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Evaluation on Fallen Trees of *Hesperocyparis guadalupensis* (S.Watson) Bartel and *Pavetta* sp. in Bali Botanic Garden Based on Visual Assessment and Acoustic Tomography

Evaluasi Kondisi Pohon Tumbang Hesperocyparis guadalupensis (S.Watson) Bartel dan Pavetta sp. di Kebun Raya Eka Karya Bali Berdasarkan Penilaian Visual dan Teknologi Tomografi

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ABSTRACT

The health of fallen tree collection, especially which has not been assessed yet, has to be evaluated in order to understand its cause. This study aimed to see the health conditions of Hesperocyparis guadalupensis and Pavetta sp. *and the causes of fallen trees. The identification of tree health was done visually with a modified Tree Risk Assessment (TRA) form from the International Society of Arboriculture (*ISA*). Meanwhile, the internal examination used ArborSonic 3D Acoustic Tomograph. The tomogram results showed a hole in the tree trunk. The cause of the fallen trees was predicted due to structural damage with wind factors*

INTISARI

Koleksi pohon yang sudah tumbang terutama yang belum pernah diperiksa kesehatannya perlu dievaluasi kesehatannya untuk mengetahui penyebab tumbangnya. Tujuan dari penelitian ini yaitu untuk mengetahui kondisi kesehatan *Hesperocyparis guadalupensis* dan *Pavetta* sp. dan penyebab pohon tumbang. Identifikasi kesehatan pohon dilakukan secara visual dengan menggunakan form *Tree Risk Assessment* yang sudah dimodifikasi dari International *Society of Arboriculture* (ISA), sedangkan pemeriksaan internal menggunakan ArborSonic 3D Acoustic Tomograph. Hasil tomogram menunjukkan adanya lubang didalam batang kedua pohon. Penyebab tumbangnya kedua pohon itu diduga karena kerusakan struktur pohon disertai hembusan angin.

Introduction

Bali has a tourist attraction both for foreign tourists and local tourists because the area has a unique natural and cultural beauty that makes many tourists visit. The Eka Karya Bali Botanic Garden, located in Tabanan Regency, Bali, is an attractive tourist attraction as well as a plant conservation institution that combines botanical research, plant conservation, education, and recreation. Eka Karya Bali Botanic Garden is located at an altitude of 1250-1450 above sea level, with an area of 157.5 hectares. The number of tourists who visit varies every year. In 2015 tourist visits reached more than 500,000 visitors and at the end of 2017, there were 1,269,711 visitors. Eka Karya Bali Botanic Gardens reopened in July 2020 after the COVID-19 pandemic subsided; visitors were limited to 1,500 people per day inside the object (Nusa Bali 2020).

As a conservation institution, Eka Karya Bali Botanic Garden has a collection of 2,473 plant species and more than 20,000 specimens (Registrasi 2021). The plant collection consists of trees, shrubs, shrubs, herbs, aquatic plants, and vines. The Eka Karya Bali Botanic Garden was established on July 15th, 1959 with the collection mostly the old trees with the age more than 50 years old. These old trees are susceptible to fall (Raihandany & Kurniawati 2016) since the internal condition. Trees with unhealthy conditions tend to be easy to fall which can threaten the safety of their surroundings (Nandika et al. 2020). For that reason, the tree inspection should be carried out on the trees especially in locations where many people pass over and near valuable properties.

At the beginning of 2021, two trees collection were fallen, i.e., *Hesperocyparis guadalupensis* (S.Watson) Bartel and *Pavetta* sp. Unfortunately, the two trees have not been inspected yet for their condition. Obtaining the information why the trees can be the fall was necessary to evaluate and anticipate the same condition. This information can help the management of Eka Karya Bali Botanical Gardens in handling collections especially for the same trees species of *H. guadalupensis*, which belongs to the Cupressaceae family. This tree species is endemic to Mexico, precisely on the island of Guadalupe. The conservation status of *H. guadalupensis* according to the International Union for Conservation of Nature (IUCN) is Endangered (EN) which means its existence is threatened with extinction (https://www.iucnredlist.org/). The wood of this species is of good quality, equivalent to the quality of spruce wood, so it is estimated that it is suitable for buildings/ infrastructure that requires high strength such as boards, bridges, tower poles, and construction materials. This causes *H. guadalupensis* wood to have a high economic value (Bektas & Kurt 2010). Meanwhile *Pavetta* sp., a tree species from the Rubiaceae family has not yet been identified.

Tree inspection as part of the tree health examination was usually carried out visually to have the physical condition of the tree. The form that can help in tree inspection is the Tree Risk Assessment Form from the International Society of Arboriculture (ISA) which has been modified. Meanwhile, the internal inspection of tree trunks use non-destructive commercial equipment, namely the ArborSonic 3D Acoustic Tomograph (Hanum et al. 2020). Arborists have long used visual inspection to examine the external condition of the tree in order to provide information regarding the condition of the inside of the tree and the stability of the tree structure (Matheny & Clark 2009). While, the Arborsonic 3D Acoustic Tomograph can detect the condition of the inside of the tree. Testing with non-destructive technology is developed to identify tree health internally without causing damage to the inspected tree, and without interfering with the tree's metabolic function. This study aimed to examine the health

condition of *Hesperocyparis guadalupensis* and *Pavetta* sp. and find out the causes of the fallen trees.

Materials and Methods

The research was conducted at the Bali Botanical Gardens from January to February 2021. The samples observed were two fallen trees, i.e., *Pavetta* sp. in plots X.A and *H. guadalupensis* in plots XIII.E. The equipments used were a set of ArborSonic 3D Acoustic Tomograph Equipment (sensor, hammer, and a computer connected to ArboSonic), roll meter (20 m), digital camera, GPS, and Microsoft Excel 2016. Visual observations of tree conditions were carried out using a modified Tree Risk Assessment from the International Society of Arboriculture (ISA). This form was modified in terms of the parameter consist of the utilization rate, topography, soil condition, wind exposure, crown density, branching type, and branch covering. The morphological characters of the trees observed were tree height which measured by a roll meter, and diameter at breast height (DBH) which was measured by a roll meter. The DBH value can be obtained by measuring the circumference of the stem at a height of about 130 cm which is then divided by phi (3,14) to have the diameter. The visual observations were done on the top to the bottom of the tree as well as the observation in rotating 360° to look the detailed condition of the tree. The visual data obtained are then given a score according to the scoring in table 1. The category of low-risk trees are pointed by a total score in a range of 7 to 11, trees with moderate risk of damage have scored in a range of 12 to 16, while trees with high risk are in a range of 17 to 21 (Hanum et al. 2020).

The ArborSonic 3D tomograph was started by preparing the equipment including a laptop to record data. Determining the starting point of the layer which will be inspected is an important step which continued by measuring the height of the first layer. The stem circumference of each the observation height were measured using a roll meter. Eight sensors was mounted perpendicular to the tree trunk; the distances between sensors were recorded in order and put in anticlockwise direction. The sensors were then connected to the amplifier box in a row in succession which then connected to the battery box and to the PC. Each sensor was then tapped using a steel hammer to generate sound waves. The color image was obtained as the result of the sound waves data processing by the software in the tool. The tomogram results are displayed in graphical form and featured, with green color indicating intact, red indicating weathering, and blue indicating hollow tree. An accurate assessment of the internal condition of the tree will be more effective by conducting several layers of testing (Hanum et al. 2020). In this study, the internal examination was carried out on the two main stems in a tree because they had a codominant stem type. Acoustic tomography tool revealed categorization of tree-level damage. Tree with high category damage were pointed

Table 1. Scoring for *Tree Risk Assessment Form* (Hanum et al. 2020)
Tabel 1. Penentuan skor *Tree Risk Assessment Form* (Hanum et al. 2020)

Parameter	Score = 1	Score = 2	Score = 3
Occupancy rate	Rare	Frequent	Continuous
Topography	Flat	Slope < 45°	Slope > 45°
Soil condition	Friable	Partially aggregated	Fully aggregated
Wind exposure	Protected	Partial	Full
Crown density	Rare: 1-33%	Normal: 34-66%	Dense: 67-100%
Branching type	Normal	*Codominant*	Twin
Branches covering	No cover/moss only/ epiphyte/liana	Moss+epiphyt/moss+ liana/epipyht+liana	Moss+epiphyt+liana

by the percentage of decayed wood above 60%, the medium category with the percentage of rotted wood between 30-60%, and damage in the low category if the percentage of weathered wood is below 30% (Helmanto et al. 2018).

Result and Discussion

Visual Tree Assessment

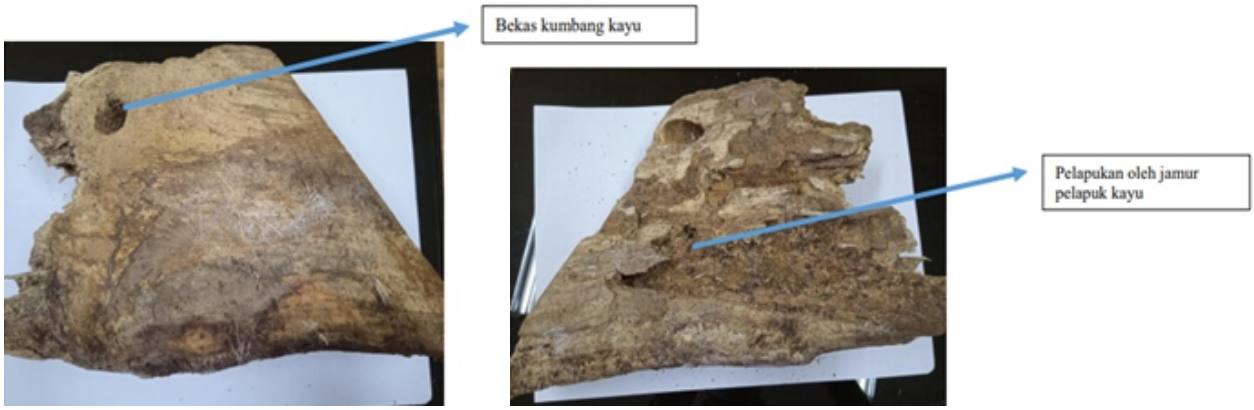
The results of visual assessment showed that *H. guadalupensis* with 12 m tall and a DBH of 70.5 cm had codominant branches (forking branches), branch covered by moss and epiphytes, and trunk condition seemed in good condition (Figure 1a). There were no visible signs of damage to those two fork branching. There were no indication of a stressed physical condition of the tree, except of tree canopy looked asymmetrical. It seemed there was in root problem since it was seen that the roots did not have primary roots with a depth of up to 180 cm (Figure 1a).

Another tree of *Pavetta* sp. species had a tree height of 21 m with a DBH of 58 cm. There was a normal tree branching type with a branch covered by mosses and epiphytes (Figure 1b). The surface of the bark, especially at the base, possessed many holes with diameter about below than 1 cm (Figure 2a) that were presumably as the entry points for insects. There were no borer insects on the logs when the inspection, but it seemed any traces decayed. The overall health of the tree (vigor) is low and the leaves underwent chlorosis. Damage to the leaves can occur due to local or systemic symptoms expressed by plants due to pests and diseases (Tsani & Safe'i 2017).

A hollow at the base of the trunk was found around the root collar in *Pavetta* sp. fallen tree. The hollow trunk was presumably caused by the insect borer which commonly attacks the trunks of Rubiaceae trees, namely Xylosandrus spp. These insects attacked weathered tree trunks and burrow trunks close to the soil surface (Egonyu et al. 2017). The sample examination results of *Pavetta* sp. which was sent to the Cibinong Advanced Characterization Laboratory - LIPI Integrated Bioproducts Laboratory and found traces of wood beetles (Figure 2a). Besides that, wood rot fungi were also found in the sample (Figure 2b). Decayed wood is very likely to occur at the base of the stem of Pavetta sp. due to the humid location of the botanical gardens which has wet condition. Eka Karya Bali Botanical Garden has temperatures ranging from 18-20°C and humidity of 70-90% (Darma et al. 2021). This condition is similar to the Cibodas Botanical Gardens so it has the potential to be a driver of fungal growth that can cause

(a) (b)

Figure 1. Fallen tree condition of *Hesperocyparis guadalupensis* (a) and *Pavetta* sp. (b).
Gambar 1. Kondisi pohon *Hesperocyparis guadalupensis* (a) dan *Pavetta* sp. (b) yang tumbang



(a) (b)

Figure 2. Wood sample with hole as a beetle bite marks (a), wood sample with decayed condition (b) in *Pavetta* sp.
Gambar 2. Sampel kayu yang memperlihatkan adanya bekas lubang gigitan kumbang kayu (a), ampel kayu dengan bekas pelapukan (b) pada *Pavetta* sp.

weathering of living trees (Raihandany & Kurniawati 2016).

The results of visual examination based on the Tree Risk Assessment (TRA) form showed that the risk of *H. guadalupensis* and *Pavetta* sp. have a low category (Table 2). Low category risk applies when the consequences are "negligible" and the probability is "impossible". Trees with this level of risk are still recommended for maintenance and mitigation that does not cut trees (Smiley et al. 2012)

Tree Health Check Using Arborsonic 3D Acoustic Tomograph

The limitation of thevisual inspection was unable to detect any damage that had occurred within the tree trunk. Therefore, it needs to be supported by internal examination tool such as using Arborsonic 3D acoustic tomograph. The internal examination results showed the blue color region in tomogram result that indicated hollow in the two stems of *H. guadalupensis*. The appearance in outside part showed tree in good visual condition. This result points out the importance to look internal condition when there is a doubt on the internal condition as our tree inspected of *H. guadalupensis*. In visual inspection, the base part of the trunk seemed to look good (Figure 1a.), but further inspection using Arborsonic showed indication holes appear (Figure 3a and 3b.) as represented in blue color in the section of layer 1 and 2 at 50 cm and 150 cm, respectively. After the one of the branches was cut, it can be seen that the inside of the

Table 2. Visual scoring for tree health
Tabel 2. Penentuan skor kesehatan pohon secara visual

Species	*Parameter*	*Category*	*Score*
Hesperocyparis guadalupensis	Occupancy rate	*Frequent*	2
	Topography	*Flat*	1
	Soil condition	*Friable*	1
	Wind exposure	*Partial*	2
	Crown density	*Codominant*	2
	Branching type	*Moss+epiphyt*	2
Total score			10
Pavetta sp.	Occupancy rate	*Rare*	1
	Topography	*Flat*	1
	Soil condition	*Friable*	1
	Wind exposure	*Partial*	2
	Crown density	*Normal*	1
	Branching type	*Moss+epiphyt*	2
Total score			8

Table 2. Visual scoring for tree health
Tabel 2. Penentuan skor kesehatan pohon secara visual

Species	Layer 1 height (cm)	% Damage	Layer 2 height (cm)	% Damage	% Max Damage
Hesperocyparis guadalupensis	50	52	150	35	52
(Codominant branch)	50	63	180	26	63
Pavetta sp.	20	32	90	1	32

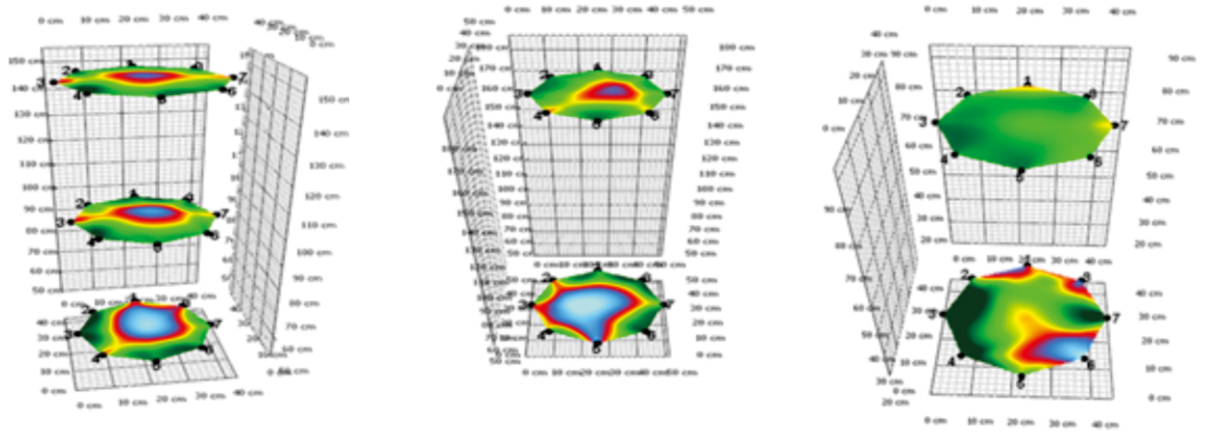


Figure 3. Tomogram first branch *H. guadalupensis* (a), second branch *H. guadalupensis* (b), *Pavetta* sp. (c).
Gambar 3. Tomogram cabang pertama *H. guadalupensis* (a), cabang kedua *H. guadalupensis* (b), *Pavetta* sp. ©.

tree trunk has no holes but found the rot condition. This difference in results might be due to differences in the selection of species from the Arborsonic software, even though the selection of species has been based on the same of wood density tree species. The stem damage of *H. guadalupensis* was greatest in the rootstock and less in the scion of the tree. Meanwhile, the internal inspection results of *Pavetta* sp. showed a hole at the base of the stem (Figure 3c.). After the tree was cut, it can be seen that the inside of the trunk has a hole in the base of the trunk. Based on the category of Helmanto et al. (2018), the category of damage to *H. guadalupensis* was high, while *Pavetta* sp. was classified as moderate (Table 3).

The cause of the fallen *Hesperocyparis guadalupensis* tree is probably contributed by an asymmetrical canopy, shallow roots, windy and wind exposure. Matheny & Clark (2009) reported that most tree failures occur when it is windy. *H. guadalupensis* has an asymmetrical canopy that affects the stability of the tree when receiving partial wind exposure because the tree is not protected by tall trees around it, thus making the tree easy to fall. The shape of the roots also affects the risk of falling trees. Trees with taproots have a lower risk of falling than fibrous roots (Suripto & Aksari 2020). *H. guadalupensis* does not have a taproot so it has a higher risk of falling. Meanwhile, the cause of the collapse of *Pavetta* sp. was presumably due to weathering at the base of the stem. Upright trees with rotting wood inside are often the cause of tree failure (Goh et al. 2018).

Examination of the internal condition of the tree is carried out on several tree layers with different heights to get more accurate results. In general, the ArborSonic 3D Acoustic Tomograph can only detect the internal condition of the tree per layer which installed by sensors, not to detect the entire tree. The existence of hollow tree trunks can be caused by termites and borer pests, these animals usually enter through tree gaps that have previously been weathered due to being overgrown with mosses and epiphytes (Safitri et al. 2017). Trees that have holes

internally, especially at the base of the tree, must be given good treatment immediately to prevent the risk of falling trees. The greatest damage to the lower part of the trunk causes the tree to be more easily damaged and fall (Tsani & Safe'i 2017)

Conclusion

The visual assessment of *Hesperocyparis guadalupensis* and *Pavetta* sp. using scoring showed that those trees had a low risk, while the tomogram results showed the opposite. There was found holes in *H. guadalupensis* tree trunks with a high damage category of 52-63%, while the tomogram results of *Pavetta s*p. the percentage of damage is 32% in the medium category. The cause of the fall of *H. guadalupensis* might be due to shallow roots and asymmetrical canopy, while *Pavetta* sp. was presumably due to a hole at the base of the stem accompanied by weathering. This condition is exacerbated by the presence of wind gusts.

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