| 1 | Very durable | < 5 |
| 2 | Durable | > 5 to < 10 |
| 3 | Moderately durable | > 10 to < 15 |
| 4 | Slightly durable | > 15 to < 30 |
| 5 | Not durable | > 30 |

**Table 3. Median mass loss of *Fagus* and *Pinus* control samples according to the three tested fungus, and decay resistance validation test conditions relative to EN 113-2 (2020).**

| | Median Mass Loss (ML) and Standard Deviation<br>In % (m/m) | Minimal (median) mass loss values of control samples, required in EN 113-2 (2020)<br>In % (m/m) |
|---|---|---|
| **Brown rot on Scots Pine**<br>*Coniophora puteana (CP)* | 32.0 $^{\pm 7.5}$ | 30 |
| **Brown rot on Beech**<br>*Coniophora puteana (CP)* | 31.5 $^{\pm 6.1}$ | 30 |
| **White rots on *Beech***<br>*Trametes versicolor (TV)* | 26.2 $^{\pm 7.8}$ | 20 |
| **Optional fungi**<br>**Tropical White rots on *Beech***<br>*Pycnoporus sanguineus (PS)* | 38.4 $^{\pm 3.9}$ | No requirement |

**Table 4. Median fungal mass loss (ML %) and associated durability class (determined from median values according to EN 350 (2016) of the 8 wood species tested, after 8 weeks exposure to *CP*, *TV* and *PS*. *Pinus* sapwood, *Fagus* and *Virola* have been tested as virulence control samples.**

| Wood species | Density (20°C, 65% HR) | Median value of fugal mass loss (ML) and durability class (DC)* for each tested fungus according to EN 350 (2016) | | | | | |
|---|---|---|---|---|---|---|---|
| | | *Coniophora puteana* (CP) | | *Trametes versicolor* (TV) | | *Pycnoporus sanguineus* (PS) | |
| | | ML (%) | *DC* | ML (%) | DC | ML (%) | DC |
| *Goupia* | 0.888 | **6.3** | **2** | **12.8** | **3** | **24.8** | **4** |
| *Hymenopus* | 1.05 | **7.7** | **2** | **6.6** | **2** | **10.4** | **3** |
| *Lecythis* | 0.869 | **4.2** | **1** | **7.0** | **2** | **8.0** | **2** |
| *Licania* | 1.079 | **1.9** | **1** | **2.9** | **1** | **6.2** | **2** |
| *Oxandra* | 1.071 | **3.2** | **1** | **2.8** | **1** | **7.3** | **2** |
| *Pouteria* | 1.083 | **3.0** | **1** | **3.4** | **1** | **4.6** | **1** |
| *Simarouba* | 0.375 | **28.5** | **4** | **24.1** | **4** | **28.7** | **4** |
| *Tachigali* | 0.751 | **14.2** | **3** | **15.0** | **3** | **24.1** | **4** |
| *Virola* | 0.499 | **17.7** | **4** | **35.5** | **5** | **44.0** | **5** |
| *Fagus* | 0.717 | **32.9** | **5** | **26.6** | **4** | **39.0** | **5** |
| *Pinus* | 0.687 | **33.1** | **5** | n.c | | n.c | |

** Class 5: Not durable; Class 4: Slightly durable; Class 3: Moderately durable; Class 2: Durable; Class 1: Highly durable.*

**Table 5. Visual rating and corresponding termite durability class determined according to the EN 117 (2013) and EN 350 (2016), of the tested species, after 4 weeks exposure to *Reticulitermes flavipes* termite using non-choice tests. *Virola* and *Pinus* sapwood were tested as virulence control samples. Class D: durable, Class M: moderately durable and Class S: not durable.**

| Species | Visual rating* | *Comments* | *Durability class EN 350 (2016)* |
|---|---|---|---|
| ***Goupia*** | 1 [5] | more than 90% of the tested specimens are rated 0 or 1 | **Class D** |
| ***Hymenopus*** | 2 [2] - 1 [3] | more than 10% of the tested specimens are rated 2 | **Class M** |
| ***Lecythis*** | 2 [3]- 1 [2] | more than 10% of the tested specimens are rated 2 | **Class M** |
| ***Licania*** | 1 [5] | more than 90% of the tested specimens are rated 0 or 1 | **Class D** |
| ***Oxandra*** | 2 [2] - 1 [3] | more than 10% of the tested specimens are rated 2 | **Class M** |
| ***Pouteria*** | 1 [5] | more than 90% of the tested specimens are rated 0 or 1 | **Class D** |
| ***Simarouba*** | 3 [3] - 2 [2] | more than 50% of the tested specimens are rated 3 or 4 | **Class S** |
| ***Tachigali*** | 4 [4] - 3 [1] | more than 50% of the tested specimens are rated 3 or 4 | **Class S** |
| ***Virola*** | 4 [5] | more than 50% of the tested specimens are rated 3 or 4 | **Class S** |
| ***Pinus*** | 4 [5] | more than 50% of the tested specimens are rated 3 or 4 | **Class S** |

**[X]: number of samples with the respective visual rating*

0, no attack; 1, attempted attack; 2, slight attack; 3, average attack; 4, strong attack.

**Table 6. Average Termites Survival Rates (%) and mass loss (%), and Visual rating of the 8 selected Guyanese wood species, after 4 weeks exposure to *Reticulitermes flavipes* termite species using multi-choice tests (with and without *Virola* samples). *Virola* and *Pinus* sapwood were tested as virulence control samples.**

| Termites resistance - Choice test with Virola | | | | | |
|---|---|---|---|---|---|
| **Species** | **Mass loss (%)** | *SD (%)* | **Survival rate (%)** | *SD (%)* | **Visual rating*** |
| ***Goupia*** | **4.46** | *0.63* | **0.40** | *0.69* | **1 [3]** |
| ***Hymenopus*** | **1.28** | *0.46* | | | **1 [3]** |
| ***Lecythis*** | **4.29** | *0.42* | | | **1 [3]** |
| ***Licania*** | **1.71** | *0.22* | | | **1 [3]** |
| ***Oxandra*** | **2.20** | *0.72* | | | **1 [3]** |
| ***Pouteria*** | **1.91** | *0.55* | | | **1 [3]** |
| ***Simarouba*** | **2.73** | *0.42* | | | **2 [1] - 1 [2]** |
| ***Tachigali*** | **2.77** | *1.13* | | | **2 [2] - 1 [1]** |
| ***Virola*** | **27.39** | *5.26* | | | **4 [3]** |
| **Termites resistance - Choice test without Virola** | | | | | |
| **Species** | **Mass loss (%)** | *SD (%)* | **Survival rate (%)** | *SD (%)* | **Visual rating** |
| ***Goupia*** | **6.38** | *0.62* | **0.00** | *0.00* | **1 [3]** |
| ***Hymenopus*** | **1.81** | *0.83* | | | **1 [3]** |
| ***Lecythis*** | **5.56** | *0.78* | | | **1 [3]** |
| ***Licania*** | **1.43** | *0.43* | | | **1 [3]** |
| ***Oxandra*** | **2.00** | *1.05* | | | **1 [3]** |
| ***Pouteria*** | **2.00** | *0.45* | | | **2 [1] - 1 [2]** |
| ***Simarouba*** | **6.61** | *1.56* | | | **4 [1] - 3 [1] -2 [1]** |
| ***Tachigali*** | **4.40** | *0.68* | | | **3 [1] - 2 [2]** |
| **Control devices** | | | | | |
| **Species** | **Mass loss (%)** | *SD (%)* | **Survival rate (%)** | *SD (%)* | **Visual rating** |
| ***Virola*** | **8.49** | 5.56 | **14.00** | 0.00 | **4 [3] - 3 [1]- 2 [2] - 1 [2]** |
| ***Pinus*** | **8.10** | 7.02 | **87.60** | 0.00 | **4 [3] - 3 [3]- 3 [2]** |

**[X]: number of samples with the respective visual rating*

0, no attack; 1, attempted; 2, slight attack; 3, average attack; 4, strong attack.

**Table 7. Summary of durability classes of the 8 tested round wood species under laboratory condition using screening tests. *Virola*, *Pinus* sapwood and *Fagus* have been tested as virulence control samples.**

| **Wood species** | ***Durability classes (EN 350, 2016)*** | | | |
|---|---|---|---|---|
| | **Fungi * [EN 113-2 (2020)]** | | | **Termites ** [EN 117(2013)]** |
| | ***Coniophora puteana*** | ***Trametes versicolor*** | ***Pycnoporus sanguineus*** | ***Reticulitermes flavipes*** |
| ***Goupia*** | 2 | 3 | 4 | D |
| ***Hymenopus*** | 2 | 2 | 3 | M |
| ***Lecythis*** | 1 | 2 | 2 | M |
| ***Licania*** | 1 | 1 | 2 | D |
| ***Oxandra*** | 1 | 1 | 2 | M |
| ***Pouteria*** | 1 | 1 | 1 | D |
| ***Simarouba*** | 4 | 4 | 4 | S |
| ***Tachigali*** | 3 | 3 | 4 | S |
| ***Virola*** | 4 | 5 | 5 | S |
| ***Fagus*** | 5 | 4 | 5 | n.c |
| ***Pinus*** | 5 | n.c | n.c | S |

** Class 5: Non durable; Class 4: Slightly durable; Class 3: Moderately durable; Class 2: Durable; Class 1: Highly durable.*
*** D: Durable; M: Moderately durable; S: Susceptible.*

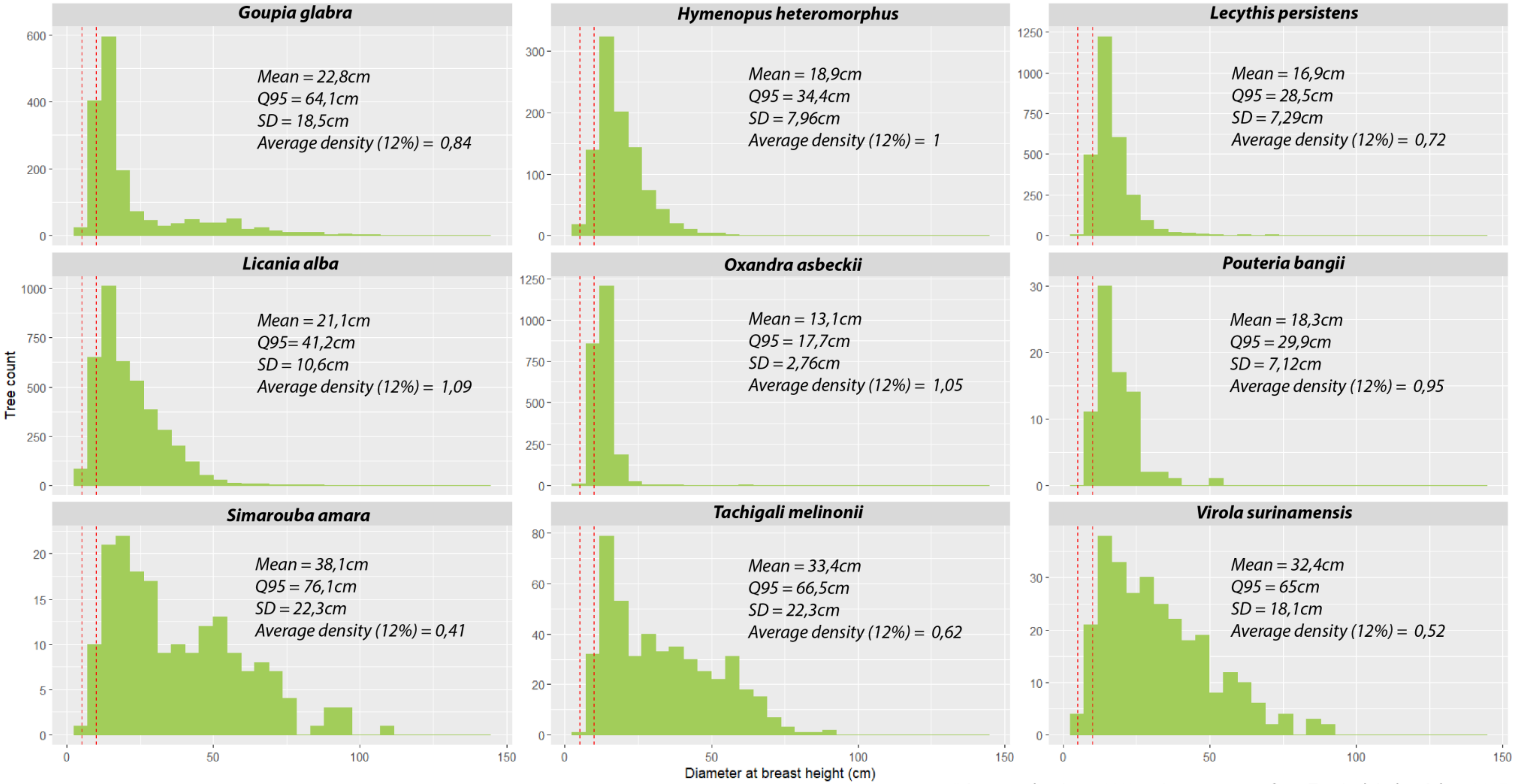


**Figure 1. Distribution of the diameter at breast height of the selected wood species in natural plots. Data are issued from the Guyafor Data Dictionary (https://paracou.cirad.fr/ and https://dataverse.cirad.fr/dataverse/paracou). The values for the average density at 12% are issued from Gerard *et al.* (2017) and Langbour *et al.* (2019).**

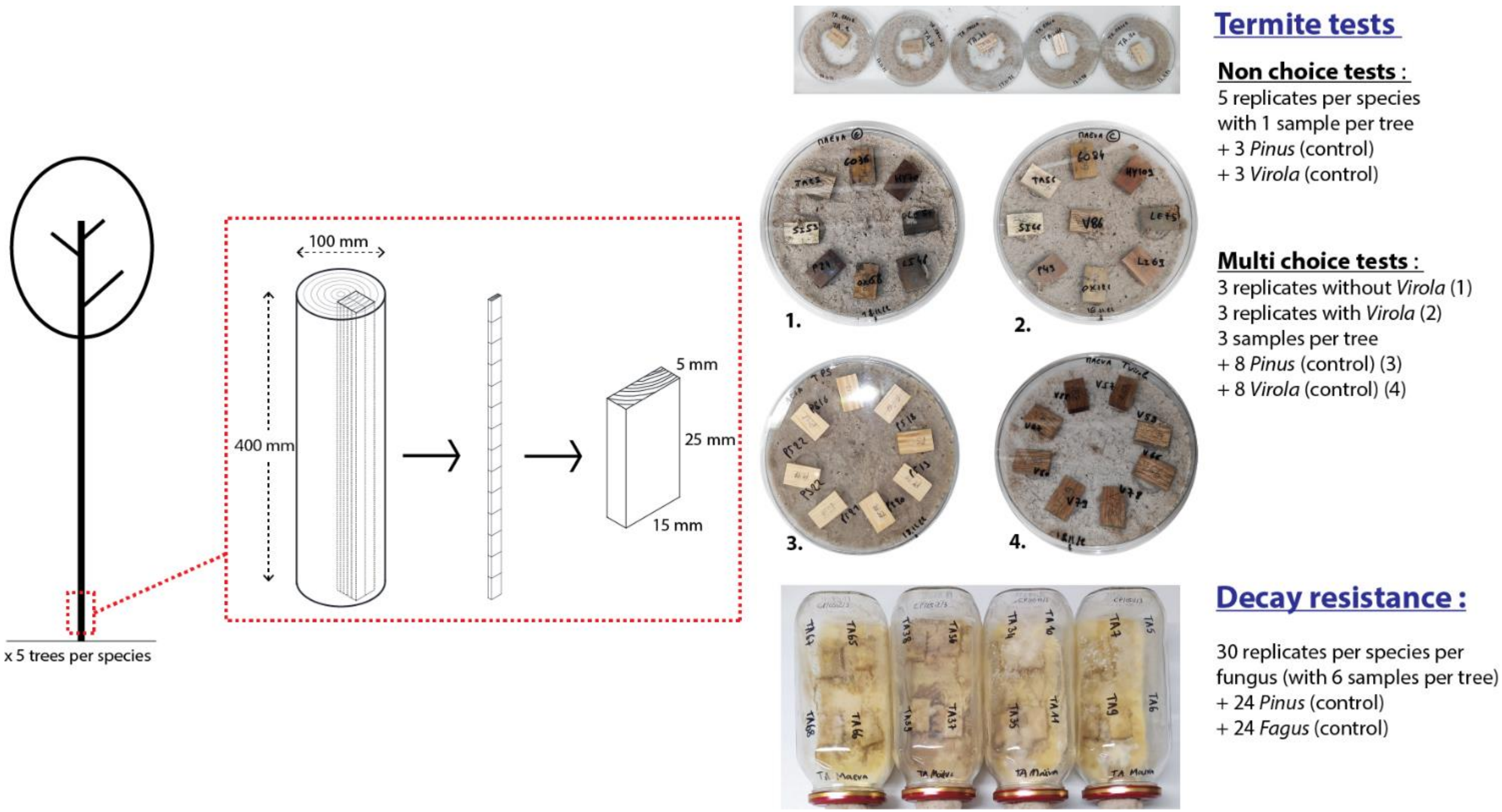


**Figure 2. Sampling plan for each tree and summary of required samples for each experiment (termite or decay tests). Five different trees per species were used to obtain a 40 cm-long stem per tree. 26 samples were cut in each stem, avoiding pith or knots, with dimensions 400 x 15 x 5 mm (L x R x T).**

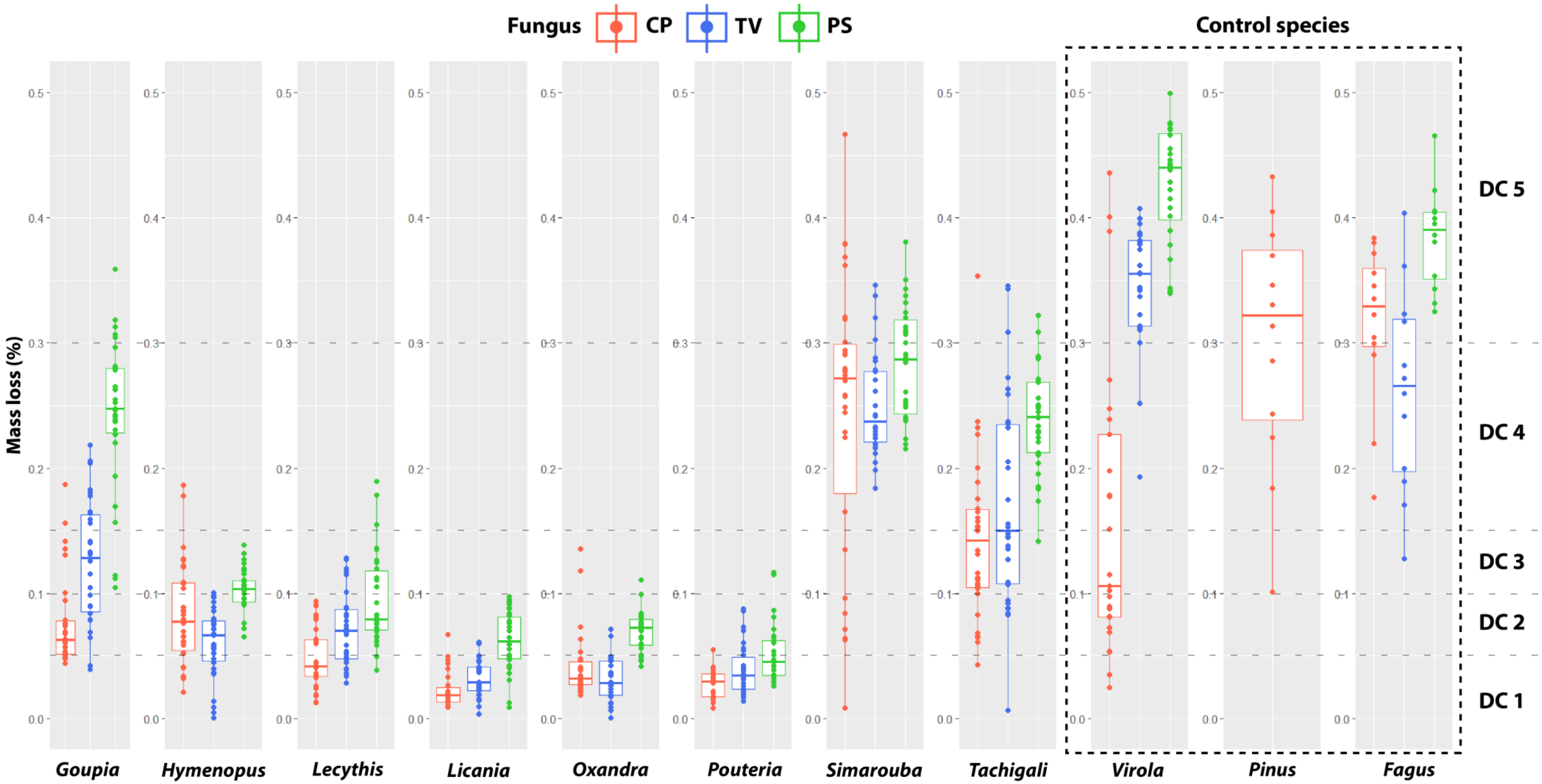


**Figure 3. Mass loss (%) and associated durability class (1 to 5) for all studied species after 8 weeks of exposure against *Coniophora puteana* (*CP*), *Trametes versicolor* (*TV*) (temperate rots) and *Pycnoporus sanguineus* (*PS*) (tropical rot).**

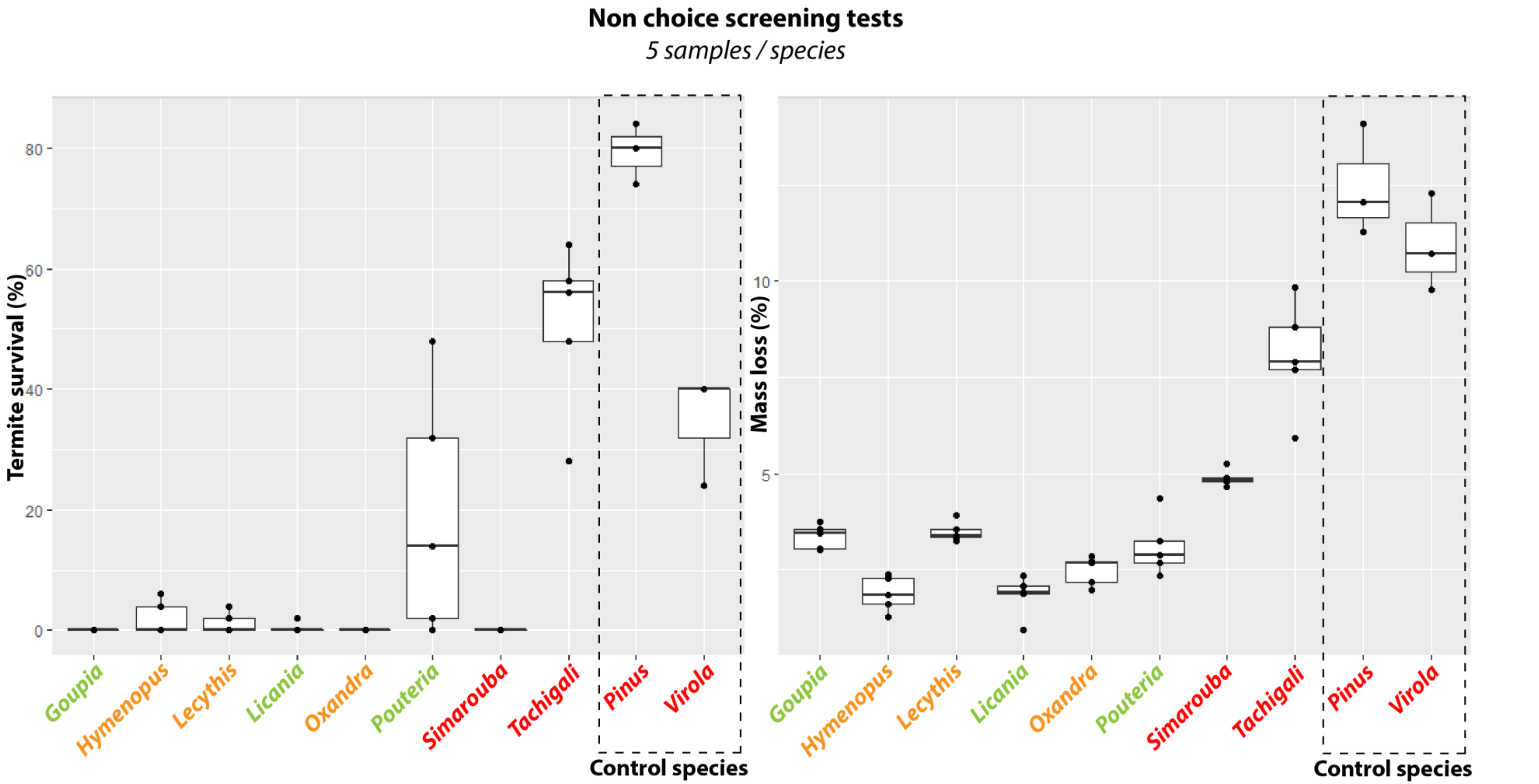


**Figure 4. Termite survival rates (TSR %) and mass loss (ML %) of the 8 tested species after 4 weeks exposure to *Reticulitermes flavipes* using non-choice tests. *Virola* and *Pinus* sapwood have been tested as virulence control samples. All the wood species were classified as durable (in green), moderately durable (in orange) or not durable (in red) to termites, according to the visual rating as specified in the EN 350 (2016).**

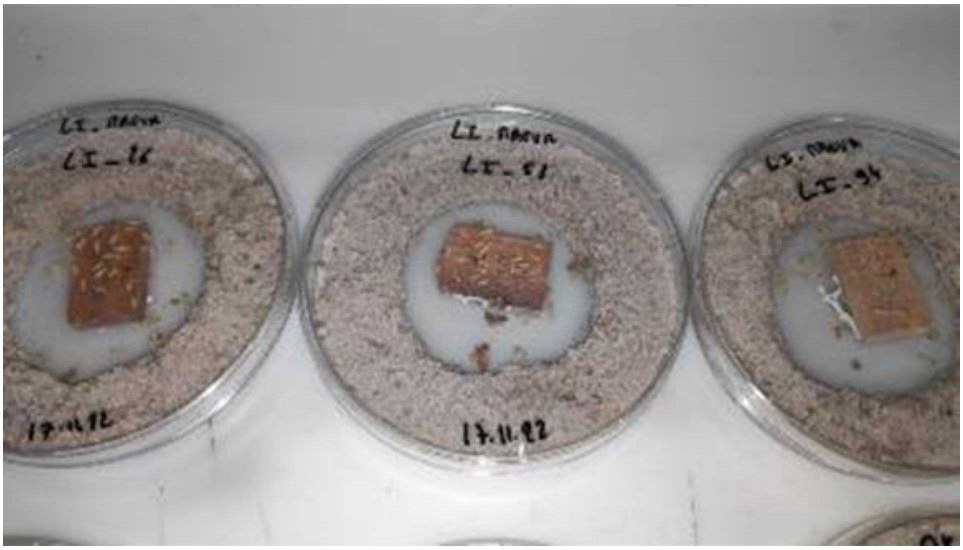


**Figure 5.** ***Licania*** **samples in termite resistance using non-choice tests. All the termites were gathering on top of the wood sample, staying motionless, for the whole duration of the test until they all died.**

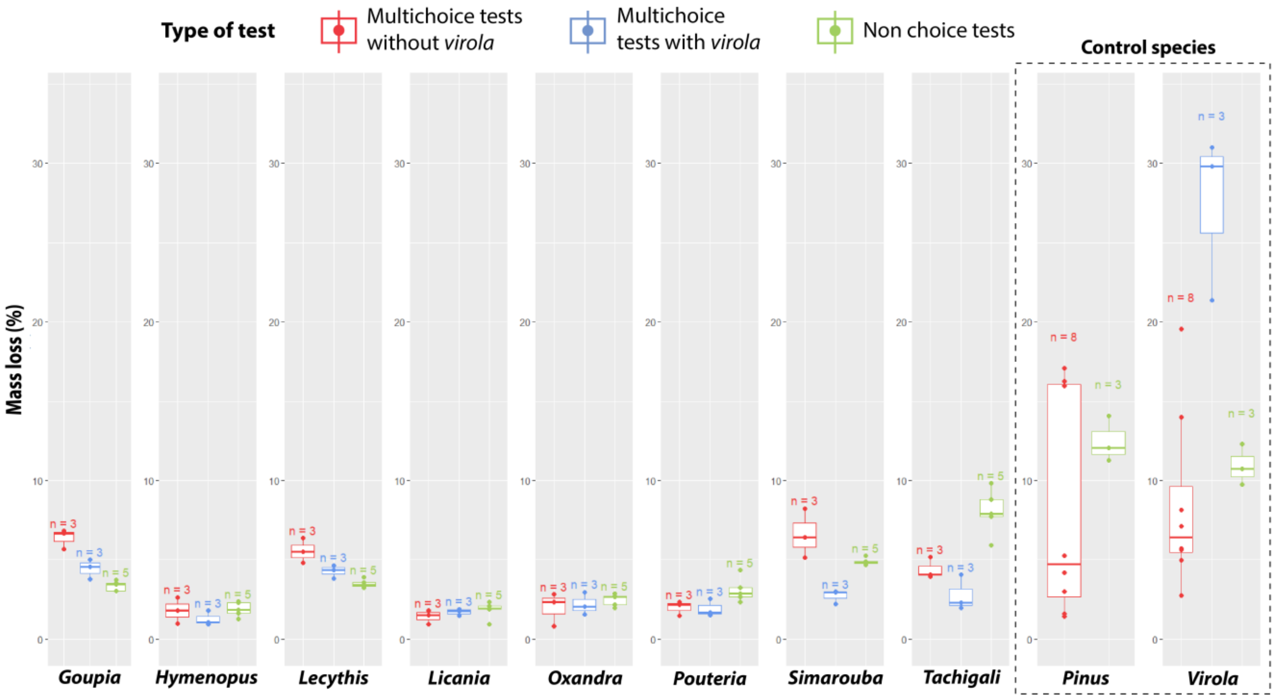


**Figure 6. Mass loss (%) per all studied species after exposure to termites in choice test without *Virola* (red), choice test with *Virola* (blue), and non-choice test (green).**

**Cover picture. (a) Fungal and (b) termites laboratory screening tests carried out on 8 Guianese wood species. © Kévin Candelier**