Wood decay diagnostic of *Joannesia princeps* Vellozo at Bali Botanical Garden using arborsonic acoustic 3D tomograph

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Abstract. Living collection such as tree in botanical garden has hazard risk. Tree hazard risk must be evaluated to give safety for visitor and employee. However, standing tree with decay wood inside is often the cause of tree failure. Internal tree defect such as wood decay cannot be seen only from visual investigation but must be done with ArborSonic acoustic tomograph to get accurate result. The objective of this research was to diagnostics wood decay in the stand of *Joannesia princeps* Vellozo tree using visual investigation and ArborSonic measurement technology. The result shows *Joannesia princeps* has severe damage cause of wood decay especially in the base of the trunk. Wood decay percentage range from 21-49%. The alleged caused of this damage is stem borer and termites. This information give advantage for Bali Botanical Garden manager to minimize this tree hazard risk by doing activity such as crown pruning, give hazard risk tree sign to limit activity around this tree and do pest management.

1. Introduction
Public safety is the important point for visitor to enjoy botanic garden. Tree failure often leads to personal injury or property damage on private or public land. However, standing tree with decay wood inside is often the cause of tree failure [1]. Moreover, non-destructive testing methods to understand the locating and quantifying wood decay and defect are needed to promote public safety. Stress wave method has been commonly used to assess internal tree condition [2]. Stress wave velocity measured in trees has also been found effective to detect moderate to severe decay in Cibodas and Bogor botanic gardens [3,4,5]. ArborSonic 3D acoustic tomograph is one example of non-destructive commercial equipment [2].

Stress wave is a sound wave produced manually, in a complex mixture of frequencies from hammer tapping on one pin to each other pin, that are inserted into the bark. Detecting decay using stress wave method is based on the observation that stress wave travels slower in decayed wood than in sound wood. By using multiple transducers, stress wave computed tomography technology has been developed, where an increase in the number of installed transducer and high frequency can give more accurate information on decays [1].

*Joannesia princeps* Vellozo (Euphorbiaceae) is a tree widespread in Brazil where it grows up to 50 m high [6]. This tree is one of Bali Botanical Garden (BBG) collection which has vulnerable status [7]. Vulnerable status means this tree is not include in endangered and critically endangered status but in future, this species facing risk of extinction in the nature [8]. This tree has several functions such as the leaves have shown antibacterial, antioxidant and anti-inflammatory activities [9], meanwhile the seed
exhibits laxative effects and has been used in many regions of Brazil as laxative [10]. *Joannesia princeps* also a pioneer tree which has potency for carbon offset plantations in degraded area and has percentage of survival rate more than 50% [11]. However, this tree collection comes from Brazil and only one planted in XIIIM at BBG [12]. This tree also located on highly visited area. Therefore, the aim of this research was to assess wood decay of *Joannesia princeps* standing tree by using acoustic tomograph of ArborSonic

2. Materials and Methods

This study was conducted in June 2020 on standing tree of *Joannesia princeps* at Bali Botanic Garden. The tree has 22 m height, 12 m diameter of crown, 73.6 cm of DBH (diameter at breast height) and three main stems branch. The equipment used is a set of ArborSonic equipment (sensors, hammers, Amplifier boxes and computers connected to ArborSonic), tape diameter, roll meter 30 meters, digital cameras. The structural tree stability was evaluated based on visual observation and acoustic tomograph of ArborSonic 3D Acoustic Tomograph (Fakopp Enterprise, Agfalva, Hungary). Visual observation of the condition of tree trunks was also done by looking at the outermost trunk of the sample tree, especially to see whether there were any symptoms or signs of deterioration on root, trunk and crown. To get accurate information about tree health conditions, visual observation was done by a minimum of four person.

Further assessment of internal trunk defect using a tomograph was conducted with ArborSonic 3D. The step to use ArborSonic 3D were: (1) drive eight sensors perpendicular to the trunk with the equal distance in counterclockwise order; (2) connect the sensors to the amplifier boxes then connect the amplifiers in a line. Connect the battery box on any end of line then connect to PC; (3) each sensor was tapped with a steel hammer to generate sound waves; (4) the software was calculated and displayed the internal sound-velocity distribution of the tree. To get accurate information about internal trunk condition, it is important to assess the tree in several layers. Tomogram result were showed in graphics with green color showed intact, red color showed decayed and blue color showed hollow tree.

The information of several layers proportion area was used to analysis the volumetric content with the cross-sectional area multiplied by based height as the calculation cylinder volume, so there are three layers can be calculated by:

\[ V = \Delta h_{1-2} \left( \frac{A_1 + A_2}{2} \right) + \Delta h_{2-3} \left( \frac{A_2 + A_3}{2} \right) \]  

where: \( V = \) Volume; \( \Delta h = \) interval high, \( A= \) area several layer class, with knowing delineation area of the segmen (hollow, decayed and intact), this math can calculate the several volume portion of class.

ArborSonic measurement results determine the type of tree handling. Trees with a high priority will get immediate treatment and special treatment (regular monitoring) compared to trees with low priority. Trees with high priority are trees located in areas that are densely populated, have large trunk diameters, are aged, or are seen to be attacked by pests and diseases [3]. The level of tree risk is obtained from the maximum percentage of decay level. A decayed area is the percentage of an area of decay compared to the total area of the selected layer

3. Results and Discussion

The results of the visual investigation to detect wood decay at *Joannesia princeps* shows that tree has three branches with cavity on the base trunk, the crown and the root intact. One branch already fallen several years ago (Figure 1a). The cavity already filling with cement to avoid fallen tree, but unfortunately one of the branches still fallen in June 2020 (Figure 1b).
Figure 1. Tree hazard risk on Joannesia princeps. Picture taken in December 2019 (a) failure tree leads to property damage in June 2020 (b).

ArborSonic 3D is used for advance wood decay detection. To get accurate information about internal tree condition several layers with different height already done. The blue colour mean hollow, the red color mean decay and the green color mean intact. Hollow still found from height 107 cm until 258 cm, only the defect size decreases as the height increase (Figure 2). Table 1 show the percentage of wood decay decrease as the height increase. Since ArborSonic only determine decay percentage per layers (Figure 2,3), volumetric calculation will support information about tree volume. This tree has the percentage hollow area 12.7% and the decaying area 32.3%. The severe defect found in the base of the trunk because this already make cavity. This can be derived that tree has high risk potentially.

Figure 2. Tomogram of Joannesia princeps on different height (a) 107 cm, (b) 182 cm and (c) 258 cm.
Figure 3. Tomogram vertical layers of *Joannesia princeps*

Table 1. Decay percentage with ArborSonic measurement on *Joannesia princeps*

| Layer | Height (cm) | Decay (%) |
|-------|-------------|-----------|
| 1     | 107         | 49        |
| 2     | 182         | 27        |
| 3     | 258         | 21        |

3.1. Identification of *Joannesia princeps* stem damage

Based on observations, the most severe tree damage occurred at the base of the trunk, as shown in Figure 4a. From that picture, it appears that almost half of the base of the stem has been damaged. The damage to the base of the stem of *Joannesia princeps* is thought to be caused by a pest, that is stem borer and termite. Although at the time the data was collected, no pests were found, but the alleged cause of damage to the base of the stem was obtained from the presence or trace of the existence of stem borer and termites. Symptoms of attacks caused by stem borer are the presence of small holes in the main stem section as shown in Figure 4b and 4c. Stem borer larvae attack cambium and xylem areas, which can cause plants to wither, dry and die [13]. While the symptoms of termite attacks are evidenced by the discovery of the termite house attached to the bark. Termites use wood as nesting sites and food sources, thus causing damage to wood [14]. Furthermore, termite attacks generally occur at the root, neck, or stem [15]. The attack on the trunk is marked by the existence of a tunnel that runs along the gap of the bark to the end of the trunk, as shown in Figure 4d.
Figure 4. Severe tree damage at the base of the trunk (a), the presence of small holes in the main trunk (b), the location of small holes (c), the tunnel a tunnel that runs along the gap of the bark to the end of the trunk (d).

Furthermore, to prevent the negative effect of tree hazard risk, BBG management give sign tree hazard risk on the trunk and do crown pruning to prevent the visitor and the employee from tree hazard. Moreover, the existence of stem borer and termites must be minimized by doing pest management.

4. Conclusion
Visual investigation and ArborSonic acoustic tomograph shows Joannesia princeps has serious wood decay. Internal decay in standing tree will affect structural safety. The percentage of wood decay range from 21%-49%. It shows the severe damage found on the base of the trunk. This information help BBG management to determine tree’s treatment. The alleged cause of damage was stem borer and termites which need further research.

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