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Tree Health Assessment of Lauraceae Collections in Bogor Botanic Gardens using Forest Health Monitoring Method

Rizmoon Nurul Zulkarnaen*, Fitri Fatma Wardani, Prima Wahyu Kusuma Hutabarat, Irfan Martiansyah, Muhammad Rifqi Hariri

Research Center for Plant Conservation and Botanic Gardens, Indonesian Institute of Sciences (LIPI). Jl. Ir. H. Juanda No. 13 Paledang, Bogor, 16122, West Java, Indonesia
* Corresponding author. E-mail address: rizmoon.zulkar@gmail.com

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ABSTRACT

Bogor Botanic Gardens (BBG) is an ex-situ plant conservation area with thousands of plant collections. The trees of the Lauraceae in BBG experienced the highest number of deaths among other families. However most of them were categorized as young planting years (0-15 years). A tree health monitoring in the Lauraceae needs to be conducted to provide an overview, trend, and value of the level of damage. Forest Health Monitoring (FHM) method was carried out on two plots consisting of 149 trees. FHM can identify the types and levels of damage through monitoring and recording a series of tree damage. The results showed that among 149 trees, with 103 healthy, 9 lightly damaged, 10 moderately damaged, 15 heavily damaged, and 12 dead. The damage was primarily found in the stem (63 trees), the crown branch (51 trees), and the roots (13 trees). The severity of the damage was mainly at a mild level (0-19%). The cause of the damage is discussed. Further observations and frequent monitoring of the health of the Lauraceae need to be conducted by management to reduce the number of dead collections of the family.

1. Introduction

The existence of a botanical garden and plant collection in it has a significant value both from an economic, historical, and scientific point of view. A botanical garden is an ex-situ plant conservation area where the collection is documented and organized according to taxonomic, bioregional, thematic classification patterns, or a combination of the tree (President Regulation No 93 of 2011). Bogor Botanic Gardens (BBG), one of the leading sectors in botanical research and plant conservation activities, has maintained more than 12,000 plant collections (Ariati et al. 2019). Most of the plant collections in BBG are dominated by tree habitus. Therefore, their management and maintenance have their challenges (Ramdhani and Fatimah 2016).

Tree health of BBG collections decreases naturally with increasing the age of the plants. The increasing age of trees increases the risk of damage and death of the collections (Setyanti et al. 2020). Tree death generally begins with physiological damage due to biotic and abiotic factors arising from adverse reactions between plants and their environment (Tsani and Safe'i 2018). Damage can be seen through symptoms that appear, such as abnormal leaves, branches, and stems, and through signs of plant-disturbing organisms (Pribadi 2010; Tsani and Safe'i 2018). The damages that are not immediately detected and addressed will cause the tree to fall or die, which means economical and social losses (Abimanyu et al. 2019; Pertiwi et al. 2019).

The number of tree death cases in BBG has increased yearly (Setyanti et al. 2020), reaching 3.197 tree death cases of 113 tree families. The Lauraceae is one of the tree-habitus families with the most significant number of death cases compared to other tree collections (Setyanti et al. 2020). Therefore, it is necessary to detect and monitor the tree health of the Lauraceae in BBG, such as using the Forest Monitoring Health (FHM) approach (Mangold 1997). FHM is one of the progressive methods or procedures in assessing tree health and has been widely practiced globally (Pertiwi et al. 2019; Susilowati et al. 2018). The FHM method could identify the type of damage and disturbance through a series of monitoring and recording of tree damage (Abimanyu et al. 2019). This study aims to assess the level of damage to Lauraceae collections in BBG. This study is expected to be the basis for maintaining Lauraceae collections so that the handling of collection damage can be improved and the death rate of Lauraceae can be reduced.

2. Materials and Methods

2.1. Research Location

This study was conducted in February 2020 in Bogor Botanic Gardens (BBG). The Lauraceae collections were randomly distributed in the BBG, but two plots were designated explicitly as plots of the Lauraceae collection, which are plots XX.A and XX.B (**Fig. 1**). The number of Lauraceae has observed 149 trees in the two plots (**Table 1**). The method used followed the procedure of Forest Health Monitoring (FHM) (Mangold 1997). Detection of tree health conditions using the FHM method will provide data on the level of tree damage based on the type, location, and severity of damage (Mangold 1997; Susilowati et al. 2018).

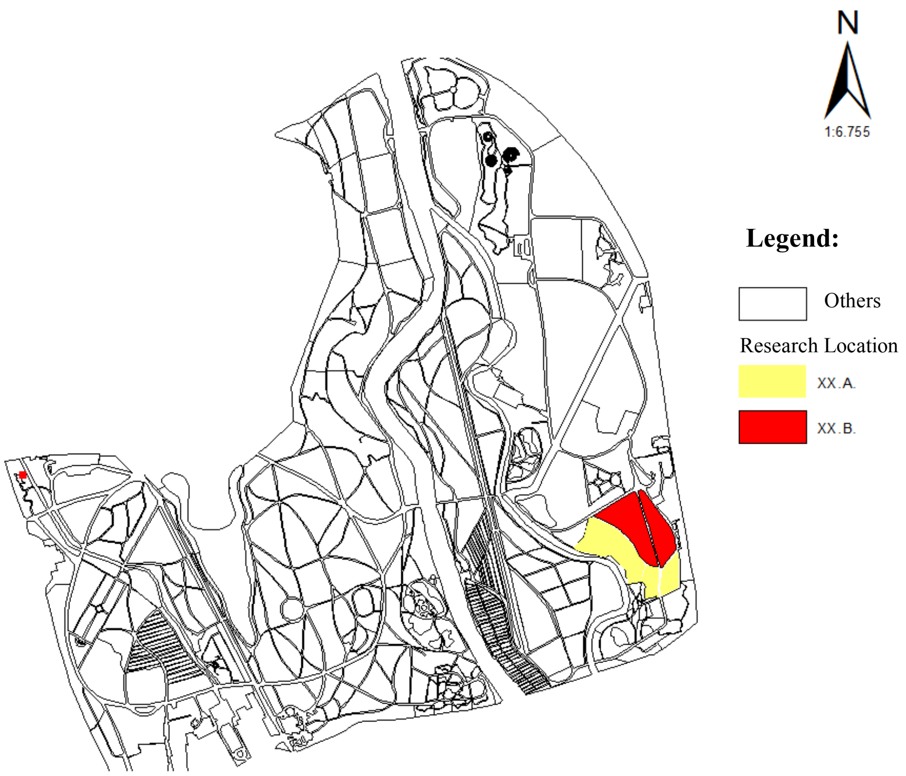

Fig. 1. Research location for the tree health monitoring of Lauraceae in Bogor Botanic Gardens.

Table 1. The Lauraceae collections in XX.A and XX.B

No	Species Name	Collection Number	Planting Year
1	*Endiandra macrophylla (Blume) Boerl.*	XX.B.209	2007
2	*Neolitsea cassiifolia* (Blume) Merr.	XX.B.276	2018
3	*Endiandra* sp.	XX.B.239	1913
4	*Eusideroxylon zwageri* Teijsm. & Binn.	XX.B.231	2012
5	*Cryptocarya* sp.	XX.B.278	2018
6	*lseodaphnopsis andersonii* (King ex Hook.f.) H.W.Li & J.Li	XX.B.251	2015
7	*lseodaphnopsis andersonii* (King ex Hook.f.) H.W.Li & J.Li	XX.B.251A	2015
8	*lseodaphnopsis andersonii* (King ex Hook.f.) H.W.Li & J.Li	XX.B.251B	2015
9	*Dehaasia sumatrana* Kosterm.	XX.B.252	2015
10	*Dehaasia sumatrana* Kosterm.	XX.B.252A	2015
11	*Dehaasia sumatrana* Kosterm.	XX.B.252B	2015
12	*Cinnamomum celebicum* Miq.	XX.B.253	2015
13	*Cinnamomum burmanni* (Nees & T.Nees) Blume	XX.B.254	2015
14	*Phoebe grandis* (Nees) Merr.	XX.B.92	1978
15	*Cinnamomum burmanni* (Nees & T.Nees) Blume	XX.B.254A	2015
16	*Litsea glutinosa* (Lour.) C.B.Rob	XX.B.25	1941
17	*Beilschmiedia* sp.	XX.B.258B	2015
18	*Beilschmiedia* sp.	XX.B.258A	2015
19	*Beilschmiedia* sp.	XX.B.258	2015
20	*Litsea firma* (Blume) Hook.f.	XX.B.257A	2015
21	*Litsea firma* (Blume) Hook.f.	XX.B.257	2015
22	*Litsea* sp.	XX.B.256A	2015
23	*Litsea* sp.	XX.B.256	2015
24	*Cryptocarya densiflora* Blume	XX.B.221	2009
25	*Cryptocarya ferrea* Blume	XX.B.222	2009
26	*Alseodaphne elongata* (Blume) Kosterm.	XX.B.219	2009
27	*Neolitsea cassiifolia* (Blume) Merr.	XX.B.217	2009
28	*Dehaasia incrassata* (Jack) Nees	XX.B.220	2009
29	*Beilschmiedia lucidula* (Miq.) Kosterm.	XX.B.223	2009
30	*Cryptocarya nitens* (Blume) Koord. & Valeton	XX.B.59	1971
31	*Litsea glutinosa* (Lour.) C.B.Rob	XX.B.62	1972
32	*Litsea glutinosa* (Lour.) C.B.Rob	XX.B.62A	1972
33	*Dehaasia caesia* Blume	XX.B.232	2012
34	*Cinnamomum javanicum* Blume	XX.B.235	2012
35	*Neolitsea cassia* (L.) Kosterm	XX.B.233	2012
36	*Litsea* sp.	XX.B.206	2007
37	*Dehaasia caesia* Blume	XX.B.248	2014
38	*Dehaasia caesia* Blume	XX.B.248A	2014
39	Lauraceae	XX.B.262	2016
40	*Neolitsea cassia* (L.) Kosterm.	XX.B.191	2004
41	*Neolitsea cassia* (L.) Kosterm.	XX.B.192	2004
42	*Cryptocarya costata* Blume	XX.B.194	2006
43	*Litsea* sp.	XX.B.170	2001
44	*Litsea* sp.	XX.B.170A	2001
45	*Cryptocarya* sp.	XX.B.72	1973

No	Species Name	Collection Number	Planting Year
46	*Cinnamomum* sp.	XX.B.149	1995
47	*Beilschmiedia* sp.	XX.B.116	2004
48	*Cinnamomum burmanni* (Nees & T. Nees) Blume	XX.B.142	1992
49	*Neolitsea cassiifolia* (Blume) Merr.	XX.B.33	1960
50	*Cryptocarya nitens* (Blume) Koord. & Valeton	XX.B.47	1965
51	*Cryptocarya nitens* (Blume) Koord. & Valeton	XX.B.47A	1965
52	*Litsea umbellata* (Lours.) Merr.	XX.B.67	1973
53	*Litsea* sp.	XX.B.244	2014
54	*Litsea* sp.	XX.B.244A	2014
55	*Litsea* sp.	XX.B.244B	2014
56	*Endiandra rubenscens* (Blume) Miq.	XX.B.247	2014
57	*Cryptocarya elliptifolia* Merr.	XX.B.226	2010
58	*Neolitsea* sp.	XX.B.249	2014
59	*Actinodaphne macrophylla* (Blume) Nees	XX.B.243	2014
60	*Cryptocarya diversifolia* Blume	XX.B.172	2002
61	*Cananga odorata* (Lam.) Hook.f. & Thomson	XX.B.20b	2017
62	*Cananga odorata* (Lam.) Hook.f. & Thomson	XX.B.20c	2017
63	*Cananga odorata* (Lam.) Hook.f. & Thomson	XX.B.20	1992
64	*Actinodaphne macrophylla* (Blume) Nees	XX.B.143	1976
65	*Litsea firma* (Blume) Hook.f.	XX.B.144	1992
66	*Machilus yunnanensis* Lecomte	XX.B.89	1976
67	*Litsea* sp.	XX.B.124a	2007
68	*Grevillea papuana* Diels	XX.B.148	2007
69	*Neolitsea cassia* (L.) Kosterm.	XX.B.146	1995
70	Persea sp.	XX.B.137	1995
71	*Cryptocarya diversifolia* Blume	XX.B.12	1995
72	*Litsea glutinosa* (Lour.) C.B.Rob.	XX.B.40a	1976
73	*Litsea monopetala* (Roxb.) Pers.	XX.B.269	2008
74	*Litsea monopetala* (Roxb.) Pers.	XX.B.270	2017
75	*Cryptocarya massoy* (Oken) Kosterm.	XX.B.141	1992
76	*Litsea firma* (Blume) Hook.f.	XX.B.82	2017
77	*Premna* sp.	XX.B.99	2017
78	*Premna* sp.	XX.B.99a	2017
79	*Cinnamomum sintoc* Blume	XX.B.202	2007
80	*Cinnamomum sintoc* Blume	XX.B.202a	2007
81	*Actinodaphne* sp.	XX.B.152a	1995
82	*Cryptocarya* sp.	XX.B.156	1995
83	*Cryptocarya* sp	XX.B.150	1995
84	*Beilschmiedia lucidula* (Miq.) Kosterm.	XX.B.83	1976
85	*Beilschmiedia lucidula* (Miq.) Kosterm.	XX.B.214	2008
86	*Cinnamomum camphora* (L.) J.Presl	XX.B.41	1991
87	*Litsea glutinosa* (Lour.) C.B.Rob.	XX. B.40	1960
88	*Neolitsea cassia* (L.) Kosterm.	XX.A.144	2017
89	*Neolitsea cassia* (L.) Kosterm.	XX.A.144A	2017
90	Neolitsea cassia (L.) Kosterm.	XX.A.144B	2017
91	*Cryptocarya* sp.	XX.A.136	2017

No	Species Name	Collection Number	Planting Year
92	*Cryptocarya* sp.	XX.A.136A	2017
93	*Cryptocarya* sp.	XX.A.136B	2017
94	*Cryptocarya* sp.	XX.A.137	2017
95	*Cryptocarya* sp.	XX.A.137A	2017
96	*Cryptocarya* sp.	XX.A.137B	2017
97	*Actinodaphne glomerata* (Blume) Nees	XX.A.129	2017
98	*Actinodaphne glomerata* (Blume) Nees	XX.A.129A	2017
99	*Actinodaphne glomerata* (Blume) Nees	XX.A.129B	2017
100	*Actinodaphne glomerata* (Blume) Nees	XX.A.129C	2017
101	*Eusideroxylon zwageri* Teijs. & Binn	XX.A.134	2017
102	*Dehaasia sumatrana* Kosterm	XX.A.138	2017
103	*Dehaasia incrassata* (Jack) Kostern	XX.A.140	2017
104	*Beilschmiedia kunstleri Gamble*	XX.A.124	2005
105	*Beilschmiedia kunstleri Gamble*	XX.A.124A	2005
106	*Eusideroxylon zwageri* Teijs. & Binn	XX.A.93	1984
107	*Eusideroxylon zwageri* Teijs. & Binn	XX.A.18	1930
108	*Litsea* sp.	XX.A.112	2002
109	*Litsea* sp.	XX.A.112A	2002
110	*Endiandra macrophylla* (Blume) Boerl	XX.A.109	1900
111	*Endiandra macrophylla* (Blume) Boerl	XX.A.109A	1900
112	*Cryptocarya crassinervia miq*	XX.A.102	1998
113	*Cryptocarya nitens* Koord. & Valeton	XX.A.105	1998
114	*Cinnamomum* sp.	XX.A.104	1998
115	*Endiandra macrophylla* (Blume) Boerl	XX.A.103	1998
116	*Endiandra macrophylla* (Blume) Boerl	XX.A.103A	1998
117	*Endiandra macrophylla* (Blume) Boerl	XX.A.103B	1998
118	*Cinnamomum iners* Reinw. ex Blume, Bijdr.	XX.A.99	1998
119	*Cinnamomum iners* Reinw. ex Blume, Bijdr.	XX.A.99A	1998
120	*Litsea oppositifolia* LS Gibbs	XX.A.107	1998
121	*Litsea oppositifolia* LS Gibbs	XX.A.107A	1998
122	*Endiandra macrophylla* (Blume) Boerl.	XX.A.55	1975
123	*Lindera aggregata* (Sims) Kosterm.	XX.A.126	2008
124	*Lindera aggregata* (Sims) Kosterm.	XX.A.126 A	2008
125	*Lindera aggregata* (Sims) Kosterm.	XX.A.126 B	2008
126	*Lindera aggregata* (Sims) Kosterm.	XX.A.126 C	2008
127	*Litsea* sp.	XX.A.133	2017
128	*Litsea firma (Blume) Hook.f.*	XX.A.132	2017
129	*Litsea* sp.	XX.A.131	2017
130	*Cinnamomum camphora* (L.) J.Presl	XX.A.62A	1965
131	*Litsea garciae* S.Vidal	XX.A.122	2005
132	*Cinnamomum camphora* (L.) J.Presl	XX.A.62	1965
133	*Beilschmiedia* sp.	XX.A.128	2017
134	*Beilschmiedia emarginata* (Meisn.)	XX.A.127	2017
135	*Cinnamomum celebicum* Miq.	XX.A.141	2017
136	*Cinnamomum celebicum* Miq.	XX.A.142	2017
137	*Litsea garciae* S.Vidal	XX.A.130	2017

No	Species Name	Collection Number	Planting Year
138	*Litsea garciae* S.Vidal	XX.A.130A	2017
139	*Dehaasia incrassata* (Jack) Nees	XX.A.139	2017
140	*Dehaasia incrassata* (Jack) Nees	XX.A.139A	2017
141	*Litsea garciae* S.Vidal	XX.A.123	2005
142	*Cinnamomum iners* (Reinw. ex Nees & T.Nees) Blume	XX.A.44.A	1930
143	*Actinodaphne glabra* Blume	XX.A.115A	2004
144	*Actinodaphne glabra* Blume	XX.A.115	2004
145	*Dehaasia incrassata* (Jack) Nees	XX.A.119	2004
146	*Dehaasia incrassata* (Jack) Nees	XX.A.120	2004
147	*Dehaasia incrassata* (Jack) Nees	XX.A.120A	2004
148	*Nectandra angustifolia* (Schrad.) Nees & Mart.	XX.A.96	1985
149	*Litsea glutinosa* (Lour.) C.B.Rob.	XX.A.75A	1972

2.2. Data Collection

The data was collected in the form of primary and secondary data. Primary data were obtained through direct observation and grouped into four age groups based on year of planting (YP), i.e.: (1) 0-15 years, (2) 16-30 years, (3) 31-60 years, and (4) ≥ 61 years. The parameters that were observed directly consisted of tree species and damage conditions. The types of damage observed in detail were the signs and symptoms that appear to determine the cause of the damage caused by physical factors (humans), fungi, and insects. If a sign of damage was found in insect attacks, the type of insect was identified.

The tree damage value variable comprises the damage location, type, and severity, categorized through coding and quality scores (x). The coding and quality scores for type (x) and severity (z) are shown in **Table 2**. Secondary data were taken from references to studies related to tree health previously carried out in BBG.

Table 2. Coding and quality scores for each location, type of damage, and severity (Mangold 1997)

Damage location code	Weight value of damage locations (x)	Damage type code	Weight value of damage types (y)	Damage severity code	Weight value of damage severity (z)
0	0	01, 26	1,9	0	1
1	2	02	1,7	1	1,1
2	2	03, 04	1,5	2	1,2
3	1, 8	05	2	3	1,3
4	1, 8	06	1,5	4	1,4
5	1, 6	11	2	5	1,5
6	1, 2	12	1,6	6	1,6
7	1	13, 20	1,5	7	1,7
8	1	21	1,3	8	1,8
9	1	22, 23, 24, 25, 31	1	9	1,9

Notes: Damage location: 1 = root, 2 = roots and rootstock, 3 = lower stem, 4 = stem bottom and top, 5 = stem top, 6 = head trunk, 7 = branch, 8 = buds and shoots, 9 = leaf; Damage types: 01 = cancer, 02 = konk, 03 = open wound, 04 = resinosis/gummosis, 05 = broken stem, 06 = termite nest, 11 = broken stem or root, 12 = brum on root or stem, 13 = broken/ dead root, 20 = liana, 21 = loss of dominant end dead end, 22 = broken or dead branch, 23 = excessive branching or brum, 24 = leaf buds or damaged shoots, 25 = leaves change color, 31 = others; Damage severity: 0 = 0-9%, 1 = 10-19%, 2 = 20-29%, 3 = 30-39%, 4 = 40-49%, 5 = 50-59%, 6 = 60-69%, 7 = 70-79%, 8 = 80-89%, 9 = 90-99%.

2.3. Data Analysis

Tree damage data processing is classified based on the value of the Tree Damage Index (TDI). There are four categories of tree damage based on the TDI calculation, namely: (1) healthy (0–5), (2) light damage (6–10), (3) moderate damage (11–15), and (4) severe damage (≥ 16).

$$\mathrm{TDI} = \sum_{i=1}^{n} (xi.yi.zi) \tag{1}$$

where *xi, yi,* and *zi* are the weight value of the location, type, and severity of tree damage, respectively.

3. Results and Discussion

3.1. Lauraceae Health Condition

The tree collection of the Lauraceae in the Bogor Botanic Gardens (BBG) consists of 17 genera, 84 species, and 860 collection trees (Ariati et al. 2019). The total tree collection of the Lauraceae that were planted in plots XX.A and XX.B is 149 trees. From the 149 Lauraceae collections, 36 trees have not been identified, while the remaining collection trees include 45 species that have been identified. In general, the Lauraceae collections has a healthy condition (**Fig 2a**). In addition, it was also known that the distribution of age groups based on the year of planting (AYP) of the Lauraceae in the plots was dominated by species with AYP of 0-15 years (**Fig. 2b**).

In detail, the number of collection trees in healthy condition was 103 trees, while those damaged were 34 trees. There were 9 trees lightly damaged, 10 trees moderately damaged, 15 trees heavily damaged, and 12 trees dead. Interestingly, the number of damaged trees was reasonably distributed in each AYP (**Fig. 2b**). However, the Tree Damage Index (TDI) calculation results show that the health condition of the Lauraceae is dominated by healthy collections (TDI 0-5).

In AYP 0-15 years, the number of collection trees that were not damaged (TMK) and damaged (MK) was almost the same, while in AYP 16-30 years, 31-60 years, and 61 years and over showed the number of collection trees that experienced damage was higher than the collection tree that was not damaged. The number of damaged trees was relatively high in the AYP 16-60 years. The damage in the early-middle AYP class causes many collection trees not to survive and eventually die. This condition causes the number of reports of dead collections of the Lauraceae from 1999-2018 to have the highest number in the BBG, as many as 155 trees (Setyanti et al. 2020).

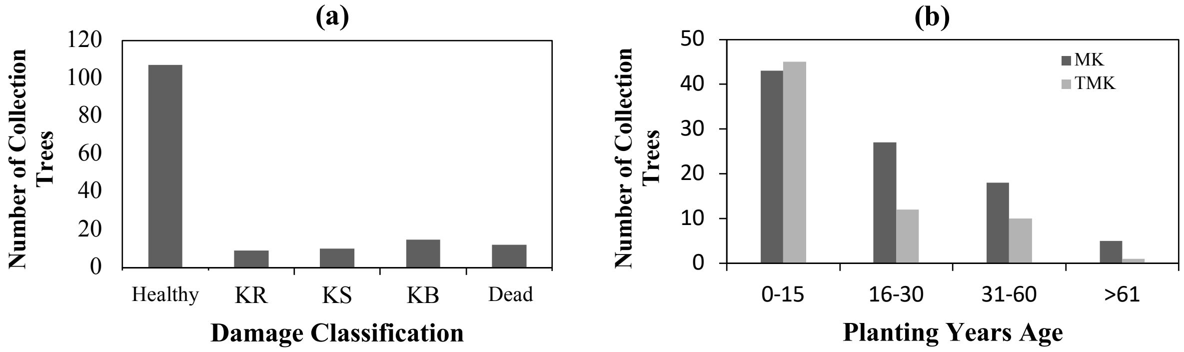

Fig. 2. (a) Health classification of the Lauraceae (KR=Mild Damage; KS=Medium Damage; KB=Heavy Damage); (b) the ratio of the age of the year of planting to the health condition of the Lauraceae in the Bogor Botanic Gardens (MK= Damaged; TMK=No damage).

3.2. Damage Location

In general, the damages of a tree occured in the stem and crown (Pertiwi et al. 2019). The damage of Lauraceae collections in BBG was generally found in the stems and crowns. The observations results showed 63 trees damaged in the trunk, 51 trees damaged in the crown branches, and 13 trees experienced damages in the roots (**Fig. 3a**). The frequency of damage each tree varies. 45 tree experienced damages in a single location, 32 trees experienced damages in two location, and 6 trees had damages in 3 location at the same time (**Fig. 3b**).

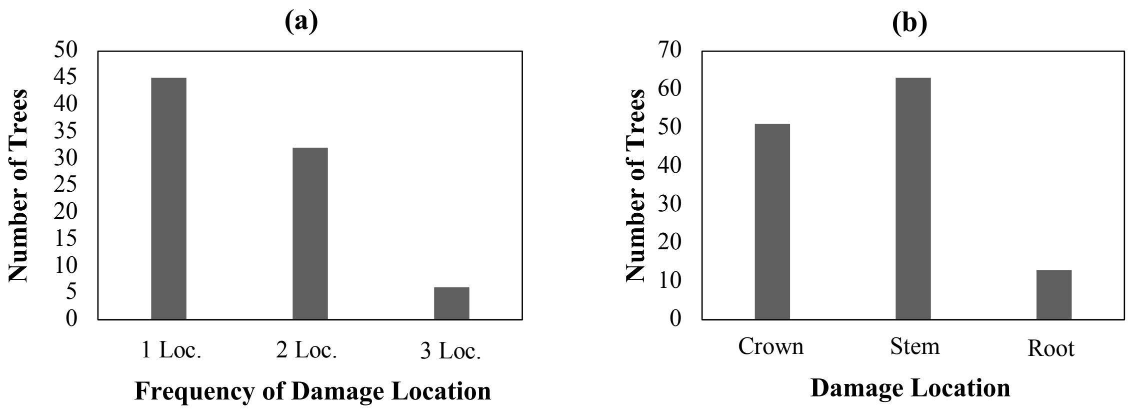

Fig. 3. Description of the damage location of the Lauraceae in the Bogor Botanic Gardens: (a) frequency of damage location and (b) damage location.

Tsani and Safe'i (2018) revealed that the dominance of the location of damage in stem was also found in trees located at the Way Kambas National Park Training Center. However, stem damages generally occur in the wounds caused by friction from animals, such as wild boars and elephants, which is different from the cause of stem damage in BBG. The results of observations at BBG showed that stem damages that occurred in the Lauraceae collection was initiated by the attack of borers and cracks in the main branches (**Fig. 4a** and **Fig 4b**). Based on observations, these cracks will usually cause the crown area dry out and die. It is presumably because these cracks disrupt the phloem tissue so that the nutrient supply path to the crown is disturbed. In some species of the Lauraceae, resin/sap will come out when experiencing symptoms of damage to the stem, which is thought to be a form of self-defense (**Fig. 4c**). However, in general, the location of the damage to these stems is still relatively light (0-19%).

Damage to the Lauraceae collection at the two locations observed was dominated by the crown and stem locations. These conditions will disrupt physiological processes, especially in the process of photosynthesis and supply of nutrients (Pokorny 1992; Sumardi and Widyastuti 2002), so that the direct impact is a decrease in plant resistance to disease (disease resistance).

The highest types of damage were broken or dead branch damage (38%) and other damage categories (28%), such as peeling bark and cracked stems (**Fig. 5a**). The severity of the damage that occurred in the Lauraceae showed that the dominant severity was mild (0-19%) and decreased in the following classification at the severity of 20-29%, 30-39%, and 40-49% (**Fig. 5b**). The score of the severity level is still relatively standard, but we need to be aware of the occurrence of the severity level that continues in the future.

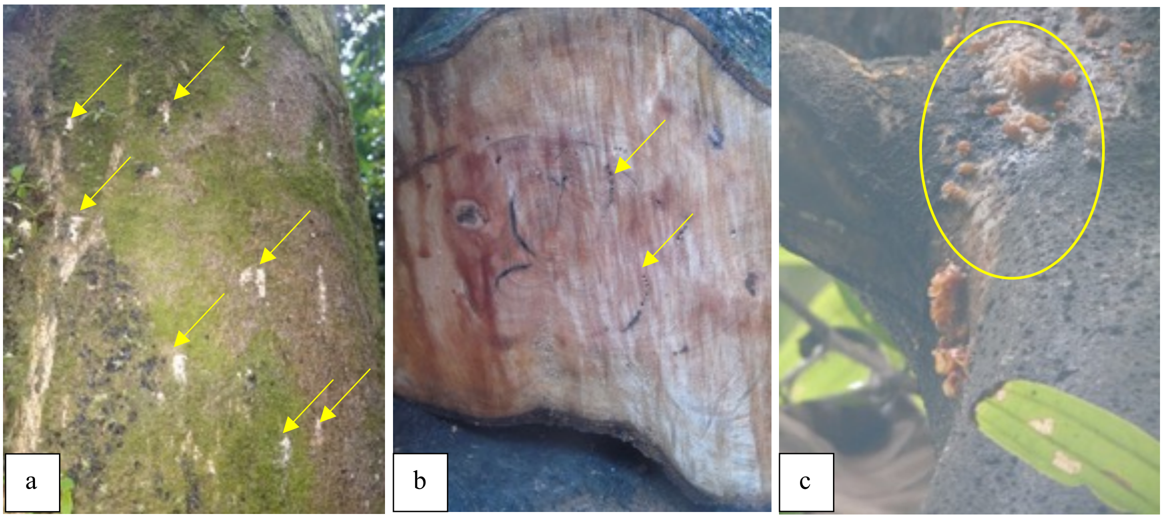

Fig. 4. (a) Traces of attack by borers (yellow arrows), (b) traces of borer insects after the collection died and were cut crosswise, (c) a form of self-defense from the Lauraceae by secreting resin.

Routine maintenance in the form of light pruning is a priority to reduce more severe damage. It is expected to be influenced by the age and height of the plant. The Lauraceae in the BBG is dominated by the relatively young age of collection trees, so many collections are still healthy.

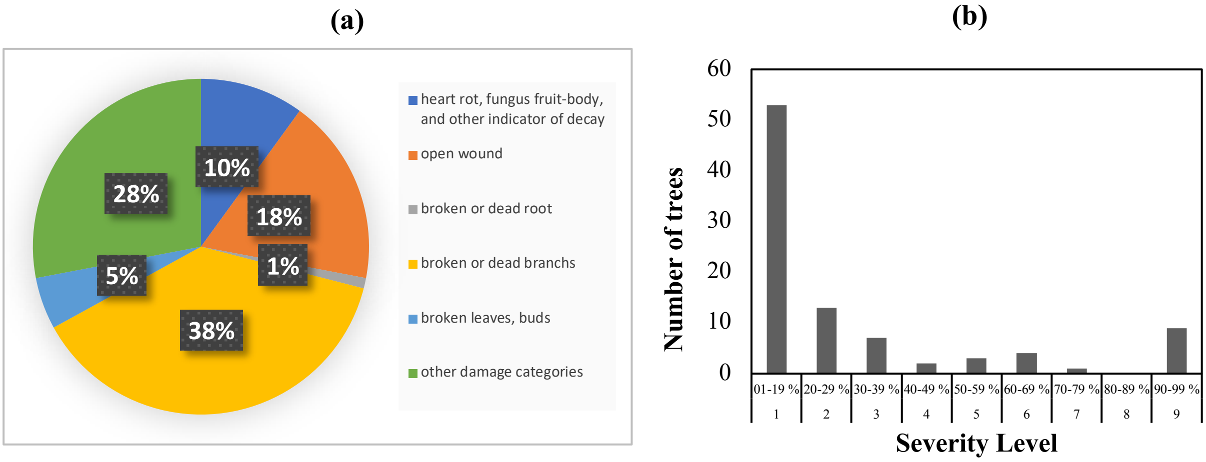

Fig. 5. (a) Damage type, and (b) severity level of the Lauraceae in the Bogor Botanic Gardens.

3.3. Type of Damage

Tree health is strongly influenced by biotic and abiotic factors (Pertiwi et al. 2019). Collection maintenance is an effort of human intervention to improve the quality collections is included in abiotic factors. Collection maintenance can affect tree health, such as light pruning. Another abiotic factor is the weather, such as rain, wind, and lightning, which can cause the collection to fall and die. Another abiotic factor is the unmet nutritional needs of the collection. Lack of nutrients will cause trees to become vulnerable to plant-disturbing insects (Abimanyu et al. 2019; Susilowati et al. 2018; Tsani and Safe'i 2018). Biotic factors that usually reduce the level of tree health are the attack of plant-disturbing organisms such as pests (for example, termites and stem borer insects), diseases (for example, attacks by fungi and other microorganisms), and weeds (Abimanyu et al. 2019; Helmanto et al. 2018; Pribadi 2010; Safe'i et al. 2020).

Insects that are often found in the Lauraceae in BBG are stem borers. Visual observation of the damage found in the Lauraceae collections in BBG showed insect traces in the form of small holes on the stems and traces of sawdust (**Fig. 4a**). The age of Lauraceae collections, which is still relatively young, can attract and increase the attack of stem borer insects. Affected plants will be short and have many branches when recovered (Kendra et al. 2013; Wikardi and Wahyono 1991). It follows the symptoms found in the collection trees in the Lauraceae plot. Therefore, appropriate efforts are needed to reduce the level of insect attack on the Lauraceae collections in BBG, such as by installing wooden traps. (FAO 2011).

Dead or dry branches (**Fig. 6a**) and broken branches on the upper branch or top section (**Fig. 6b**) were common in the Lauraceae tree collections. Dead branches and broken upper branches are caused by shoot-sucking insects from the Lepidoptera nation (Wikardi and Wahyono 1991). In addition to the conditions previously mentioned, there were also infected trees and overgrown with Ganoderma fungal bodies (**Fig. 6c**). The fungus indicates that there is a suspicion that further weathering has occurred in the main stem. This is also often found in several hosts of the Ganoderma fungus, which have many hosts, especially for woody plant species (Susanto et al. 2013). Ganoderma fungus are also commonly found in the Yellow Nature Tourism Park on rotting wood. Their presence is detrimental to tree trunks because they absorb nutrients from their hosts (Harahap et al. 2017; Sankaran et al. 2005).

Fig. 6. Damage typr of the Lauraceae in the Bogor Botanic Gardens: (a) damage to some dried branches; (b) damage to the top of the header; (c) stem damage due to Ganoderma fungus.

The frequency of symptoms and damage that leads to sudden death in the Lauraceae also indicates the possibility of fungal diseases associated with borer insects. Several collections experienced symptoms of leaf wilting in part or all of the branches and symptoms of stem borer on the same tree, which caused symptoms of drought and tree death in a short time. The species of borer that is thought to be the ambrosia beetle from the subfamily of Scolytinae or Platypodinae is attracted to the ethanol produced by stressed or sick Lauraceae trees. However, the ambrosia redbay beetle is attracted by the specific essential oil produced by several species of Lauraceae even though the tree is healthy (Olatinwo et al. 2021). The ambrosia beetle mainly carries fungal pathogens that simultaneously infect trees when the ambrosia beetle gnaws on the tree's xylem.

One of the phenomenal wilt diseases that attack Lauraceae trees with an association mechanism with borer insects is laurel wilt. The laurel wilt is a vascular disease caused by the fungus *Raffaelea lauricola* transmitted by an invasive vector, Ambrosia redbay bettle (*Xyleborus glabratus*) from the subfamily of Scolytinae (Kendra et al. 2013; Olatinwo et al. 2021). This disease so far only affects members of the Lauraceae. Symptoms caused by the disease are a change in the color of the wood sap to blackish in the form of small strokes which later infect the whole xylem tissue. The laurel wilt infection is followed by wilted leaves and shoots and dieback branches. The reddish or purplish-brown color on dead leaves can remain visible for more than a year after the leaves die. The whole tree will die within weeks to months of infection (Kendra et al. 2013; Olatinwo et al. 2021; Spence et al. 2013).

In the southeastern United States, laurel wilt has become a significant problem since its introduction to America in 2002. The disease affects redbay (*Persea borbonia*) and sassafras (*Sassafras albidum*) trees. Laurel wilt also affects the production of avocado trees (*Persea americana*) and is thought to potentially attack other native species of the Lauraceae (Olatinwo et al. 2021; Ploetz et al. 2017). The origin of *Xyleborus glabratus* and *Raffaelea lauricola* is known to come from Southeast Asia. However, the symbiosis of the two is found in warm and humid areas of Asian countries (India, China, Vietnam, Japan, Taiwan, and others) and invades the southeastern United States. The Ambrosia Redbay beetle is only known to attack Lauraceae in North America. Nevertheless, in Asia, this beetle is also associated with species from the Dipterocarpaceae, Fagaceae, Theaceae, Pinaceae, and Fabaceae families (Kendra et al. 2013; Olatinwo et al. 2021; Spence et al. 2013).

In Indonesia, the existence of this disease has not been well documented. Rodearman's (2017) observations regarding the ambrosia beetle on *Albizia chinensis* in East Java and Haneda et al. (2020) regarding the diversity of borers on Hopea odorata in West Java did not show the presence of the Ambrosia beetle. Seeing the symptoms, especially wilting and sudden dryness in the collections of the Lauraceae in BBG, it is necessary to carry out further observations regarding the possibility of disease attacks resembling laurel wilt. According to Olatinwo et al. (2021), the appropriate action in tackling the widespread spread of the attack is to implement an integrated pest management strategy, such as implementing good sanitation to suppress insect populations, applying chemical and biological controls, and killing host trees.

4. Conclusions

The tree health of the Lauraceae collections in the Bogor Botanic Gardens is generally in a healthy condition with a Tree Damage Index (TDI) of 0-5. The total number of trees collected by the Lauraceae in plots XX.A and XX.B are 149 trees with 103 healthy, 9 lightly damaged, 10 moderately damaged, 15 heavily damaged, and 12 dead. The most common locations of damage were found in the stems and crowns. More comprehensive research on plant pests and diseases is needed to mitigate damage to the Lauraceae collections in the Bogor Botanic Gardens.

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