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Tree crown architecture: a tool for decay resistance evaluation

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ABSTRACT

The variability of natural durability contributes to the bad perception of some wood end-users. In our search, we need to adjust our methods and strategies to estimate natural durability and extract higher value from wood resources. Architectural analysis is essentially a detailed, multilevel, comprehensive and dynamic approach to plant development. Numerous biological process which impact some wood properties like durability are linked with tree development. A better understanding of the interelationship between tree physiology through tree achitecture analysis and natural durability could be an approach to predict this property. This study explore the relation between the crown architecture, decay resistance and wood extractives in *Dicorynia guianensis* in order to propose tree crown architecture as an evalution decay resistance tool.

Keywords: decay resistance, architecture, heartwood, wood extractives, crown

1. INTRODUCTION

Some tropical forest species have interesting characteristics like natural durability, which is an essential property for wooden constructions in situations with a high risk of fungus and insect infestations. However, different wood parts may not have the same natural durability due to the intraspecific variability in natural durability. We recently observed this variability in *Dycorinia guianensis* (Cesalpiniacae), an endemic tree species well represented in French Guiana forests. This species represents the largest part of the French Guiana wood production in a large range of use. It is the first commercial species (M. Bereau et *al*, 2000). The durability of the wood is known to be variable: durability class 1 to 3 (very durable to moderately durable ; Amusant, 2004). This high variability has a negative impact for the end- users which could focus on other materials than wood although its better ecological interest.

In all cases, the variability of natural durability is due to extractives synthesized during heartwood formation (Taylor *et al*, 2002). Heartwood formation is an important physiological process in perennial plants as trees. It is the ultimate process leading to the death of living sapwood tissues due to internal phenomenon depending on the cycle of tree life involving both water mechanical gradients. So factors influencing the allocation of resource between the different compartments of tree could have an impact on extractives synthesis (Taylor *et al*., 2007).

Some authors showed the station effect on wood durability which could be due to soil properties (Kokutse, 2009). Genetic factors also could not be excluded since different provenances of a given species may have different response to edaphic parameters (Fries et *al*., 2000; Erickson *et al*, 2001). Growth dynamic parameter plays also an important role in the wood durability (Taylor *et al*., 2003), and it is also influenced by the local conditions (Thulasidas *et al*, 2006). Finally, tree crown architecture that could be could be considered as an integrative response of the tree individual to local conditions, is showed to be indicative of tree growth dynamic (Rutishauser et *al*. 2010). So we may think that the tree crown architecture considered at an individual level could be a suitable indicator of tree wood quality, and natural wood durability particularly.

The main topic of this study is to gain a better overall understanding of the heartwood formation dynamic in relation to decay resistance with *Dicorynia guianensis* though an architectural consideration of the crown structure in different individuals.

Architectural analysis of plant (Nicolini and Chanson 1999; Lauri and Kelner 2001 ;Hallé and Oldeman 1970; Hallé et al. 1978; Edelin 1984; Barthélémy et *al*. 1989, 1991) can highlight the different ontogenetic stages of development from germination to mature stages. This analysis consists of a structural description of individuals that have reached various stages of development in differing environments (gap or understorey conditions for example). This approach involves an a posteriori reconstitution of the crown development of each individual, based on the consideration of different parameters as main branch number (also called “reiterated complexes”, Hallé *et al.* 1978) and main branch mortality. Several methods were proposed to predict wood decay resistance. Some of them are based on an indirect measure of wood extractives content: colorimetry (Kokutse, 2006; Thusalidas *et al*, 2006), near-infrared spectroscopy with Teak (Ballères *et al*., 2000; Alves *et al.* 2012). The aim this study was to propose the crown architecture analysis with Dicorynia guianensis, as a tool for decay resistance evaluation.

2. EXPERIMENTAL METHODS

This study was conducted in the Paracou experimental station (5°18'N; 52°23'W) (O.Flores et al., 2006), setting in 1984, in French Guiana. Paracou is located in 40 km West of Kourou, on the coast. The climate is equatorial he two main seasons: dry season, from August to December and a rainy season, from December to June. Annual precipitation: 3041mm (Gourlet-fleury et al, 2004). The primary forest is composed with 550 wood species with a high specific diversity (140 -200 species by hectare) and the main family are : Lecythidaceae (17%), Chrysobalanaceae (14%), Caesalpiniaceae (13%) (Sabatier and Prévost, 1990; Favrichon, 1995; Molino and Sabatier, 1999).

2.1 Field sampling

The selection of the trees was oriented in order to obtain a wide variability of the heartwood and sapwood area: same ontogenic stage, same class of diameter (25 – 30 cm) but with different architectural characters which reflect difference in development dynamic of the trees. These parameters are: height of tree, Breast height diameter (cm), crown position (location of an individual live crown in relation to the surrounding overstory canopy), size of crown, number of main branch, presence of liana.

2.2 Heartwood sapwood determination

A disc was preleved at breath height for each tree and it was polished until the annual rings were clearly determined and scanned. The heartwood radius (HR, cm), sapwood width (SW, cm), xylem radius (HR+SW) were measured from 18 radial directions of each discs and averaged. The sapwood and heartwood proportion were determined according to the section at 1.30m.

2.3 Sampling for decay test and wood extractives contents

The sampling was carried out directly after harvest. Two twins boards were sawn from each tree, including sapwood and outermost heartwood (60 x 50 x 620 mm T, R, L). "A" boards for decay tests and "B" boards for wood extractives content tests. For the two measurement properties, A and B were divided in fives zones: outer sapwood, inner sapwood, sapwood-heartwood boundary, outer heartwood, inner heartwood.

2.3 Decay tests

2.3.1 Sampling Material

These bioassays allow us to study the decay resistance against soil microflora after 6 months exposure. For each radial position, 6 wood sample tests (2 x 10 x 100 mm, T, R, L) were longitudinally prepared and considered as replicate. The dry masses were measured for the entire wood sample tests after an exposition to 103°C in an oven. The wood samples tests were installed in contact with soil according to the procedure described by American Wood Protection Association with the standard method AWPA E14-07 (2007) in soil bed. Wood sample tests from *Virola michelli* a non durable species were used as control in order to control the virulence of soil microflora.

2.3.2 Extractives content

The wood samples tests from B board were directly stocked at – 18°C until the extraction procedure. The wood from each radial position et from each tree were ground to 0.5 mm of size of the particles in a Retsch SM 100. 1g of the sawdust from each radial position was extracted successively with ethyl acetate (technical grade) and methanol (technical grade) during 14 hours. The solvents were respectively evaporated by rotavapor. Three replicates were used for each radial position and each tree. The ethyl acetate and methanolic mean content were calculated in percentage of the dry mass (three replicates for each tree, each radial position and solvent).

3. RESULTS AND DISCUSSION

3.1 Dynamic of heartwood formation

Table 1 and Fig 1 show the characteristics of the different trees. The tree N°1 is from a plantation and showed an important crown (six main branchs), and the lager tree diameter. The proportion of heartwood (19%) is also the smaller. Some authors suggested that heartwood formation serves to regulate the amount of sapwood to a physiological optimum level (Bamber, 1976) following the pipe model theory relating sapwood area to foliage mass (Shinozaki, 1964). This phenomenon allows the tree to maintain balance between the conducting zone (sapwood) and the assimilation surface.

Tree n° 2, was also dominant with an important crown and presents high reiterated complex which characterizes a good development of the tree. The heartwood proportion is 23%. The Tree n° 3 showed a reduced crown due to a loss of primary branch (Fig 1). This tree was also covered with liana. In these conditions the proportion of heartwood is higher: 41% than Tree N°2.

Tree n°4, was dominant and subjected to an accidental event leading to a loss of a part of the crown. Due to these conditions, this tree presents the higher proportion of heartwood: (98%). Priestley (1932) and Harris (1954) suggest that entry and accumulation of air into the wood initiates the heartwood formation. The description of the tree architecture in relation to heartwood proportion confirms the variability of the dynamic of heartwood formation in *Dicorynia guianensis*. In conclusion, heartwood and sapwood content vary between and within species and have been related to growth rates, stand and individual tree biometric features site conditions and genetic control.

Tree	Crown position	Heartwood percentage (cm)	Main branch	Height (m)	Tree diameter (cm)	Particularity
Tree n° 1	Co-dominant (plantation)	19	6	26		/
Tree n° 2	Future dominant	23	1	35	31	/
Tree n° 3	Highly suppressed	41	4	27	29	liana
Tree n° 4	Dominant	98	0	18	34	liana

Table 1: Trees characteristics

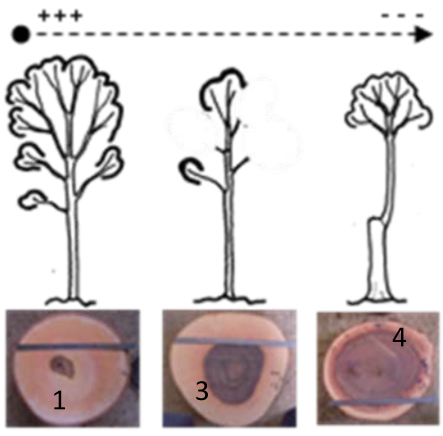

Figure 1: Tree description in relation to wood section

3.2 Decay resistance

The control wood samples from *Virola surinamensis* valids the bioassay, with a mean mass loss of 34% (±6.37). The Figure 2 shows decay resistance of the different part of the stem after 6 months exposure to the soil microflora. As expected, the heartwood is more resistant than sapwood due to the synthesis of extractives in the heartwood-sapwood boundary during heartwood formation. These metabolites are implied in the decay resistance. We can observe that there is a relation between the decay resistance of wood tissue and the crown architecture which gives information about the dynamic development of the tree. With the most recent heartwood (outer heartwood) we observed the following decay resistance ranking: tree N°4 >tree N°3 > Tree N° 2 > Tree N°1. Tree with high development dynamic are less resistant. The Tree N°4 is the most resistant; the accidental wound triggered the heartwood formation with a consequence: improvement of decay resistance. This event caused an activation of secondary metabolite pathways (Magel *et al*, 1994, Niamké *et al*, 2012). There is also a gradient of decay resistant in the sapwood but there is no relation between tree development and decay resistance.

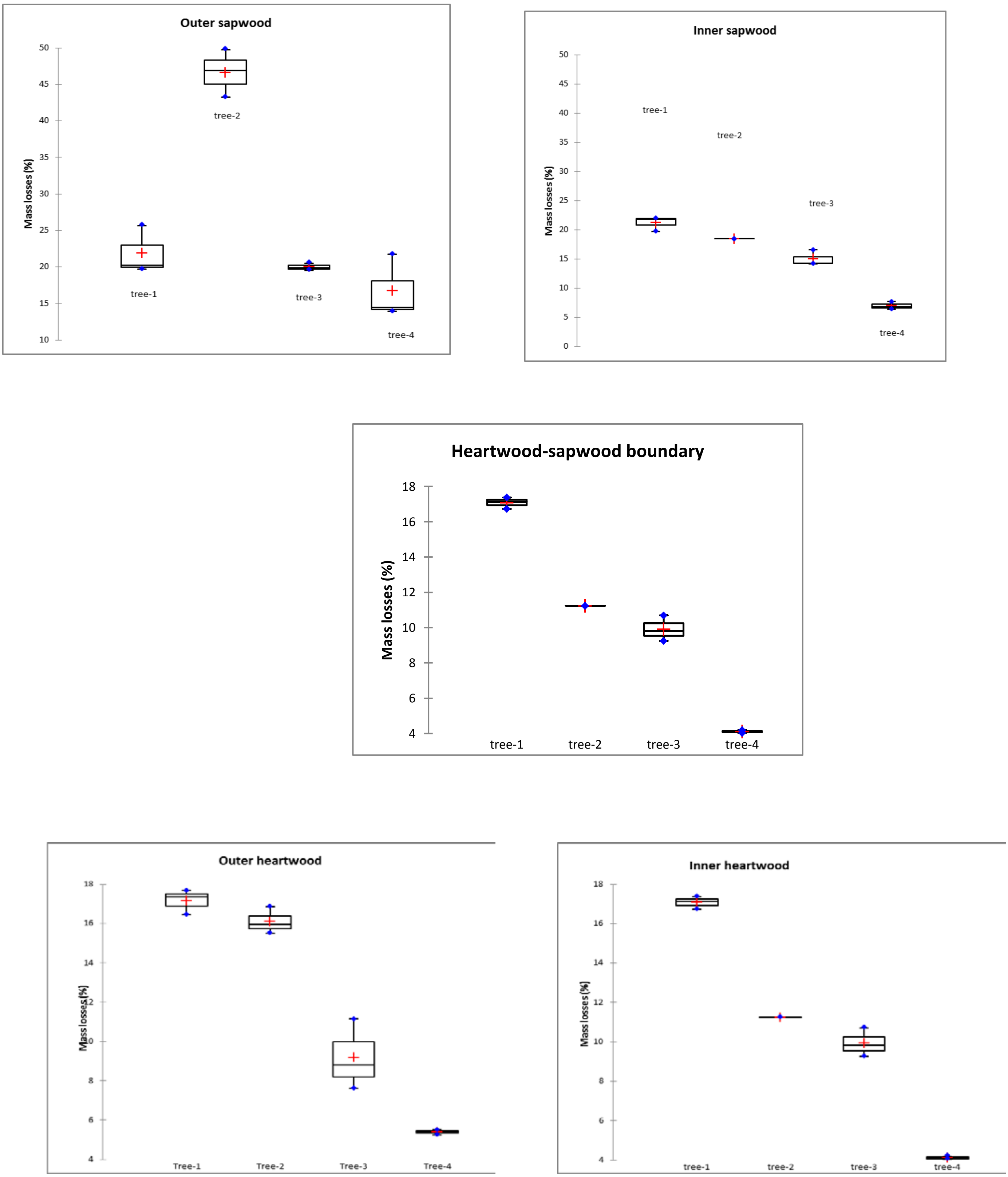

Figure 2: Mean mass losses according to the different radial position (outer heartwood, inner heartwood, transition zone, outer heartwood, inner heartwood)

3.3 Wood extractives content

We determined the content of acetate and methanolic extracts with all the trees except the tree n° 1. The Fig. 3 shows the relation between wood extractives and decay resistance. The tree N°4 showed the highest content of extractives comparatively to the Tree N°2 and N°3. Tree N°4 which presents a loss of a part of the crown has synthetized higher proportion of wood extractives. There is a correlation between the decay resistance and the content of extractives (respectively R^2 = 0.54; R^2= 0.49): higher is the content of extractives higher is the decay resistance of the wood against soil microflora. Several study showed the role of extractives in decay resistance and their synthesis is activated during heartwood formation (Niamké *et al*, 2012). The heartwood of species having naturally durable wood contains extractives that prevent attack by wood destroying insects and fungi (Hillis 1987). The amount of extractives present in heartwood varies within and among individual trees. Because sapwood extractives differ from heartwood extractives, it is assumed that extractives in senescing sapwood also contribute to the formation of heartwood extractives (Hillis 1987).

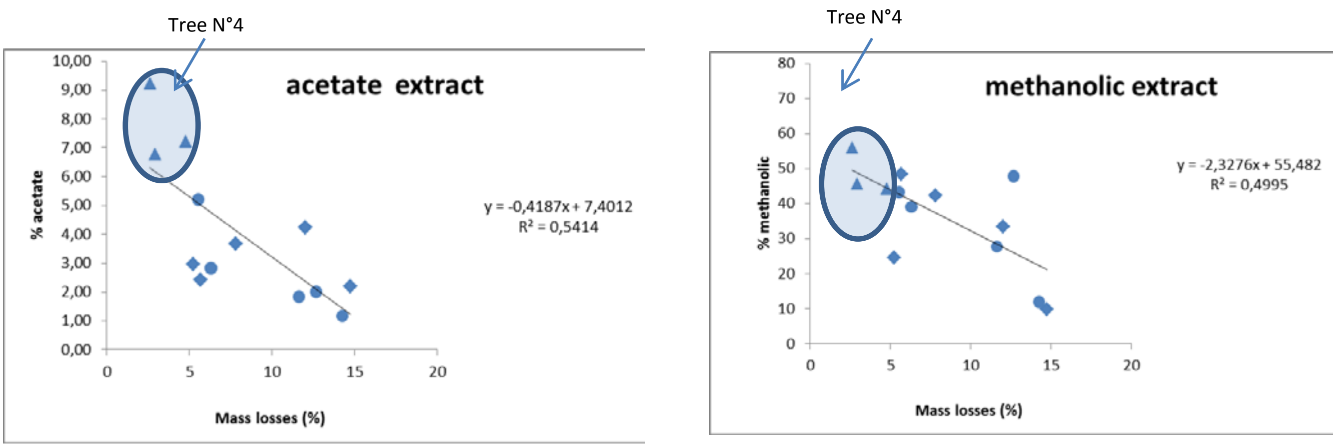

Figure 3: Correlations between heartwood extractives and decay resistance in the outermost heartwood (♦Tree 2 ; ● Tree 3 ; Δ Tree 4).

4. CONCLUSION

This study allows to show that crown architecture could be used to evaluate de decay resistance in *Dicorynia guianensis*. Tree characterized with high dynamic of growth presents small proportion of heartwood. This observation is particularly important because the proportion of sapwood is quality criteria for wood industry. These first results showed also that the relation between decay resistance and the crown architecture analysis have the potential to enable to classify standing timber based on tree architecture study : higher is the growth development, lower is the decay resistance and the content of extractives. Nevertheless, for an application it is necessary to extend the study with an important sampling.

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