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Detection of acoustic velocity and electrical resistance tomographies for evaluation of peripheral-inner wood demarcation in urban royal palms

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ABSTRACT

The material properties and thickness of peripheral wood of royal palms have significant impacts on in-situ structural safety. Stress wave velocity (V) and electrical resistance (ER) tomograms were detected in royal palms (*Roystonea regia*) for understanding the soundness and standard values of the peripheral region. The position of the peripheral-inner wood demarcation was measured using drilling resistance profile from living trees and the corresponding V and ER of the peripheral-inner wood boundary was acquired respectively from V and ER maps. The two parameters V and ER of the peripheral-inner wood demarcations were linearly related to the results obtained from tomogram. Furthermore, the positions of the peripheral-inner wood demarcation were determined by corresponding V and ER, and the critical V and ER can be established by average V and ER of tomographic data. The experimental results from this study indicated that V and ER tomogram techniques can be employed to determine the position of the peripheral-inner wood boundary and can serve as a technique to determine the structural stability status of living palms.

Introduction

Concerns for public safety and urban forest conservation strongly support the development and application of rapid and precise diagnostic techniques for detecting decay and other types of structural defects in trees (Wang and Allison, 2008). Standing trees must be evaluated in order to maintain in-situ structural safety. Various nondestructive evaluation (NDE) techniques have been employed to detect decay in trees in order to identify hazardous trees. NDE is the science of identifying physical and mechanical properties of a piece of material without altering its end-use capabilities and then using this information to make decisions regarding appropriate applications (Pellerin and Ross, 2002).

Visual tree assessment (VTA), a systematic method of tree assessment using biological and biomechanical indicators to evaluate overall vitality and structural integrity of a tree, includes visual inspection of the tree to look for external evidence of internal defects, instrumental measurements of internal defects and evaluation of the residual strength of the wood (Mattheck and Breloer, 2003). Arboriculturists consider VTA an essential practice, which serves as the starting point for evaluating tree defects and providing basic information of tree growth performance and stability. Gruber (2008) indicated that tree breakage depends on many features of tree, including its height, width of crown, crown architecture, crown density in branching and leaves, form, condition, physical wood properties, and species. The loads exerted by wind, rain, and snow, either singly or in combination, are also concerned.

Acoustic wave evaluation measurements of wood have proven to be effective parameters for detecting and estimating deterioration in tree stem and wood structure (Lin et al., 2000, Pellerin and Ross, 2002). NDE techniques have been developed for tomographic investigations (Rinn, 1999). Acoustic tomographic measurements in wood have been found to be effective in detecting and estimating decay in tree stems (Gilbert and Smiley, 2004; Bucur, 2005; Wang et al., 2007, 2009; Deflorio et al., 2008; Lin et al., 2008, 2013; Wang and Allison, 2008). Acoustic tomography has been proven to be an effective technique for detecting internal decay, locating the defects, and estimating their size, shape and characteristics. In addition, because location of decay is more important in terms of strength loss than just the size of decay, sonic tomography allows to determine relative strength loss (Rinn, 2011).

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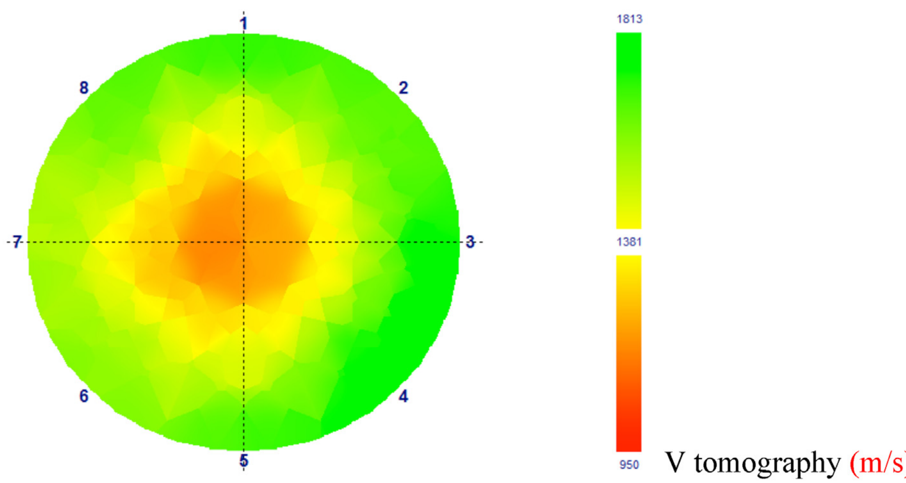
Many diagnostic devices such as penetrometer (e.g., resistograph), acoustic detector, electrical conductivity meter and fractometer are available for detecting internal decay and other defects in living trees (Larsson et al., 2004; Lin et al., 2012). Electrical resistance (ER) measurements were related to the occurrence of both discolored and decayed wood in red spruce (*Picea rubens* Sarg.), balsam fir (*Abies balsamea* (L.) Mill.), Norway spruce (*Picea abies* (L.) H. Karst.), and eastern red cedar (*Juniperus virginiana* L.) (Shortle and Smith, 1987, Larsson et al., 2004, Shortle et al., 2010). Electrical resistivity tomography can be used as a nondestructive technique for evaluating standing trees, discolored wood, decay, and roots (Bieker and Rust, 2010a,b). Thus, ER tomogram is valuable and has been employed to measure tree vigor (vitality) or pathology (injury).

In a royal palm tree, the peripheral (shell) region of several centimeters thick comprises high-density area while the inner region of low-density area lies in the cross-section (Rinn, 2013a,b). The properties (quality) and thickness (residual wall) of the peripheral wood in royal palm is very important for tree structural safety and hazard evaluation (Lin et al., 2011). However, the position and standard value of the peripheral-inner wood demarcation were not identified but estimated by stress wave velocity (physical) and electrical resistance (pathological) values. This study aims to resolve the efficiency of stress wave tomography and electrical resistance maps in accurately detecting and identifying the peripheral-inner wood demarcation in royal palms. Relationship between *V* and ER values and the peripheral-inner wood demarcation in *V* and ER maps are investigated. Also, tables of standard values for future application of this method for royal palm tests are presented.

Materials and methods

The experiment was carried out in situ on 19 royal palms in Tainan, Taiwan. Multiple stress wave measurements (Fakopp



(a)

		1633	1655	1666	1650		
	1620	1544	1475	1505	1580	1640	
1536	1543	1434	1320	1359	1479	1614	1660
1506	1429	1307	1206	1242	1380	1580	1704
1514	1409	1288	1203	1245	1384	1595	1745
1539	1499	1402	1339	1370	1528	1692	1753
	1561	1503	1479	1513	1647	1745	
		1580	1629	1661	1697		

V mapping grids (m/s)

(b)

Fig. 1. (a) Stress wave velocity (*V*) 2D tomogram and (b) corresponding *V* calculated for every grid square in royal palm (no. 24).