Preliminary study of canker disease for development of urban tree health standard in Malaysia

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Abstract. Canker disease (CD) mainly infected trees planted in urban areas in Malaysia. This disease is caused by several plant pathogens and may cause tree death and tree failure. The aims of this study are to identify tree species which are susceptible to canker diseases and to identify the causal agents especially plant pathogens of the disease. To perform the study, a survey on planted trees in several urban parks and sites in Malaysia were conducted. In this study, the Canker Disease (CD) assessment procedure was developed and modified from Thousand Cankers Disease Survey Guidelines by the United State Department of Agriculture (USDA). Later, the assessment procedure was improved based on surveys in the ground to fit and get the best quality of data from the observations. As a result, several canker diseases were identified on twenty-three (23) trees, the species were, Acacia sp, Bucida molineti, Cinnamomum iners, Citrus sp, Eucalyptus urograndis, Eucalyptus camaldulensis, Eucalyptus sp, Khaya grandifoliola, Mangifera indica, Manilkara zapota, Mimusops elengi, Pentaphorum indicus, Samanea saman, Swietenia macrophylla, Swietenia spicifera, Tabebuia argentea, Terminalia catappa, Terminalia mantaly, Araucaria heterophylla, Casuarina equisetifolia, Gymnostoma sumatrana and Polyalthia longifolia. Based on symptom development the canker diseases known as Sphaeropsis canker, Cryphonectria canker, Chrysoporthe canker, Biscogniauxia canker, Hypoxylon canker, Cypress canker, Nectria canker, Ceratocystis Wilt, Pink disease, and Slime flux disease. This study can be the starting point in developing the Canker Disease (CD) Assessment Standard in Malaysia. It is important for Malaysia to have a Canker Disease (CD) Assessment Standard in order to become a guideline for future study or research that specifies canker disease towards common trees planted in Malaysia especially the urban areas.

1. Introduction

The existence of trees in urban trees provide shelter and shading spots which act well for recreation and relaxing time [1]. Trees in urban parks give important services especially in terms of environment such as air and water pollution due to heavy use vehicles in city areas, control the temperature and humidity which minimise urban heat island, reduce stormwater, surface runoff and many more [2]. Surface runoff is the flow of excess water resulting from stormwater or rainfall where the soil ground cannot longer absorb water, causing waterlogged and flooding to happen especially in urban areas [3]. To maintain the benefits, urban trees must be in good conditions and grow well in the urban...
environment. Some urban tree failures in Malaysia were fallen trees because of strong winds (storms), aged trees that are very old in number, parasitic higher plants, mechanical injury, and diseased trees especially root rot, canker, and galls [4, 5]. There were several cases reported in the news such as The Star, The Straits Times [6, 7] which proved how serious tree failure was in Malaysia where accidents, death, property damages were happening because of the hazard trees.

There are various tree problems and diseases that infect trees in urban parks. One of them is canker which recently has been quite a serious disease infecting tree species in Malaysia. Cankers are regions which consist of necrotic bark and outer sapwood that can be seen sunken, discolored, and injured appearance which is caused by various fungal infections that invade the stems areas [8, 9]. Canker affected trees showed symptoms of stem and root necrosis, gummosis, branch dieback and caused a tree to fail [10]. Canker was caused by fungal or bacterial pathogens [11] which caused injury to happen especially in bark areas, starting from a wound or branch stub. The fruiting bodies of canker pathogens appeared as pinhead-sized, black, or colored raised bumps embedded in or beneath the bark [12, 13]. These fruiting bodies rarely can be seen and not easily identified by visual assessments.

There were more than 20 types of canker disease that have been acknowledged and recorded all across the world. There were Biscogniauxia canker, Cryphonectria canker, Botryosphaeria canker, Hypoxylon canker, Phomopsis canker, Cytospora canker, Sphaeropsis canker, Nectria canker, Thronectria canker, Cypress Canker, Butternut Canker, Lasiodiplodia Canker, Cryptodiaporthia canker, Eutypella canker, Larch Canker, Calosphaeria Canker, Pitch canker, Pink disease and Phytophthora disease. Cryphonectria cankers have been known as one of the pathogens that infect and cause death of Eucalyptus trees in urban landscapes [14]. Other than that, currently Biscogniauxia canker was identified caused infection towards Khaya and Mahogany tree species which these two species are commonly planted in urban streets and parks in Malaysia. Other cankers that infected landscape and urban trees were such as Thronectria canker, Sphaeropsis canker, Cytospora canker, Nectria canker Phomopsis canker, Botryosphaeria canker and Hypoxylon canker. These canker diseases slowly weakened and cause damaged to the trees.

The symptoms of canker differed based on the species and the health of the tree. Different canker causal agents also infected and showed different symptoms and characteristics. As the assessments have been carried out in several sites, the biological and environmental factors also influenced the canker symptoms. The general objectives of this study were to assess canker infection on urban trees all across Malaysia. The specific objectives were (1) To identify tree species infected by canker disease in Malaysia (2) To identify pathogen or causal agent of canker diseases and (3) To develop standard methods for examining canker disease in Malaysia.

2. Method

2.1. Study site and sampling method

This study was conducted at 22 sites of different locations consisting of urban streets and urban parks in Malaysia. This study was carried out in several states and cities in Malaysia included Perak, Melaka, Selangor, Johor, Pahang, Putrajaya, and Kuala Lumpur. All sites chosen were ‘hotspots’ areas where the places are in the urban environment, located nearby residential communities and essential urban facilities that receive numerous amounts of visitors every day especially during the public holiday and weekends. Besides, the trees in the study sites have not been studied yet especially for canker evaluation.

In this study, more than 2200 trees were investigated. The trees evaluated by using selective sampling method as sampling techniques for the study and performed visual tree inspections according to symptoms of canker appeared on the trees such as gummosis, necrosis, crack or swell bark, dieback, and sunken or elongated in shape. The appearance of symptoms on the trees were taken as indicators that showed the development of canker diseases.
2.2. Canker disease assessment

Canker assessment was a method to determine the infestation rate of canker. The assessment was visual inspections started by observing the physical appearance of trees and the existence of the fruiting bodies on the trees. Identification of the canker was based on symptoms development on trees. Next, causal agent identification by observing morphological, and isolation of pathogens. Canker disease information was obtained via journal, guideline, and book such as Thousand Cankers Disease Survey Guidelines by United State Department of Agriculture (USDA) [15], The Plant Pathology book. Result from the evaluation, analysis of the assessment has been done. The symptoms and position of each canker on the tree infected was photographed. The percentage of canker infection rate was done by observing the proportion of infection area to the whole area of the tree infected. Canker assessment survey method or protocol for this study was developed and modified from Thousand Cankers Disease Survey Guidelines by United State Department of Agriculture (USDA) [15] shown in the figure 1.
3. Result and Discussion
Based on this study, there were twenty-three (23) trees found to have been infected by various types of canker. The results were listed and recorded in the following table 1 and table 2. The symptoms appeared differing between tree species. Cankers were localized as the dead areas on the bark of diseased tree trunks and branches. The examples of symptoms were crack and sunken on trunk (figure 6), presence of fungi stromata on trunk (figure 17) and scars (figure 18); resinous (figure 20); bleeding (figure 23); and swelling (figure 24). Infection rate of canker disease were various which are between 5% to 90% for individual range and 10% to 30% for population range.

There are up to 20 types of canker disease that have been recorded in the world. These cankers also occurred and happened towards trees in Malaysia but there were limited references or guidelines to
identify and examine the canker diseases. At first canker commonly happened towards trees in forest and plantation. Over the years, there were many cases such as tree falls, injuries or accidents that happened in urban areas especially streets and urban parks. Canker was a disease that hardly can be observed at the early stage of infection as it takes a long period to form callus and appear on the surface of trees. It was noticeable when the canker symptoms appeared on the surface of the barks; the tree infected was already weakened and can cause hazard to the targets.

The symptoms of canker were vary depending on host species, but some canker pathogens will attack the same host species as they were compatible with the host species. Canker disease assessments on trees in Malaysia were very limited and only a few have been done in the urban areas. It is important to have a standard guideline or methods to examine the canker in Malaysia, with the proper and standard guidelines; one is able to identify and prevent any accidents to happen especially in the urban areas.

There are currently no standard guidelines for the assessment of canker disease identification in Malaysia. This study uses assessment canker disease (CD) which has been modified from Thousand Canker Disease (TCD) Survey Guidelines by the United State Department of Agriculture [15]. During the works in fields, it was found that this modified assessment needs to be improved to get the best quality of data that is collected in the fields. In figure 2, the orange highlight boxes were suggested improvement from assessments that have been done in the fields. However, this modified standard is still in the preliminary stage. Therefore, in order to produce Canker Disease (CD) Assessment Standards in Malaysia, further studies should be done such as the severity of canker disease of different tree species and mitigation study.

In this study, canker disease severity was taken in general by recording the percentage of infected areas of the trees. Based on the site evaluations, the part that is infected with canker diseases will be weakened, this is due to the mycelia that had colonized the sapwood and hardwood parts of the trees [16]. Normally the infected parts will crack, swollen and sunken. These weakened and infected parts usually break or tore apart when there were strong winds or storms. Based on field data observations, trees that highly vulnerable and easy to break when infected with canker were *Samanea saman* which known as ‘rain tree’ (figure 16), *Tabebuia argentea* which popular as ‘sakura Malaysia tree’ (figure 20), *Eucalyptus urograndis* tree (figure 8) and *Eucalyptus camaldulensis* (figure 9).

The identification of canker disease in this study was based on symptoms that developed and referred to the published material that reported the same tree species being infected with what kind of canker pathogens. There was no confirmation that a DNA sequence-based method was used to identify the pathogens. Therefore, it is possible that the identified canker diseases in this study were identified based on symptoms that have been published and described in the published material. It is also possible that the proposed pathogens species are inaccurate therefore for future studies identification, DNA sequence-based methods should be done.
Figure 2. Suggested improvement of Canker Disease (CD) assessment.
Table 1. Tree species that are infected with diseases.

| No | Host Scientific Name | Local Name | Disease | Potential Causal Agent | Individual infection rate | Population in infection rate | Location | References |
|----|-----------------------|------------|---------|------------------------|--------------------------|----------------------------|----------|------------|
| 1. | *Acacia sp* (figure 3) | Akasia     | Ceratocystis Wilt and canker | A species of *Ceratocystis* | 30 to 50%                | 50%                        | Kulai Jaya | [17-19]    |
| 2. | *Bucida molineti* (figure 4) | Doa        | Canker disease | Unidentified           | 10%                      | 52%                        | Ipoh, Perak | [20]       |
| 3. | *Cinnamomum iners* (figure 5) | Medang     | Pink Disease | *Erythricium salmonicolor* | 70% to 90%                | 50%                        | Serdang, Selangor | [21] |
| 4. | *Citrus sp* (figure 6) | Limau      | Bacterial canker | Unidentified           | 20%                      | 20%                        | Kuala Lipis, Pahang | [22] |
| 5. | *Eucalyptus sp.* (figure 7) | Kayu Putih | Nectria canker | Unidentified           | 30%                      | 40%                        | Sandakan, Sabah | [23] |
| 6. | *Eucalyptus urograndis* (figure 8) | Kayu Putih | Chrysoporthe canker | *Chrysoporthe deuvarubins* | 40%                      | 10%                        | Brumas, Sabah | [24-26] |
| 7. | *Eucalyptus camaldulensis* (figure 9) | Kayu Putih | Botryosphaeria / Cryphonectria canker | *Cryphonectria cubensis* | 40%                      | 50%                        | Serdang, Selangor | [27] |
| 8. | *Khaya grandifoliola* (figure 10) | Mahogany   | Nectria canker | *Nectria galligena* | 20%                      | 10%                        | Putrajaya, Selangor | [28] |
| 9. | *Mangifera indica* (figure 11) | Mangga     | Cryphonectria canker | Unidentified           | 20%                      | 10%                        | Ipoh, Perak | [29] |
| 10. | *Manilkara zapota* (figure 12) | Ciku       | Pink Disease | *Erythricium salmonicolor* | 5%                       | 10%                        | Puchong, Selangor | [30, 31] |
| 11. | *Mimusops elengi* (figure 13) | Bunga      | Ceratocystis Wilt | *Ceratocystis manginecans* | 30%                      | 20%                        | Kajang & Serdang, Selangor | [32] |
| 12. | *Polyalthia longifolia* (figure 14) | False Ashoka | Canker disease | Unidentified           | 5%                       | 10%                        | Serdang, Selangor | [33] |
| 13. | *Pterocarpus indicus* (figure 15) | Angsana    | Fusarium canker | Unidentified           | 5%                       | 10%                        | Sg. Besar, Selangor | [34] |
| 14. | *Samanea saman* (figure 16) | Hujan-hujan | Canker disease | *Fusarium semitectum* | 10%                      | 30%                        | Putrajaya, Selangor | [35, 36] |
| 15. | *Swietenia* | Mahogany   | Hypoxylon / *Lasiodiplodia* | 50%-90%               | 30%                       | 30%                        | Serdang, Selangor | [37, 38] |
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macrophylla (figure 17 & 18)
Biscogniauxia
canker
theobromae

16. Swietenia spicifera (figure 19)
Merpuah
Nectria canker
Unidentified
10%
10%
Kemasul, Pahang
Kuala Terengganu
Kajang
Selangor
[39]

17. Tabebuia argentea (figure 20)
Sakura
Malaysia
Canker disease
Unidentified
50%
70%
Kulai Jaya
Kajang
Selangor
Serdang
Selangor
[40]

18. Terminalia catappa (figure 21)
Ketapang
Nectria canker
Unidentified
20%
30%
Serdang
Kulai Jaya
Kajang
Selangor
[41-43]

19. Terminalia mantaly (figure 22)
Doa
Slime Flux Disease
Bacteria
10%
10%
KLCC, Selangor.
[44, 45]

Table 2. Coniferous tree species that are infected with disease.

| No | Coniferous Host Scientific Name | Local Name | Disease | Potential Causal Agent | Individual infection rate | Population in infection rate | Location | References |
|----|---------------------------------|------------|---------|------------------------|---------------------------|-----------------------------|----------|------------|
| 1. | Araucaria heterophylla (figure 23) | Star Pine | Sphaeropsis canker | Unidentified | 5% | 5% | Johor Bahru, Johor | [46-48] |
| 2. | Casuarina equisetifolia (figure 24) | Rhu Pantai | Nectria canker/ Diploda canker | Unidentified | 70% | 10% | Kuala Terengganu, Terengganu | [49, 50] |
| 3. | Gymnostoma sumatrana (figure 25) | Sumatran Ru | Cypress canker | Unidentified | 10% | 10% | Serdang, Selangor | [51, 52] |
Figure 3. Ceratocystis wilt and canker infested on Acacia sp tree. A species of Ceratocystis commonly as potential causal agent or pathogens of this disease that caused threat towards Acacia sp host tree in Malaysia [19]. The symptoms of canker appeared as swelling parts on the trunk of the tree.

Figure 4. Unidentified canker infected on Bucida molineti. The symptom of canker on the trunk was elongated and sunken bark while on the branch parts was cracked and discolored bark. Bucida molineti is a very popular landscape tree planted along the streets and parks due to its characteristics which are the branches that pointed skywards in symmetry, dense twigs that grown in storeys or layered, the leaves are tiny and variegated, which the reasons this species were used as the ornamental and shading plant [20].
Figure 5. Pink diseases infested on *Cinnamomum iners* in Maeps Serdang Selangor. The pathogen of this disease has been identified which is *Erythricium salmonicolor*. The disease causes pale pinkish white covering the regions on the stems or branches of the tree in the early stages of infection and later infection spreads over the bark, killing the tree [21]. Symptoms of canker appeared on the trunk of this tree in forms of cracks bark, pink orangish spore on the stems and the death of the tree. Besides that, fruiting bodies (conks) also present on branches of the death tree.
Figure 6. *Citrus sp* was infested by Bacterial canker in Kuala Lipis, Pahang. The canker signs were visible on the tree’s trunk, which was cracked dark brown and raised with longitudinal fissures exposing the vascular tissues [22].

Figure 7. The *Eucalyptus sp* was infected by Nectria canker. Stromata of canker appeared and swollen at the bottom part of the trees were the symptoms of this disease. Canker infection was observed approximately 30% along the trunk areas. This disease spread on the trunk that appeared reddish swollen which was due to extensive production of kino that indicated variation in susceptibility between the Eucalyptus species [23].
Figure 8. Chrysoporthe canker infested on *Eucalyptus urograndis* in Brumas Sabah. The canker caused cracks on the bark of the trunk which can lead to wound or injury to the tree. *Chrysoporthe deuturocubensis*, a highly pathogenic on Eucalyptus tree species that has been discovered and identified as the causal agent of this disease [24-26].

Figure 9. Botryosphaeria canker/ *Cryphonectria* canker infested on *Eucalyptus camaldulensis* in Serdang, Selangor. The pathogen of this disease was *Cryphonectria cubensis*. The canker infected more than 50% of the tree, especially at the bottom parts of tree.
Figure 10. Nectria canker which produced by *Nectria galligena* infected *Khaya grandifoliola* found in Putrajaya, Selangor. The canker attacked the tree in the heartwood part and weakened the strength of the tree. The roots of the tree showed very minimal hold of surrounding soils which was the effect of canker infestation. A weakened tree can easily fall when storms hit and cause hazards towards urban dwellers [28].

Figure 11. Cryphonectria canker infested on *Mangifera indica* that was found in several street trees in Ipoh Perak. This type of canker normally found attacked this host species and caused the death of the tree. Black galls appeared on various parts of the tree especially on crotch and branches.
Figure 12. Pink disease infested *Manilkara zapota* in Puchong, Selangor. The symptoms of this disease appeared on the trunk of the tree, which was swollen, discolored and cracked barks which exposed the sapwood of the tree. Canker-infested areas appeared dark or discolored compared to the healthy bark [30]. The pathogen that infected this tree was *Erythricium salmonicolor* [31].

Figure 13. Ceratocystis wilt was found to have infected a few hosts of *Mimusops elengi* in Kajang and Serdang, Selangor areas. The causal agent of this disease was identified which is *Ceratocystis manginecans*. This species is common in urban areas.
especially in urban parks or residential areas in Malaysia. Swollen parts appeared on branches and trunk areas.

Figure 14. *Polyalthia longifolia* that is commonly known as ‘False Ashoka’ was infected by unidentified canker on a tree found in Serdang, Selangor. Canker infected on crotch of the tree which can cause hazard [33] if it weakens internally and leads to tree failure as split or snap can happen.

Figure 15. *Pterocarpus indicus* was infected by Fusarium canker (unconfirmed) as an unidentified causal agent in Sungai Besar, Selangor. The canker caused major damage to the tree resulting from swelling and cracked barks on the trunk of the trees. This species is commonly planted in urban areas due to its attractive characteristics and its scenic value [34]. As the canker attacked the tree, this caused the tree to become less functioning and become unhealthy.
Figure 16. *Samanea saman* was infected by *Fusarium semitectum* [35]. Canker infections for the most part begin from pruning wounds, the cracks resulting from the tree crotch or trunk [36]. For this tree, the pathogens invaded and attacked the crotch part of the tree which weakened the strength of the spots. When strong winds hit or storm happened towards the infected weakened point of the tree, the tree broke and split.

Figure 17. Hypoxylon canker infested *Swietenia macrophylla* in an urban park that received numerous visitors every day. Stromata are present on the branches parts of the tree which can caused hazard or injury to the target in the urban areas.
Figure 18. *Swietenia macrophylla* was infected by Biscogniauxia canker or Hypoxylon canker on several street trees in Serdang, Selangor area. This canker can be easily identified as the stromata are present and symptoms appeared sunken brown at young age while as the number of years increases, the center of the canker becomes grayish white and raised [37]. It was reported that even when the causal agent of this canker is active on a mature tree, a tree still can still stand healthily and resilient [38].

Figure 19. *Swietenia spicifera* was one of Mahogany species that was infected by Nectria canker. The symptom of canker was a few irregular swollen parts that appeared on the trunk of the trees.
Figure 20. *Tabebuia argentea* that is commonly known as ‘Sakura Malaysia’ was infected by unidentified canker. This canker caused swollen, cracked, exposed tree tissues and heavy gummosis produced. Canker disease attacks and weakens the strength of the tree which causes the tree to become vulnerable towards storms, pest infestation [40] and others. The infected tree became hazards especially towards the users of the road in Kulai Jaya Johor, Kajang, Selangor and Putrajaya.

Figure 21. *Terminalia catappa* was infected by Nectria canker that was found in several urban trees in Serdang and Pulau Indah, Selangor areas. Stromata appeared on the trunk of the trees as the symptoms of canker. Several studies of canker had been published on *Terminalia catappa* revealed that this host species was vulnerable towards canker disease and infected trees exhibiting a variety of symptoms including die-back, canker, blight, and rot on all above ground tree organs [41-43].
Figure 22. Slime flux disease caused by bacteria infected *Terminalia mantaly* near KLCC area while the tree is also associated with termites’ infestation. Causal bacteria entered the host through the wound and commonly attacked the heartwood of the tree [44]. White and fermented odor fluxes that ooze out from the hole of the trunk was caused by bacterial infection. Slime flux was often associated with canker and cracks, and rarely found in forested areas as it is normally observed on urban trees such as plane trees, landscape trees and trees in urban parks [45].

Figure 23. *Araucaria heterophylla* was infected by Sphaeropsis canker found on street trees in Johor Bahru, Johor. The symptoms of this canker were orange resin oozing out from the wound or crack barks (gummosis) and brown tip blight needles [46]. This host species has been mentioned as one of host species that are vulnerable towards *Botryosphaeria parva* that widely known pathogens caused this disease [47, 48].
Figure 24. Nectria / Diplodia canker infected on *Casuarina equisetifolia* was found in street trees in Kuala Terengganu, Terengganu. This canker infected approximately 70% of the tree area where formation of swollen parts located along the trunk. *Casuarina equisetifolia* is commonly used as an ornamental as well as for windbreak that is suitable to plant as street trees. There were studies published [49, 50] on this host species where the findings observed that this species was vulnerable towards die-back and diplodia stem canker which led to death of the tree.

Figure 25. A host of *Gymnostoma sumatran* was infected by Cypress canker which caused major damage to the tree. The canker infected the tree which resulted in loss of crown almost 90% which can be observed only a few leaves cluster remained on the branches. Cypress canker causes water stress, withering and other negative consequences on the leaves and tissues of the affected tree [51, 52].

4. Conclusion
Based on the observations done on the sites and data analysis, there were ten (10) types of different canker diseases found on twenty-three (23) trees. The types of canker are Sphaeropsis canker,
Cryphonectria canker, Chrysoporthe canker, Biscogniauxia canker, Hypoxylon canker, Cypress canker, Nectria canker, Ceratocystis Wilt, Pink disease, and Slime flux disease. As a preliminary study, it is hoped that this result will help arborists in Malaysia and become a guideline to identify tree disease problems, especially canker disease in urban areas, parks, and sites in Malaysia. Trees especially in urban areas must be in the best condition and be monitored from year to year to minimize the risks of hazard trees. Management of canker diseases generally depends on prevention. So, proper tree care such as sanitation before pruning, prevent wounds to happen, selection of timing to do the tree care works are important to prevent canker diseases. With the development of canker diseases standard that consists of various identification and symptoms of canker found in Malaysia, will allow better and precise data in future studies related with canker diseases. Indirectly, arborists and forest managers can monitor, manage, and take initial precautions of the diseased trees. From this preliminary study, it was found that common pathogens or causal agents that infected same species trees on different sites proved that all data from canker diseases studies were very important and can become a reference for future studies specifically for trees in Malaysia. Further studies and research of the fungal pathogen species should be done using molecular work and morphological study.

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