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Methodology for Internal Damage Percentage Assessment by Subterranean Termites in Urban Trees

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Abstract
One of the most important problems in urban trees is termite infestation. Simple observations of damages on outside trunks or dead branches and leaves do not always confirm infestations. Several trees may present severe termite damage internally that can only be observed through drilling. This paper presents a methodology to evaluate estimated percentages of internal damage caused by termites in urban trees. Tests were made on 1,477 plants in a neighborhood in the city of São Paulo, Brazil and 27% of them were infested by subterranean termites. The results showed that the methodology is simple to use, fast and inexpensive, and it allows assessment of termite internal damage which may help in making decisions on tree management. The trees did not show any phytosanitary problems along the 9 year study after being submitted to the new technique.

Introduction

Problems associated to urban trees are common and are mostly caused by inadequate management (Jim, 2001; Rodrigues et al., 2002; Nowak & Dwyer, 2007). Lack of planning to choose suitable plant species to the site, lack of knowledge on plant biology and physiology, lack of care when transplanting the trees, lack of space for plant growth, drastic pruning, infestations by wood boring, sucking and defoliating insects, termites, ants, besides plant diseases, and negligence are some of the problems that make urban trees die early (Zorzenon & Potenza, 2006).

Tree survival in different environments depends on the mechanical reliability of its structures, and problems in the trunk may cause falling risks followed by serious or fatal accidents (Niklas, 1992, Mattheck & Breloer, 1997; Pereira et al., 2007). Infestations by subterranean termites are common in Brazil (Constantino, 2002) and promote damping off, especially when attacks occur in street trees.

Studies have evaluated methods for assessing termite infestations in trees. Mattheck and Breloer (1994) developed a method called visual tree assessment (VTA). If symptoms are detected the related defect has to be confirmed and measured by deeper inspection, which includes measuring the speed of a sound wave traveling through a cross-section on the trunk and by drilling methods. The strength of the remaining healthy wood is determined with a fractometer. Lax and Osbrink (2003) refers to other nondestructive methods using a resistograph. Nicolotti et al. (2003) reported application of electric, ultrasonic, and georadar tomography for detection of decay in trees and their comparison with the penetrometer. Mankin et al. (2002) used a portable, low-frequency acoustic system to detect termite infestations in urban trees. The likelihood of infestation was rated independently by a computer program and an experienced listener that distinguished insect sounds from background noises. Mankin and Benshemesh (2006) used a geophone system to monitor activity of subterranean termites and ants in a desert environment with low vibration noise.

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Therefore, the methodology must be used in quiet environments due to its sensibility and it is not adequate to urban environments.

Pereira et al. (2007) reported that nondestructive techniques have been developed by tomography investigations, where the impulse tomography enables transversal section reconstructions of the whole tree, through the energy that flows through the wood. However, they advise that the technique is still under development and needs further study. Osbrink and Cornelius (2013a) as well as Osbrink and Cornelius (2013b) on the other hand used an acoustic emission detector (AED) to evaluate the presence of termite infestations in trees and could determine the presence of the insects.

Since termite damages are common, pest control operators should have a range of methods which can be chosen for each condition. This paper proposes a simpler methodology for tree assessment to estimate the percentage of internal damages caused by subterranean termites in urban trees that could be used worldwide.

Material and Methods

The study was conducted from January 2004 to January 2013, in a neighborhood with 1,609 plant specimens, including trees and palm trees along eight kilometers of streets and avenues, in the city of São Paulo, Brazil (S 23º 35' 34.72" / W 46º 41' 57.60"). We identified 1,339 trees and 138 palm trees, totaling 1,477 plant specimens to test the proposed methodology.

Steel drills, measuring 6 mm diameter by 200 mm in length, and 10mm diameter by 320 to 400mm in length, normally used to drill wooden stakes and fiber cement tiles, were used with single or triple ends. A professional hammer driller (Bosch GSB 19-2 Model 650-watt) and an electric/gasoline generator (Branco Model BT2 950) were also used.

Small drills were used on trees with the Circumference at Breast Height (CBH) smaller than or equal to 40cm and the larger ones for the trees with CBH greater than 40cm. The CBH was measured at 1.30m height from the base of the plant (Daniel, 2006). All plants were georeferenced.

After perforation, holes were painted with Bordeaux mixture (copper sulfate, hydrated lime and water), and sealed with silicone rubber to prevent penetration of moisture and the entry of plant pathogens.

A borescope, which is a micro camera attached to a 6mm flexible stem joined to a LCD monitor, was used to visualize internal damage caused by termites, and to check for the presence of live termites inside the trunk of the trees.

To determine the size and exact location of the termite damage in the inner region of the trunk, three holes (n) were drilled at a 45 degree angle into the base of the trees to establish triangulation points (Fig. 1 – wider arrows). The intention was to reach the deepest regions of the heartwood for inner exploration to confirm termite infestations that are not externally visible, and to estimate the percentage of damage. The percentage of internal damage ranged from 0% (no damage) to 90% (extensive damage); this range was used to determine the correlation between CBH and percentage of internal damage.

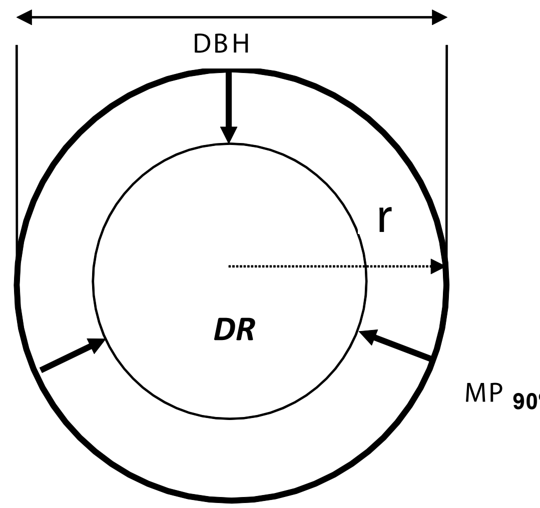

Figure 1 **-** Schematic cross section of tree trunk showing *DBH*, *r, DR*, and $MP_{90º}$ Holes drilled are indicated by wide arrows.

Termite assessments were conducted in 2004. Infested trees and palm trees were controlled, and plants were individually inspected each month during the nine year study to determine if the technique caused any other damage to the trees.

Estimated percentage of internal damage

To obtain the estimated percentage of internal termite damage a methodology was developed for assessing and adapting trigonometric formulas for converting values into percentage estimates of internal damage.

Percentage estimates were obtained by measuring the depths penetrated by the drills, to evaluate the difference in strength of a healthy tissue of the trunk (high resistance) to a termite-damaged tissue (low resistance) or hollow (no resistance). The estimated average was obtained from the sum of the three depth measurements.

Once the angle of the drill relative to the tree trunk is 45 degrees ($DP_{45º}$), the mean obtained values from the three holes were converted to the following formula to obtain $MP_{90º}$ (average measured depth of the drill at 90 degrees):

$$\boldsymbol{MP}_{\mathbf{90º}} = \frac{\left(\dfrac{\Sigma DP45º}{n}\right)}{\sqrt{2}}$$

$\boldsymbol{MP}_{\mathbf{90º}}$ = average measured depth of the drill at 90 degrees
$\boldsymbol{DP}_{\mathbf{45º}}$ = diagonal depth of the drill at 45 degrees
$\boldsymbol{n}$ = hole number

For those results of depth measurements in which the drill did not hit any cavity, the number to be considered in the sum of DP_{45^o} should be a value obtained through $r.\ \sqrt{2}$.

For practical purposes it was assumed that the cross section of the trunk was a circular shape. It was also assumed that the transverse extent of internal damage was circular in shape. Therefore, to make the calculations of estimated percentages of internal damage, it is necessary to first obtain the trunk diameter:

CBH = Circumference at Breast Height (1.3 m)
DBH = Diameter at Breast Height (1.3 m)
π = 3,1416
r = radius of the circumference
PD = % of internal damages
DR = trunk damaged region

For obtaining the diameter:

$$DBH = \frac{CBH}{\pi}$$

Subsequently determine the radius of the circle:

$$r = \frac{DBH}{2}$$

Subtracting the *MP90º* (average measured depth of the drill at 90 degrees) of *r* (radius of the circumference), an estimated value of the injured area is obtained, where:

$$DR = r - MP90^o$$

Thus, to obtain the estimated percentage of the injured area (*PD)*:

$$PD = \frac{DR.100}{r}$$

Results and Discussion

According to Juttner (1997) unique observations of external damage, such as tunnels, do not correspond to real termite infestations on urban trees. Numerous trees, apparently healthy, have serious internal damage that can only be determined after drilling.

The survey on the 1,477 plants revealed 27% (399) trees infested by subterranean termites. The practical methodology presented here proved to be feasible both in operational terms, regarding the use of low cost tools, and reliability when compared to the reported difficulties using other methods (Lax & Osbrink, 2003). Tomography, for example, is a noninvasive way to assess internal injuries caused by termites in trees (Pereira et al., 2007). Although technologically superior, the equipment has high cost (ca. US$ 12,500.00) and must be calibrated according to the density of the wood, what makes operating it in the field difficult and time consuming. The methodology used in this work costs approximately US$ 550.00.

The procedure used during this nine year study did not promote significant lesions on the assessed trees, and there were no interferences due to phytosanitary aspects. The injuries due to the holes drilled in the trees did not lead to diseases, and there was satisfactory healing after some months. It was not observed any tree death or impoverishment due to the adopted procedure. It is suggested that once the termite infestations are found trees must be treated, but trees with more than 60% of damages must be cut off, once they have risk of falling down.

The mathematical formulas for data conversion and obtention of internal damage estimated percentages were developed to be simple and easy to understand. They have the advantage of being easy to use by properly trained technicians.

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