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DURIAN STEM CANKER STATUS AND RELATIVE SOIL PROPERTIES IN PENINSULAR MALAYSIA

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Abstract: The arising stem canker issues can be devastating when new durian orchards are developed without proper disease management strategies. Hence, this study aims to obtain the current durian stem canker incident rates in Peninsular Malaysia including soil properties. 15 plots (2,500 m^2 per plot) of durian orchards were evaluated and composite soil samples were analysed. Results showed that the greatest disease incidence (100%) was in old orchards (> 10 years), with a severity of 63% whereas young orchards (< 10 years) are at risk of severe stem canker with 71% of incidence and 43% of severity. There was a negative correlation (r = –0.220) between the incidence of stem canker and soil pH which indicated that durian trees grown in acidic soil (pH < 5.0) were more prone to disease dispersion in the orchards. Moreover, severely infected trees were observed more in durian orchards with a higher proportion of finer sand particles in the soil (DI/ r = 0.199 & DSI/ r = 0.206) compared to coarse particles of clay and silt. Our work will play a crucial role in advancing real-time monitoring of durian stem cankers and enabling the prediction of potential disease outbreaks for the implementation of preventive measures.

Keywords: Oomycete, *Phytophthora*, soil.

Introduction

In Malaysia, durian stem cankers are reported to be caused primarily by the destructive fungal-like oomycete, *Phytophthora palmivora* from the kingdom Chromista (Singh, 1980; Lim, 1990; Lee *et al.,* 2012; Ho, 2018; Zakaria, 2022). This disease has greatly affected durian production in Southeast Asia causing global economic losses ranging between 10% and 30% (Drenth & Sendall, 2004; Drenth & Guest, 2013). Besides durian stem cankers, *P. palmivora* has also been reported to cause *Phytophthora* disease outbreaks in over 170 different crops and ornamental plants (Torres *et al*., 2016; Mohamed Azni *et al*., 2017; Latifah *et al*., 2018; Misman *et al*., 2022; Zakaria, 2022).

The increase of local demand (for fresh durian marketing, "duriotourism" and additive food-based products) as well as international exports to other countries especially China have contributed greatly to the expansion of more durian plantations, with the estimated total plantation area in Malaysia reaching 85,300 hectares in 2021 (Sukumaran, 2019; Statista, 2023). In 2020, durian production was the top fruit crop at 390, 635 tonnes, followed by pineapples, bananas, and watermelons (Suhana *et al.,* 2022). Plantations replaced mature, oil palm, and rubber trees, with durian trees, particularly after China approved the import of frozen whole durians in October 2018 (Suhana *et al.,* 2022). Both oil palm and rubber plants are also susceptible to *Phytophthora palmivora* (Singh, 1980; Lee *et al.,* 2012)

However, the lack of disease management plans prior to establishing new durian plantations raises concern, especially in areas with a history of *Phytophthora* pathogen invasion. The whole area could potentially serve as a reservoir for

Phytophthora. Also, the complex biological life cycle of this species contributes to its ability to use various dispersal pathways, including water, air, and other vectors to spread. Additionally, over multiple generations with susceptible hosts, the pathogen could evolve making it even more difficult to control the spread of the disease (Goodwin, 1997; Judelson & Blanco, 2005; Jiang *et al*., 2008; Raffaele *et al*., 2010; Ho, 2018; Latifah *et al*., 2018; Misman *et al*., 2022).

Moreover, the active production and dispersal of *Phytophthora* pathogens are closely related to the presence of various biotic, abiotic, and agronomic practices risk factors. Biotic factors are such as plant host susceptibility, pathogen species virulency as well as the presence of vectors and other soil microorganisms. On the other hand, abiotic factors include the weather conditions such as warm and wet seasons with high humidity and waterlogging, and also deprived soil conditions with nutrient deficiency (Duncan, 1999; McMahon & Purwantara, 2004; Cahill *et al*., 2008; Drenth & Guest, 2013; Paterson *et al.*, 2013; Ab Rahman *et al.*, 2018; Mohamed Azni *et al*., 2019; Zakaria, 2020).

Tropical countries like Malaysia with a high annual rainfall are typically ideal for the development and dispersal of *Phytophthora* spores (Lee & Lum, 2004). After heavy rain occurs, durian planting sites with waterlogging issues are at risk from the sporulation of sporangia *Phytophthora* zoospores being easily disseminated throughout the cultivation area via water (Misman *et al*., 2022). Other reproductive structures such as chlamydospores and oospores can survive in extreme environmental conditions which supports the continuous reproduction and development of *Phytophthora* consequently, becoming an inoculum reservoir (Goodwin, 1997; Cahill *et al*., 2008; Mohamed Azni *et al*., 2019; Misman *et al*., 2022).

Although the *Phytophthora* disease is frequently reported to affect tropical perennial crops in Southeast Asia including durians (Drenth & Sendall, 2004; Latifah *et al*., 2018; Misman *et al*., 2022; Zakaria, 2022), however, updates on disease distribution and the incidence in Malaysia are inadequate. Without the continuous updating of real-time disease distribution and incidence records, growers are often unaware of the necessity for an appropriate disease management strategies. Moving forward, the cooperation of all relevant parties, including local growers is necessary for the successful implementation of comprehensive disease strategies. Continuous disease monitoring is also crucial for the early detection of new pathogenic species. For example, the discovery of a new oomycete species, *Phytopythium vexans* that causes durian root rot in Vietnam has provided a fresh perspective (Thao *et al*., 2020). This highlights the potential for the introduction of new pathogens in crops, evolving over centuries influenced by both biotic and abiotic stresses (Kännaste *et al*., 2023).

Therefore, a thorough understanding of the three key elements (the disease triangle) of stem canker disease consisting of a susceptible host (the durian tree), a virulent pathogen (*Phytophthora palmivora*) and a conducive environment is essential (Agrios, 2005; Lim & Sijam, 2015). This understanding will help in predicting outbreaks and ensuring that the most efficient control measures can be implemented. Meanwhile, the continuous monitoring of durian stem cankers enables the tracking of local disease distribution trends that are useful for better crop protection and disease control strategies. This study aims to report the current incidence of stem cankers in different durian orchards across Peninsular Malaysia and establish a correlation between abiotic soil risk factors and stem canker incidence.

Materials and Methods

Sampling Area and Sampling Design

Field observations and sampling were conducted at 15 durian cultivation sites around Peninsular Malaysia, covering the northern, central,

Table 1: Field observation and sampling location of durian stem canker in Peninsular Malaysia

Orchard	Sampling Location	State	Regions	GPS Location	Age of Orchard (In 2022)
1	Marang[2]	Terengganu	A	N05°09.430', E103°06.759'	30
2	Jeli[1]	Kelantan	A	N05°46.046', E101°53.691'	5-12
3	Seberang Perai[2]	Penang	B	N05°41'33.7", E102°41'55.6"	32
4	Seberang Perai[2]	Penang	B	N05°17'17.4", E100°31'50.3"	50-100
5	Kota Bahru[1]	Kelantan	A	N04°31.545', E103°26.426'	35
6	Rompin[1]	Pahang	A	N05°24.083', E103°05.565'	3
7	Kulim[2]	Kedah	B	N03°02.899', E103°06.788'	10-20
8	Georgetown[2]	Penang	B	N05°19.949', E100°15.541'	> 50
9	Sepang[1]	Selangor	C	N05°19.942', E100°15.547'	24
10	Hulu Langat[1]	Selangor	C	N02°57.163', E101°44.798'	24
11	Kuantan[2]	Pahang	A	N02°57.144', E101°44.829'	2.5
12	Jasin[1]	Melaka	D	N02°16.199', E102°23.332'	2-5
13	Merlimau[1]	Melaka	D	N02°07.908', E102°27.750'	> 10
14	Muar[1]	Johor	D	N02°07.903', E102°27.753'	2
15	Pagoh[2]	Johor	D	N02°02.304', E102°51.823'	30-40

*Sampling location (geographical conditions): 1-flatland, 2-hilly/tropical forest.
*Regions: A- East Coast, B- Northern, C- Central, D- Southern

southern and east coast regions from May 2022 until March 2023 (Table 1). The selection of sampling sites was based on accessibility to orchards with durian stem canker issues. Most of the orchards had a mix of durian varieties such as D197 (Musang King), D24, D168 (IOI), D175 (Udang Merah), D99, D200 (Black Thorn), and local 'durian kampung'.

In a plotted sampling quadrat of about 2,500 m^2 (50 m X 50 m), systematic random sampling was conducted for disease assessment and soil sampling. However, this sampling plan was slightly restructured for each sampled durian orchard to suit their geographical conditions, assessing at least 15 to 20 durian trees per sampling site (Figure 1).

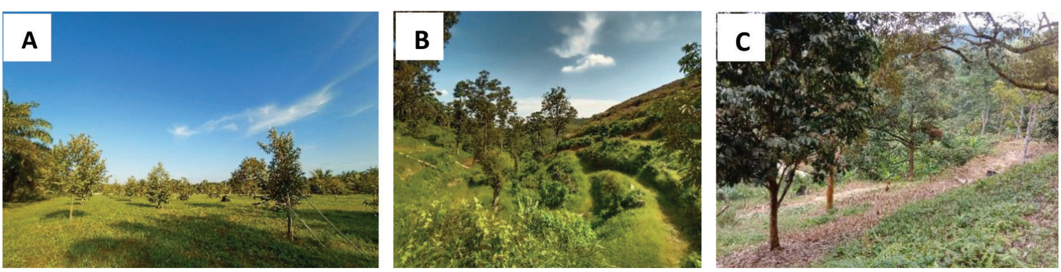

Figure 1: Durian orchards have different types of geographical conditions, such as (A) flatland, (B) hilly with terraces, and (C) tropical forest
Source: Authors

Durian Stem Canker Assessments

All durian trees in the plotted sampling quadrat (50 m X 50 m) were assessed for stem canker severity (DS), which was then calculated for the disease incidence (DI) and disease severity index (DSI) per durian orchard using the formulas described by Mekonen *et al*. (2015).

$$\textbf{Disease Incidence (\%)} = \frac{\text{Number of infected trees (x)}}{\text{Total number of evaluated trees (n)}} \text{ X } 100\ \%$$

$$\textbf{Disease Severity Index (\%)} = \frac{\text{Sum (class X number of trees in class)}}{\text{Total number of trees X maximal disease index}} \text{ X } 100\ \%$$

The severity (DS) of durian stem canker was evaluated based on the canker severity scale with a slight modification, from 0 to 4 (Anderson & Guest, 1990; Tho *et al*., 2015); 0 = no symptoms; 1 = canker area < 100 cm^2; 2 = canker area > 100 cm^2 but < 70% girdling of trunk; 3 = canker area > 100 cm^2 and > 70% girdling of trunk and, 4 = tree death due to cankers (Table 2). Early symptoms of durian stem cankers appear as small lesions with dark gum-like ooze that turns into dark patches extending around the trunk of a durian tree. Upon reaching the severe stage, dieback on branches and defoliation occurs and the tree gradually dies.

Table 2: A modified durian stem canker severity scales from 0 to 4 with the observation of disease symptoms in the field

Canker Severity	Symptom Description	Symptom Observation
0	No canker symptoms	
1	Area of cankers less than 100 cm^2	
2	Area of cankers more than 100 cm^2 but less than 70% girdling of the main trunk	
3	Area of cankers more than 100 cm^2 and more than 70% girdling of the main trunk	
4	Defoliation/tree dead due to canker	

Soil Sampling and Soil Analysis

Composite soil from 10 randomly selected durian trees in a sampling plot (50 m X 50 m) were sampled. The soil samples were collected from a soil depth of about 5 cm under the durian tree canopy. For soil pH analysis, 5 g of air-dried soil sample was added into 5 mL of distilled water (ratio 1:1) and stirred thoroughly for 5 seconds using a vortex mixer. The mixture was left to stand for 10 minutes before being analysed using a calibrated benchtop pH meter (TRANS Instruments BP3001) (McLean, 1982).

A soil texture analysis was performed to measure the proportions of clay (< 2 µm), silt (2-50 µm), and sand (50-2,000 µm) of the composite soil using a Particle Size Analyser (Anton Paar PSA 1190). The wet dispersion technique was used where a few drops of the prepared slurry solution (the amount of soil and water depends on soil texture to form slurry solution) [Figure 2 (A)] were transferred into an autosampler of the PSA for sample measurement (Anton Paar, 2022). The characteristics of soil texture were obtained [Figure 2 (B)].

Data Presentation and Statistical Analysis

All data was recorded and tabulated in Microsoft Excel Office 16. Descriptive statistics in the form of histograms and scatter plots were used to visualise and present the recorded data. Pearson correlation (r) was used to analyse the correlation between disease data and soil data using IBM SPSS Statistics 25.

Results and Discussion

Disease Observation of Durian Stem Canker

Infected durian trees were observed to have dark wet patches on the tree trunks [Figure 3 (A-E)] which showed similar symptoms of durian stem canker disease as described by Zakaria (2020) and Zakaria (2022). While the outer bark surface was observed to have dark patches, the inner bark tissue had reddish-brown lesions after the bark surface was excised [Figure 3 (D)]. As the disease progresses into a severe state, necrotic symptoms showing browning leaves, defoliation and dead trees can be observed [Figure 3 (H)].

Forest areas or open woodlands were common habitats for vectors such as termites, ants, and beetles. Unfortunately, durian trees grown in such geographical environments are at risk as the presence of those vectors can escalate the spread of pathogen spores between lower tree bark sections and upper leaf branches (Keast & Walsh; 1979; Mueller & Gerardo, 2002; Mathew *et al*., 2012; Macháčová *et al*., 2022; Merga, 2022). Durian trees with signs of termite infestation showed inconsistent stem fissures [Figure 3 (G)].

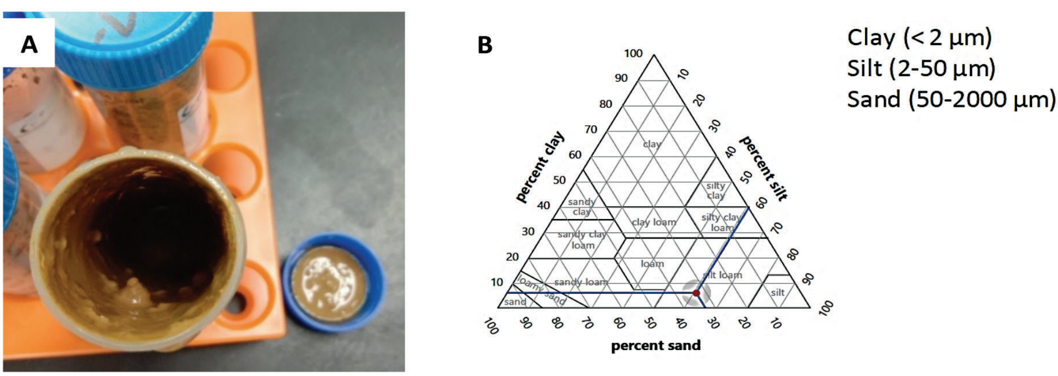

Figure 2: (A) A slurry solution was prepared with a higher amount of soil to water, adjusted to different soil textures. (B) Soil texture triangle showing a result of silt loam characteristics (low clay, moderate sand, and high silt)

Source: Anton Paar (2022)

Heavy rain and flooded areas were more prone to the rapid spread of *Phytophthora* zoospores (Merga, 2022; Mestas *et al*., 2022; Misman *et al*., 2022). This happened in one of the Melaka orchards (orchard 13) when several dead trees with dry leaves were spotted after being flooded [Figure 3 (H)]. Disease assessment confirmed that more than half of the trees in the orchard were infected with stem cankers. Besides, topographical factors like orchards with slopes (e.g., orchard 2 - Kelantan and orchard 3 - Penang) also contribute to severe waterlogging especially when water pools in low lying areas in the orchard. Orchards with severe waterlogging issues would be more prone to constrained plant growth and more susceptible to pathogen invasions (Dron *et al*., 2021).

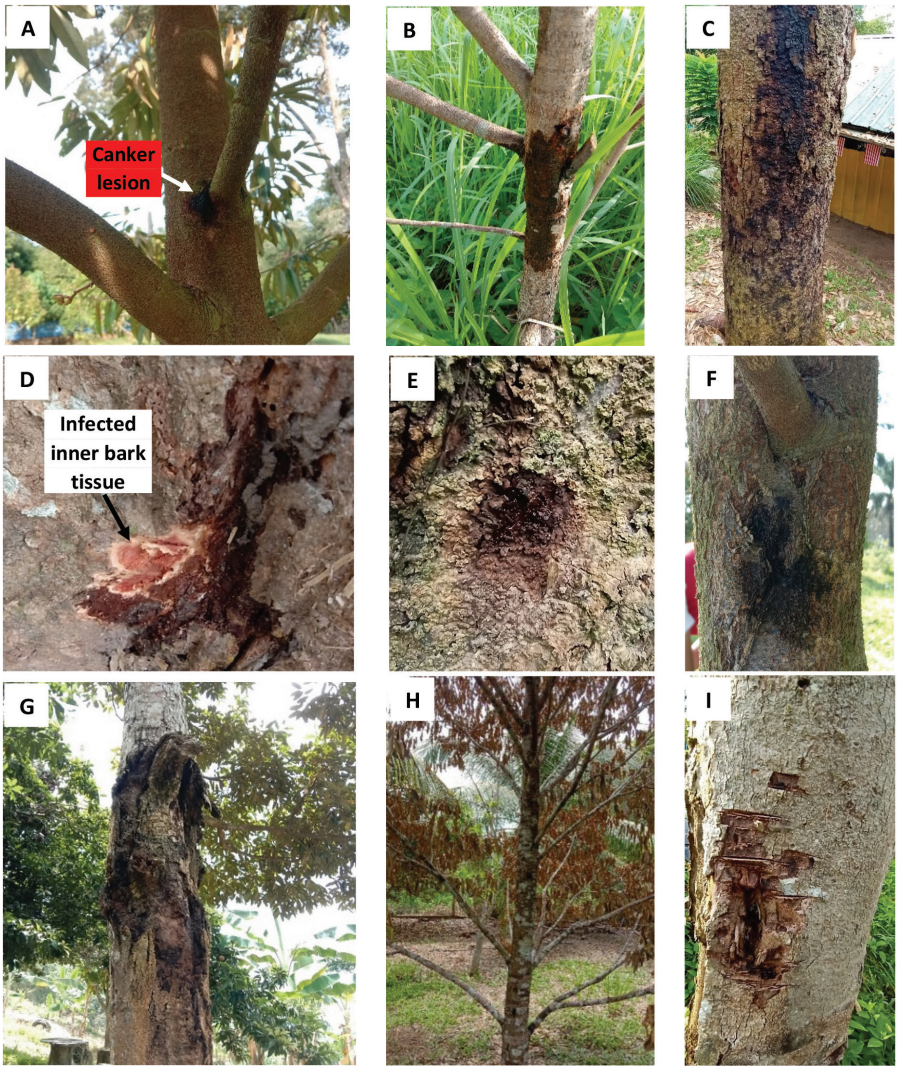

Figure 3: The stem canker symptoms at different durian orchards. (A-C) Stem canker symptoms from mild to severe. (D-E) A close-up observation of wet stem canker lesion. (F) A drying canker lesion after chemical treatments [active ingredient: Fosetyl aluminium]. (G) Severe stem canker with termite infestation. (H) Dying durian tree after flooding. (I) A stem canker infection was observed on a purposely injured (blade-cut) durian tree to enhance flowering (local beliefs and practices)
Source: Authors

Local grower practices such as wounding durian trees to induce flowering increase the risk of stem canker infections. This is an inappropriate practice that can cause the trees to be more vulnerable to a stem canker invasion with open wounds making it easier for the pathogen to infect the tree [Figure 3 (I)]. However, the risk is depending on the tree susceptibility and pathogen virulence (Kännaste *et al*., 2023). It is possible to control stem canker if the disease is detected during the early stage showing mild symptoms [Figure 3 (A)]. For example, in Johor (orchard 14) canker lesions were managed and treated on time by applying systemic fungicide (active ingredient: Fosetyl aluminium), which saw the canker lesion gradually drying out [Figure 3 (F)].

Durian Stem Canker Incidence and Disease Severity Index

The durian trees in 15 orchards around Peninsular Malaysia were seen to be at risk of distressing points when most orchards including young ones (< 10 years) showed a high incidence of stem canker with severe lesion symptoms. Out of 15 durian orchards, five young orchards had stem canker incidence (DI) ranging between 3% and 71.4% and a disease severity index (DSI) of between 0.8% and 42.9% (Figure 4). Meanwhile, in old orchards (≥ 10 years) the highest DI had reached 100% (orchards 9 and 10 - Selangor) with the lowest DI (< 40%) in orchard 5 (Kelantan) and orchard 15 (Johor) (Figure 4). In addition, the DSI was also moderately high, ranging between 10.2% and 63%. In coastal areas of Cambodia, older durian trees were also observed to be more prone to higher disease severity (Zakaria, 2022). This suggests that under favourable conditions, the older trees will face a significant threat of severe stem canker and could easily infect nearby susceptible younger trees.

Three decades ago, Khew (1990) documented that in Penang, the highest incidence rate of stem canker was 30%. Our recent observations reveal a notable increase in severe stem canker incidence in Seberang Perai and Georgetown (orchards 3, 4, and 8) (Figure 4). This study represents the latest local survey of durian stem canker in Penang since Khew's report. Now, various durian varieties are extensively cultivated, and there is unquestionably a higher incidence of stem canker compared with three decades ago. This highlights the importance of ongoing monitoring for durian stem cankers, as early detection plays a vital role in the implementation of effective disease control strategies.

Several young orchards in this study showed moderately high DI and DSI such as orchards 2, 6, and 12 that without proper disease management strategies, these orchards will be expected to face increased infection risks from the early stages of stem canker infection. The increase of stem

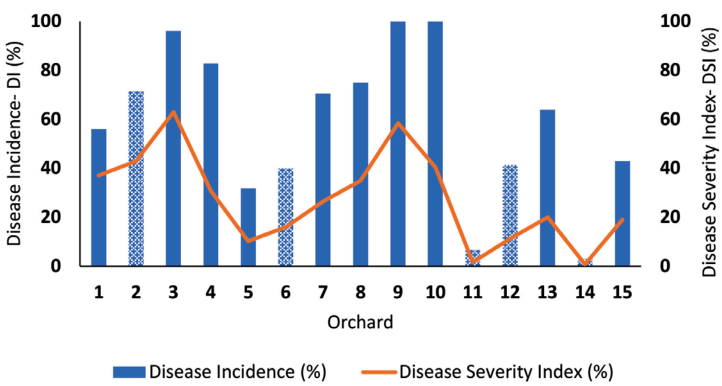

Figure 4: A total of 15 durian orchards from Peninsular Malaysia were assessed for stem canker disease from May 2022-March 2023. Overall, young orchards (< 10 years; blue-dotted pattern) had lower disease incidence (DI) and disease severity index (DSI) compared to old orchards (≥ 10 years; solid blue)

canker severity in the new orchards may be due to the monoculture of susceptible durian hybrid clones such as the most popular Musang King clone (D197). However, a lack of knowledge on stem canker management among new growers poses a significant threat to the durian industry, particularly amid climate changes that have brought heavy rains conducive to the spread of *Phytophthora* infections (Ahmad *et al*., 2020; Mustafa, 2022).

Soil pH Conditions

Our findings on soil pH conditions in different durian orchards showed that under the influence of acidic soil pH (< pH 5.0), durian orchards are prone to the spread of stem canker. A weak negative correlation (r = –0.220) was significantly shown between soil pH and disease incidence (Figure 5). This can be explained by the survival and growth of both the pathogen (*Phytophthora* sp.) and the host (durian trees). *Phytophthora* is viable in soil pH ranging from acidic to slightly neutral (3.5-6.6), and its growth could be inhibited at soil pH above 7.0 (Falcon *et al*., 1984; Andrivon, 1994; Ann, 1994; Jung *et al*., 2000). The durian growth and development are best in slightly acidic fertile soil (5.5-6.5) (Zakaria, 2020). Hence, at lower soil pH below 5 (very acidic), durian trees will grow under abiotic stress conditions (very acidic soil). This would then affect the nutrient availability in the soil and the uptake amount by the durian tree, causing unhealthy durian growth (McCauley *et al*., 2009; Neina, 2019). Eventually, it causes durian trees to be more susceptible to disease.

A total of four young orchards (orchards 6, 11, 12, and 14) faces a notable susceptibility to stem cankers due to the soil pH ranging between 4.14 and 5.56 (more acidic soil) (Figure 5). Several studies have observed a reduction in *Phytophthora* zoospores germination and suppression of disease development in crops at low soil pH levels (Kong *et al*., 2009; Gillespie *et al*., 2020), but Li *et al.* (2022) showed that higher *Phytophthora* DNA could also be found at acidic soil pH. This indicated that under certain conditions, the *Phytophthora* pathogen could be infectious with the presence of highly survival reproductive structures such as oospores and chlamydospores in the soil, mainly depending on the host susceptibility as well as the pathogen aggressiveness and viability (Judelson & Blanco, 2005; Jönsson, 2006; Brugman *et al*., 2022).

Soil Texture (Proportion of Clay, Silt, and Sand)

Generally, all 15 infected durian orchards were found to have a high proportion of finer particles in soils which are clay and silt, ranging between 42.1 and 98.9% (clay + silt) (Figure 6). Both the clay and silt proportions were negatively correlated with stem canker incidence (DI clay/

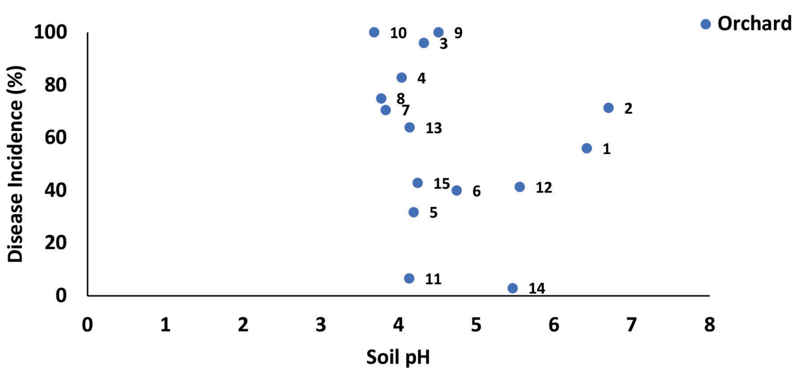

Figure 5: A total of 150 composite soil samples from 15 durian orchards were analysed for soil pH. There was a weak correlation (r = –0.220) between soil pH and disease incidence of stem canker. This negative correlation indicated that with acidic soil of lower than pH 5.0, durian orchards were more prone to higher stem canker incidence. Correlation is significant at the 0.01 level (2-tailed)

r = –0.306; DI silt/ r = –0.166) and disease severity index (DSI clay/ r = –0.411; DSI silt/ r = – 0.155), showed that higher DI and DSI were observed in durian orchards with a lower proportion of fine soil particles like clay and silt. The presence of sandy soil elevated the potential for the spread of stem cankers in these orchards. A subtle yet obvious positive correlation occurred, linking the proportion of sand in the soil with disease parameters (DI/ r = 0.199; DSI/ r = 0.206) (refer to Figure 4 for DI and DSI values).

In the soil, with continuous heavy rains and water-logged the *Phytophthora* zoospores can swim following water movement (Kasteel *et al*., 2023). However, extremely high levels of clay and silt in the soil may limit the zoospores mobility through fine-textured soil due to soil compaction during the dry season hence, the dissemination of disease will be lowered (MacDonald & Duniway, 1978; Jung *et al*., 2000). Therefore, it can be implied that the orchards with a finer texture of soil particles primarily depend on the presence of water which can facilitate the zoospores movement from tree to tree. Particularly, most orchard having silt that is slippery when wet and do not stick together as strongly as clay particles. This poses a great risk especially new areas of durian cultivation having the greatest clay and silt soil properties (Figure 6).

Conclusions

This study provides the latest information on the current status of durian stem cankers, addressing a notable gap as the previous disease report was recorded for the Penang area more than three decades ago. The stem canker disease assessments of durian orchards in Peninsular Malaysia showed varying levels of stem canker incidence and disease severity index, ranging from low to moderately high, DI = 6.67% to 100% and DSI = 0.75% to 63.00%, respectively. From this study, it can be expected that young durian orchards (below 10 years) possess a great risk of severe stem canker infection and rapid disease spreading without proper disease management strategies being implemented. Especially when susceptible durian growth occurs under abiotic stress, which eventually triggers the pathogen such as in very acidic soil below pH 5.0. Furthermore, it will deteriorate durian plant health by affecting their nutrient uptake, leading to weakened plants that are more susceptible to stem canker disease. Soil

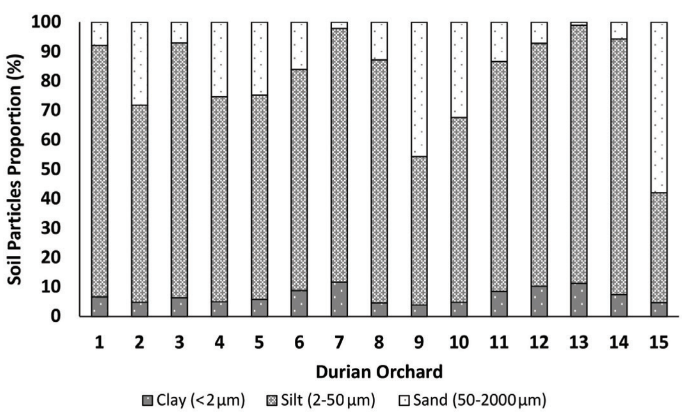

Figure 6: The proportion of clay, silt, and sand was analysed using composite soil samples from 15 durian orchards, where the total proportion of clay, silt, and sand per soil sample is 100% (clay + silt + sand = 100%). Overall, most durian orchards were found to have soil texture of either silt or silt loam which have a higher proportion of finer particles (silt; 2-50 µm). The greatest disease incidence and severity index were observed in orchards with low amounts of clay and silt (indicating a negative correlation) while showing a positive correlation with high sand content in the soil (refer to Figure 4 for DI and DSI values). The correlations are significant at either 0.01 or 0.05 level (2-tailed)

texture is also a secondary factor that may contribute to the increased dispersal of disease. For new growers making decisions on land suitability for durian cultivation, it is crucial to avoid soil with a higher proportion of sandy soil that can facilitate the movement of zoospores in waterlogged areas. Moreover, monoculture has underlying risk factors contributing to rapid disease progression. Therefore, durian growers should consistently monitor the soil conditions and conduct assessments for stem canker disease. This proactive approach serves as a valuable reference for predicting potential disease outbreaks in the future.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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