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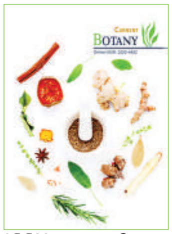

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Morphological diversity and disease severity of *Ceratocystis fimbriata* on duku (*Lansium domesticum*) varieties in South Sumatra

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ABSTRACT

Wilt and stem canker diseases have caused sudden mortality of duku (*Lansium domesticum*) trees in several major production districts of South Sumatra Province, Indonesia. First reported in 2013, the disease has led to up to 100% tree mortality in severely affected orchards by 2025. The causal species, *Ceratocystis fimbriata*, was consistently isolated from symptomatic tissues and identified based on morphological characteristics and β-tubulin region analysis. Field observations revealed variation in disease incidence among duku varieties, with lower levels in Ogan Ilir compared to Ogan Komering Ulu Timur, Ogan Komering Ulu Selatan, and Musi Banyuasin. The capacity of this pathogen to infect multiple duku varieties represents a significant threat to the genetic diversity of duku in Indonesia.

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INTRODUCTION

Duku (*Lansium domesticum*) produces delicious edible fruits with numerous health benefits (Zulaikha *et al.*, 2022). Duku fruit resembles langsat or kokosan, but differs in that it has an elongated, egg-like round shape, thin skin, small seeds, a closed canopy with dense foliage, and hairless leaves (Hanum *et al.*, 2013; Ardila *et al.*, 2022). In terms of its stem, this plant has a monopodial branching type, in which the main stem is clearly visible and easily distinguished from its branches by direction and size (Syafitri *et al.*, 2016). Duku also contains antifeedant compounds that function as environmentally friendly and human-safe pest repellents (Abdallah *et al.*, 2022). Several ASEAN countries, such as Thailand, Malaysia, and the Philippines, recognize duku as one of their major fruits (Abdallah *et al.*, 2022).

Fertile soil and favorable climatic conditions enable duku to be widely cultivated in various provinces of Indonesia, such as Sumatra, Java, and Kalimantan (Sugiarto *et al.*, 2022). Duku production in South Sumatra Province in 2014 reached 104,567 quintals (BPS South Sumatra Catalog, 2015). According to the BPS OKI Catalog (2017), duku production in Ogan Komering Ilir Regency in 2016 was 5,814 tons. In Ogan Komering Ulu Timur Regency, duku production in 2016 reached 2,045.5 tons based on the BPS OKU Timur Catalog (2017). Meanwhile, duku production in Ogan Komering Ulu Selatan Regency in 2016 was 695,333 quintals, according to the BPS OKU Selatan Catalog (2017). For Ogan Komering Ulu Regency, duku production in 2014 was recorded at 48,143 quintals (BPS South Sumatra Catalog, 2015). Duku from South Sumatra has long been widely recognized as “Duku Palembang” in the national market and “Duku Komering” in the local market. Several types of local duku are usually named after their region of origin, but the most popular ones are Duku Palembang and Duku Rasuan. Both were designated as national superior varieties in 1995 under the names Palembang and Rasuan. Considering its popularity and high economic value, the South Sumatra Provincial Government designated duku as the “Floral Mascot” of the region (Deroes & Wijaya, 2010).

The cultivation of duku (*L. domesticum*) is inseparable from pest and disease disturbances. Several pests such as red caterpillars, fruit flies, stink bugs, and tree termites have the highest populations compared to other insects, causing damage to various parts of the duku plant, especially the tree trunk (Umayya *et al.*, 2024). Several vertebrate phyla, such as green pigeons and bats, are also pests that attack duku fruits (Sinaga *et al.*, 2020). Pest cases on duku have also been reported in the Philippines (Silva *et al.*, 2019). A lethal wilt disease caused by *Ceratocystis* was reported in 2017 on duku plants along the Komering River, including Lubuk Batang (Ogan Komering Ulu District) and Rasuan (East Ogan Komering Ulu District), all located in South Sumatra Province, Sumatra. Field observations in 2019 found this disease sporadically killing duku trees in East Ogan Komering Ulu District (within 100 km of the disease origin). Between 2019 and 2021, the occurrence of this disease spread widely across eight districts in South Sumatra, namely Ogan Komering Ulu, South Ogan Komering Ulu, East Ogan Komering Ulu, Musi Banyuasin, North Musi Rawas, Musi Rawas, Ogan Komering Ilir, and Muara Enim (Muslim *et al.*, 2022).

Wilt disease caused by *Ceratocystis* is a serious threat to the production of various tree crops (Marincowitz *et al.*, 2020). In South Sumatra, this disease poses a major threat to *Mangifera indica* (Pratama *et al.*, 2023a), causes lethal wilt in soursop (*Annona muricata*) (Pratama *et al.*, 2023b), stem canker and wilt in mahogany (*Swietenia macrophylla*) (Muslim *et al.*, 2025), and Italian cypress (*Cupressus sempervirens*) (Pratama *et al.*, 2025). It also attacks various industrial forest species, causing severe damage to *Acacia mangium* (Amelia *et al.*, 2024) and *Eucalyptus* (Pratama et *al.*, 2023c). The fungus infects through wounds on the plant and spreads throughout the vascular system, leading to characteristic symptoms such as wilting, dieback, and root rot, which often result in plant death and significant yield losses. Susceptibility to this disease varies substantially among different plant varieties. While some varieties exhibit strong genetic resistance, characterized by defense mechanisms that inhibit pathogen growth and proliferation, others are highly susceptible, accelerating disease development and increasing symptom severity (Smith & Jones, 2023). Therefore, research on the resistance of different duku varieties in South Sumatra to *Ceratocystis* provides crucial baseline information for effective *Ceratocystis* disease management.

RESEARCH METHODS

Research Location

Field observations were conducted on two predominant *Lansium domesticum* varieties in South Sumatra, namely Duku Palembang and Duku Rasuan. Observations of the Palembang variety were carried out in two regencies, Ogan Ilir (OI) and Musi Banyuasin (MUBA). In Ogan Ilir, the surveyed sites included the villages of Sirah Pulau Padang, Serdang Menang, Sukaraja, Kotabumi, and Tanjung Lubuk, whereas in Musi Banyuasin, observations were conducted in Kasmaran, Babat Toman, Bruge, Sereka, Sanga Desa, and Tanjung Raya. Survey locations were selected using the purposive sampling method. Observations of the Rasuan variety were conducted in Ogan Komering Ulu Timur (OKUT) and Ogan Komering Ulu Selatan (OKUS) regencies. In OKUT, observations took place in the villages of Sukabumi, Harisan Jaya, Campang Tiga Ilir, Negeri Agung, Bantan, Bantan Pelita, and Pulau Negara. In OKUS, survey sites included Bumi Agung, Tanjung Beringin, Muara Dua, Damarpura, Buana Pemaca, Gunung Tiga, and Simpang Hadji. For each village, observation plots were established in three duku orchards, resulting in a total of nine plots per site. Within each orchard, the incidence and severity of disease were assessed. Diseased plant samples collected from each village were subsequently isolated to identify the causal pathogens and to examine their morphological diversity.

Isolation and Diversity of Pathogen Isolates

Isolation from diseased tissue was conducted using a modified carrot baiting method (Moller & Devay, 1968). Diseased tissue samples (2×2 cm) were surface-sterilized with 2% sodium hypochlorite (NaClO), placed between two thin carrot slices (5 mm), enclosed in a plastic container, and incubated at 20-25 °C for 7-10 days. Before use, carrot slices were sterilized in a 500 mg streptomycin solution to suppress bacterial growth. Following the emergence of mycelial growth on the carrot surface, the mycelial mass was transferred onto malt extract agar (MEA) and incubated at 25 °C. Morphological characteristics of all resulting isolates were subsequently examined. Isolation by direct plating was generally similar to the carrot baiting method, except that the sterilized diseased wood tissue was directly placed onto the culture medium.

Colony Morphological Characterization of *Ceratocystis fimbriata*

Morphological characterization of fungal isolates was conducted by transferring 7-day-old pure cultures using a 5 mm cork borer and placing them at the center of 9 cm Petri dishes containing PDA and MEA media. Cultures were then incubated at 25-27 °C. Isolates were subsequently described both quantitatively and qualitatively. Quantitative characterization was performed by measuring the diameter of mycelial growth on PDA and MEA media. Colony area was recorded every two days for up to 30 days, or until the colonies completely covered the surface of the medium in the Petri dishes. Qualitative characterization included observations of odor, colony color, and vegetative growth. Colony color was assessed on 14-day-old isolates, while colony shape and margin were examined after 14 days of incubation. For vegetative growth assessment, colonies of fungi associated with *Ceratocystis* were obtained from 7-day-old cultures using a 5 mm cork borer, transferred onto PDA and MEA media in 9 cm Petri dishes, and incubated under varying temperature and light conditions. The vegetative growth of fungi associated with *Ceratocystis* was evaluated at three temperatures: 10 °C, 25 °C, and 35 °C. Growth was assessed by measuring colony diameter. For testing, 7-day-old pure isolates were excised with a 5 mm cork borer, placed in the center of 9 cm Petri dishes containing 10 mL of PDA or MEA medium, and incubated at 10 °C, 15 °C, 20 °C, 25 °C, and 30 °C. Colony diameters were measured at 2-day intervals over a period of 30 days.

Molecular Identification and Phylogenetic Analysis

Pure cultures used for DNA extraction comprised four isolates representing varieties from affected regions, namely Ogan Ilir (OI), Ogan Komering Ulu Selatan (OKUS), Ogan Komering Ulu Timur (OKUT), and Musi Banyuasin (MUBA). The isolates were cultivated in Potato Dextrose Broth (PDB) at 25 °C for 10 days. Mycelia obtained from the PDB cultures were filtered, dried, and finely ground using a mortar. Genomic DNA was extracted using the YeaStar Genomic DNA Kit (Zymo Research Corporation, Irvine, CA, USA). DNA concentration and purity were assessed with a NanoDrop ND-1000 spectrophotometer (NanoDrop Technologies, Montchanin, DE, USA).

PCR amplification and sequencing were performed using the beta-tubulin primers βT1a (TTCCCCCGTCTACTTCTTCATG) and βT1b (GACGAGATCGTGTGTGTTGAACTC) (Pratama *et al.*, 2021a). Reactions (50 μL) contained 20 μL Master Mix (Eppendorf, Hamburg, Germany; 25 mM $MgCl_2$, 0.06 U/μL Taq DNA polymerase, 0.2 mM each dNTP), 1 μL of each forward and reverse primer, 1 μL DNA template, and 27 μL sterile water. PCR was conducted in a C1000 Touch thermal cycler (Bio-Rad, Hercules, CA, USA) with the following conditions: initial denaturation at 94 °C for 3 min; 30 cycles of denaturation at 94 °C for 30 s, annealing at 52 °C for 30 s, and extension at 72 °C for 1 min; followed by a final extension at 72 °C for 10 min. Amplicons were sequenced at 1st BASE (Malaysia), and sequences were compared against the GenBank database using BLASTn (NCBI, Bethesda, MD, USA). Relevant sequences were aligned and edited using BioEdit software (Pratama *et al.*, 2021b).

The phylogenetic tree was visualized and edited in MEGA v.7 using maximum parsimony (MP) analysis with 1,000 bootstrap replicates (Kumar *et al.*, 2016). Branch support was assessed through 1,000 bootstrap resamplings of the aligned sequences. In the MP analysis, calculated metrics included tree length, retention index, and consistency index. *C. virescens* were designated as the outgroup taxon, while the ingroup was treated as monophyletic.

Observation of Symptoms, Disease Incidence, and Disease Severity

In each observation plot, all duku plants were examined. For diseased duku plants, observations included disease symptoms such as wilting, yellowing, and drying of leaves. In the sapwood tissue, the presence or absence of lesions, cancer symptoms, and holes or wounds caused by insects or squirrels was recorded. The incidence of disease attack in the field was determined by calculating the number of diseased plants divided by the total number of plants observed in each plot. The calculation of disease incidence percentage referred to Kuruppu *et al.* (2025) using the following formula:

$$P = \frac{a}{b} \times 100\%$$

Note:
P = Disease incidence percentage
A = Number of diseased plants
B = Total number of plants observed

The intensity of disease attack or the severity of plant disease is assessed based on wilting symptoms observed on the leaves in the field, and the calculation is carried out using the following formula (Yang *et al.*, 2023). Disease incidence and intensity data were analyzed using R-Studio.

$$KP = \frac{\sum(\text{ni x vi})}{\text{N X V}} \text{X}100\%$$

Note:
KP = Disease severity (%)
ni = The number of plants or plant parts assigned to the i-th severity score.
vi = Plant damage score value
N = The number of plants or plant parts observed.
V = The highest plant damage score

RESULTS

Symptoms of Attack in the Field

Field observations of disease symptoms in several duku (*C. domesticum*) varieties indicated consistent and characteristic manifestations. Infected trees exhibited foliar wilting, typically initiating at the apical shoots or branch tips. Affected leaves progressively wilted, turned chlorotic, and became necrotic, and ultimately abscised, leading to partial or complete tree mortality (Figure 1a). Necrotic lesions resembling scratches or bite marks, often attributable to squirrels and monkeys, were frequently observed on stems. Additional stem injuries were associated with mechanical damage caused by agricultural implements (Figure 1b). Examination of the sapwood in symptomatic trees revealed extensive linear lesions consistent with fungal colonization (Figure 1c). The continuous progression of these lesions extended into the heartwood (vascular tissues), resulting in impaired translocation of water and nutrients, thereby inducing systemic wilting, desiccation, and eventual tree death.

Diversity of *Ceratocystis* Isolates from each Variety

At the early growth stage, all isolate colonies exhibited a predominantly white coloration. After 10 days of incubation, the colonies developed an olive-gray coloration, characterized by irregular mycelial morphology and undulate margins (Figure 2).

All *Ceratocystis* isolates showed no significant differences in morphology or microscopic features. Observations at 7-14 days of incubation on MEA at 25 °C revealed that perithecia matured by day 7, dark brown to black, with subglobose to globose bases. The necks were erect or slightly curved, black at the base, and subhyaline toward the lower part. Ostiolar hyphae released hyaline, hat-shaped ascospores. Conidiophores produced cylindrical conidia, and all isolates formed oval, thick-walled chlamydospores (Figure 3).

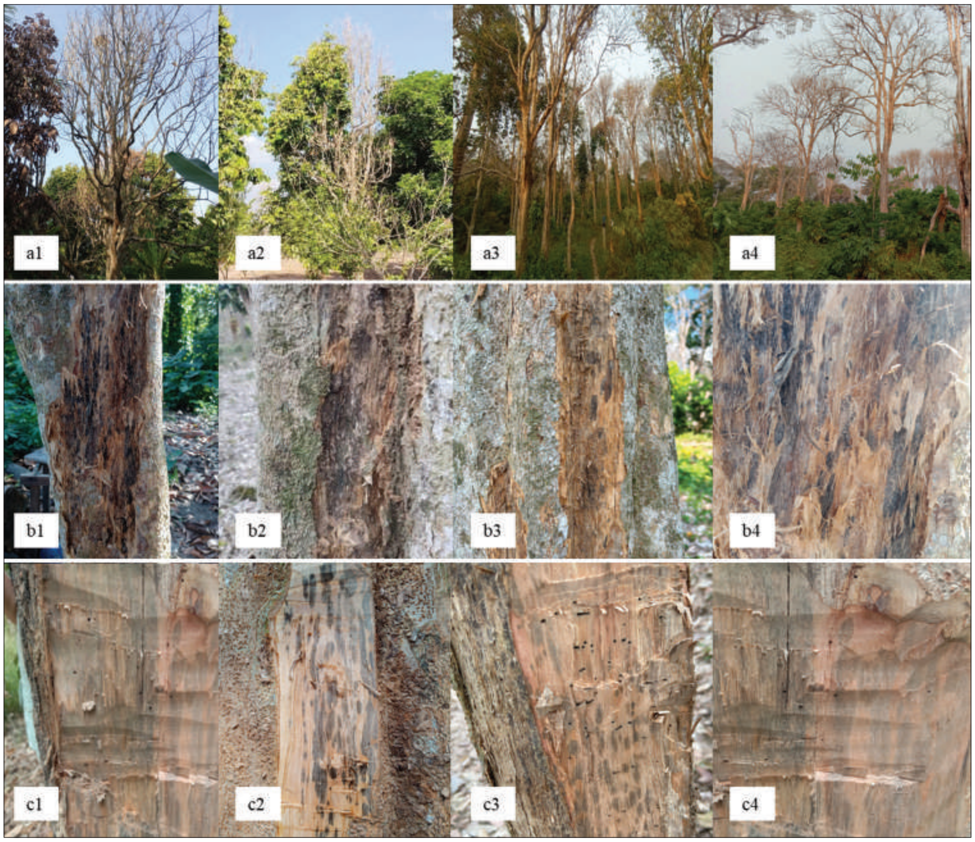

Figure 1: Symptoms of wilt disease in duku plants. a) Infected duku plants exhibit leaf wilting, eventually leading to plant death and desiccation, b) Wounds observed on the stem of infected duku plants and c) Lesions formed on the stem. 1-OKUT, 2-OKUS, 3-OI, 4-MUBA

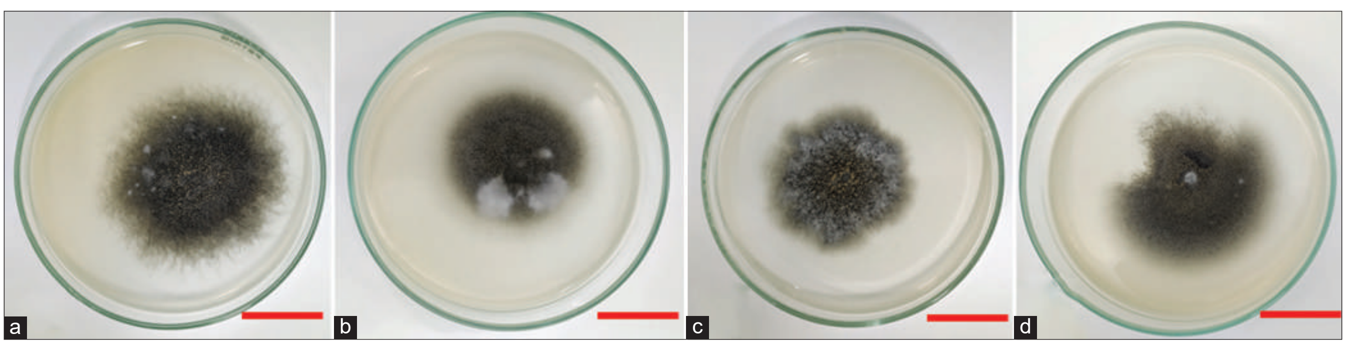

Figure 2: Isolates of *C. fimbriata* on MEA medium: a) OKUT, b) OKUS, c) OI and d) MUBA. — = 4.5 cm

Based on the morphological measurements of Ceratocystis isolates obtained from various duku (*L. domesticum*) varieties, represented by isolates OKUT, OKUS, OI, and MUBA, no significant differences were observed in their morphological characteristics. In general, the dimensions of the isolates were as follows: the base of the perithecium measured 130.3-426.5 × 125.2-343.2 μm, the perithecial neck 358.1-789.9 μm, the ostiolar hyphae 31.5-44.2 μm, the hat-shaped ascospores 3.2-5.6 × 4.8-6.6 μm, the cylindrical conidia 11.4-26.4 × 3.2-5.2 μm, the barrel-shaped conidia 5.9-11.9 × 4.3-7.7 μm, and the chlamydospores 9.7-16.1 × 5.3-10.2 μm. Overall, the observed Ceratocystis isolates showed morphological similarity to those found on *Mimusops elengi* in Indonesia (Pratama *et al.*, 2021a), as well as to isolates from *Prosopis cineraria* and *Dalbergia sissoo* collected in Oman and Pakistan. These studies concluded that, morphologically, the isolates belong to *C. manginecans*, a synonym of *C. fimbriata* (Al Adawi *et al.*, 2013).

All isolates exhibited the fastest growth at 25 °C, with the highest growth rate recorded for the OKUS isolate (4.6-5.0 mm/day). This indicates that 25 °C is the optimal temperature for the growth of this fungus. Variation in growth rates was observed among the isolates. The OKUS isolate consistently showed the highest growth rate at 15 °C, 20 °C, and 25 °C, making it the fastest-growing isolate. In contrast, the MUBA isolate tended to have the lowest growth rate at nearly all temperatures.

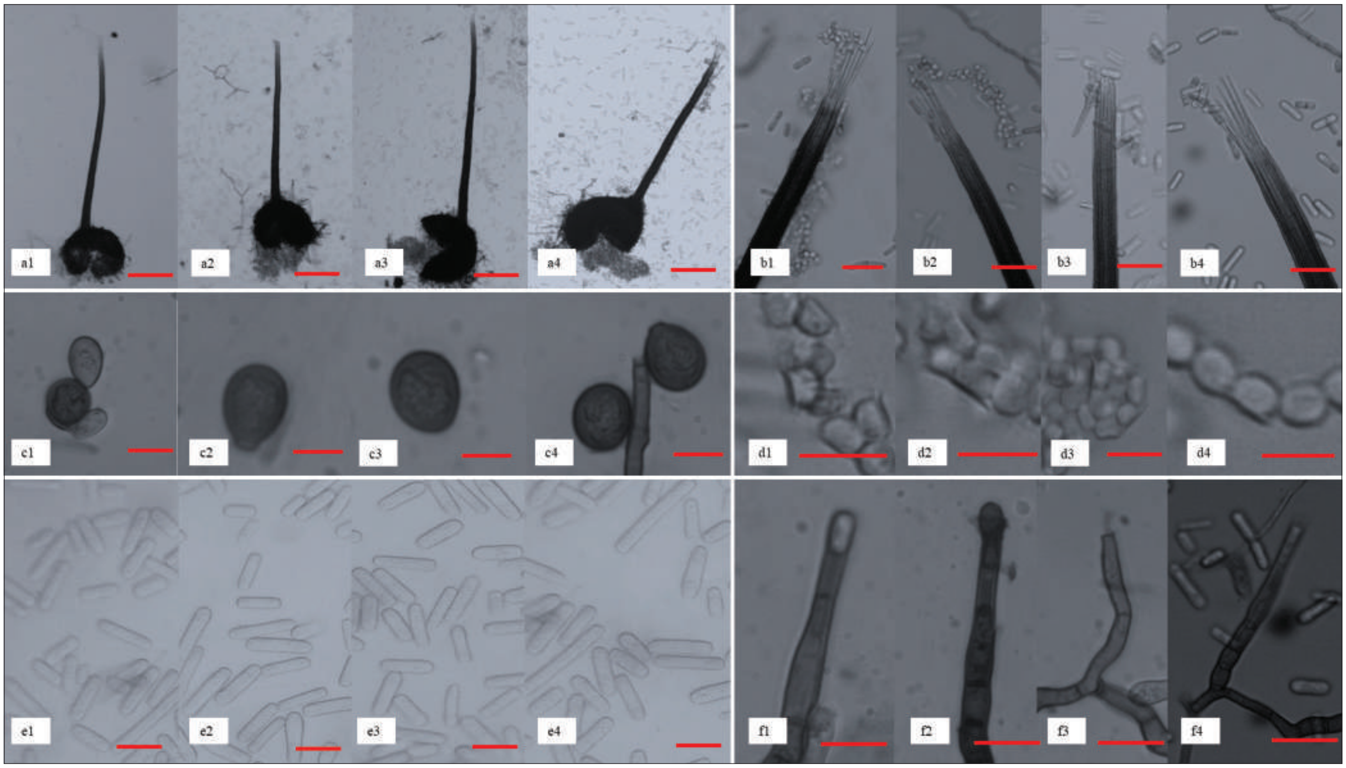

Figure 3: *C. fimbriata* morphology. a) Perithecial-shaped ascomata, b) Divergent ostiolar hyphae, c) Chlamydospores, d) Hat-shaped ascospores, e) Cylindrical conidia, and f) Conidiophore/phialide. 1-OKUT, 2-OKUS, 3-OI and 4-MUBA. Scale bars: a=100 μm; b, c, e, f=5 μm

Molecular Identification and Phylogenetic Analysis

PCR amplification of the β-tubulin gene successfully produced a DNA fragment of approximately 550 base pairs (bp). The amplified sequences were deposited in the GenBank database for comparative analysis with other *Ceratocystis* species. Subsequent BLAST searches using the β-tubulin gene revealed that isolates identified as *C. fimbriata* shared 99% sequence identity with their group (Figure 4). Phylogenetic analysis, supported by maximum parsimony with 1,000 bootstrap replications and β-tubulin sequencing, confirmed that all examined isolates belong to the Latin American clade of *C. fimbriata* sensu lato.

Incidence and Intensity of Disease

The Ogan Komering Ulu Timur region exhibited a wide range of disease severity, from symptom-free to very severe. Sukabumi, Harisan Jaya, and Campang Tiga Ilir showed no disease symptoms (0% incidence and intensity), indicating very healthy crop conditions in these locations. In contrast, Bantan Pelita and Pulau Negara experienced extremely severe infections. With incidences of 94.11% and 90.90%, respectively, nearly all plants in these areas were affected. Disease intensity was also very high (89.70% and 81%), classifying them as Very Severe. Negeri Agung (based on two datasets) and Bantan (also based on two datasets) showed varying levels of infection, ranging from Mild to Moderate and Severe. This suggests that even within the same region, environmental conditions or other factors can lead to different levels of disease severity.

The Ogan Komering Ulu Selatan region experienced significant disease outbreaks, with some locations reaching the highest severity levels. In Buana Pemaca and Damarpura, disease incidence reached 100%, meaning all plants in these sites were infected. Disease intensity was also nearly complete (100% and 97.08%), classifying the severity as Very Severe. In contrast, Muara Dua, Bumi Agung, and Tanjung Beringin exhibited lower levels of infection, ranging from Mild to Moderate. The data from Simpang Hadji and Gunung Tiga recorded the lowest incidence and intensity in this region (Mild). Compared to the two previous regions, Ogan Ilir generally showed more favorable conditions. Most sites, including Sirah Pulau Padang, Serdang Menang, and Miji, exhibited no visible disease symptoms (0% incidence and intensity). Only one site, Tanjung Lubuk, showed disease presence, but at a very low level (7.69% incidence and intensity), categorized as Mild. The Musi Banyuasin region displayed varying levels of disease severity, from Mild to Very Severe. Similar to Ogan Komering Ulu Selatan, Sanga Desa and Tanjung Raya experienced extremely severe infections, with both incidence and intensity reaching 100%, classified as Very Severe. Other locations, such as Kasmaran, Babat Toman, Bruge, and Sereka, exhibited Moderate to Mild infection levels.

DISCUSSION

Symptoms of disease attack on duku (*L. domesticum*) across different varieties show similarities, with leaves changing color from green to yellow, followed by partial to complete wilting, and ultimately plant death through dry wilt. The wilting symptoms closely resemble those caused by *Ceratocystis* disease in Spanish

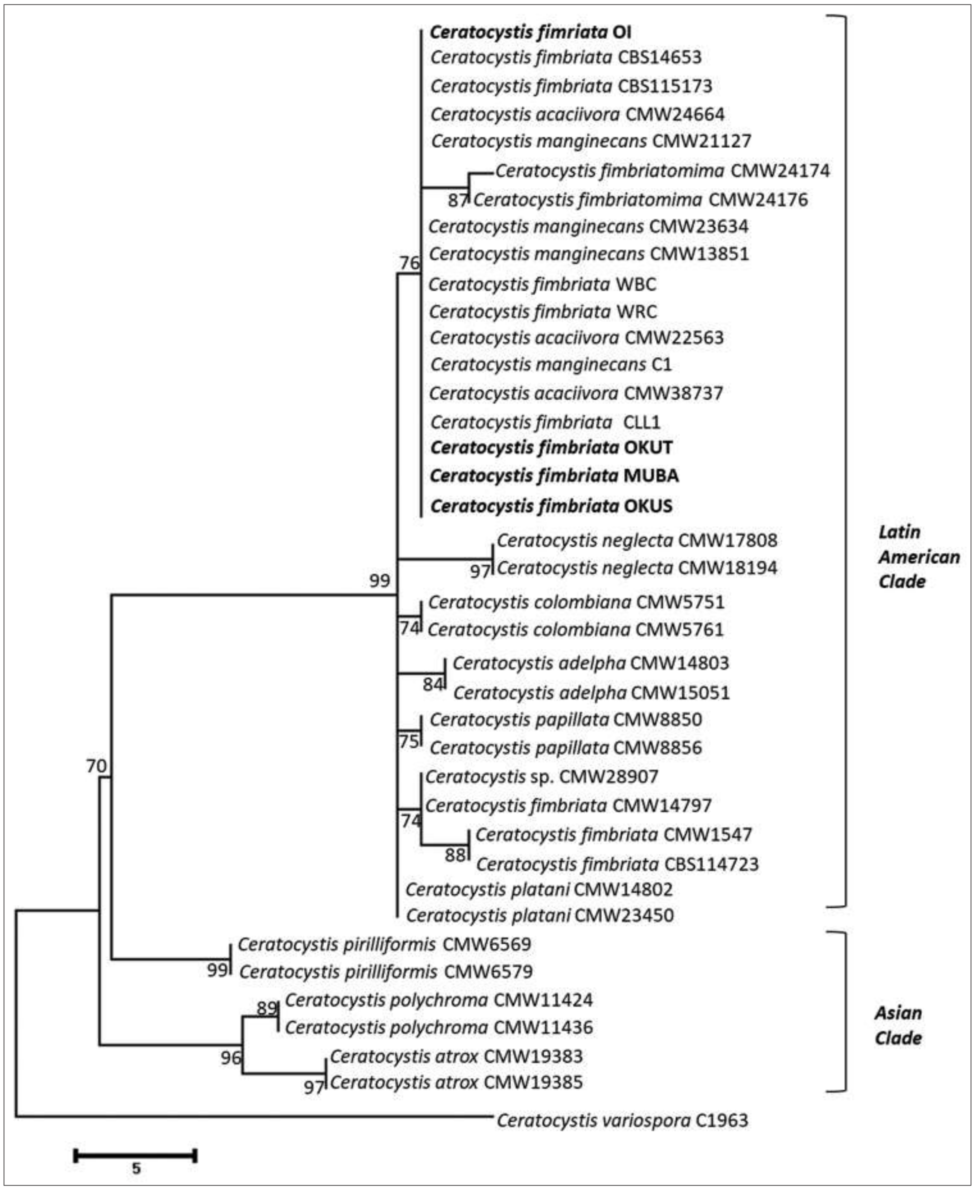

Figure 4: The phylogenetic tree illustrates the relationship of *C. fimbriata* isolated from Duku (*L. domesticum*) in Indonesia (highlighted in bold) with other members of the Latin American and Asian clades. The tree was constructed using maximum parsimony analysis of β-tubulin sequences, with *C. variospora* as the outgroup

cherry (*Mimusops elengi*) and soursop (*Annona muricata*), where leaves wilt and eventually the entire plant dies. In the sapwood of infected duku stems, lesions appear as dark brown to black streaks. These lesions result from pathogen development within the vascular tissues, leading to blockage and tissue damage (Muslim *et al.*, 2022). Symptoms of *Ceratocystis* infection vary by location. In areas with moderate to severe infections such as OKUT, OKUS, and MUBA, combined symptoms are often observed, ranging from dieback of shoots and branches to root infections. In contrast, infections in certain OI locations are limited to shoot and branch dieback. Disease severity is strongly influenced by the presence of holes in the tree caused by ambrosia beetles. The high number of holes observed in severely affected duku trees indicates that ambrosia beetles play a major role in pathogen transmission between trees. Additional wounds are also caused by squirrel and monkey feeding activity. In heavily infected areas, high populations of squirrels and monkeys have been observed gnawing of branches and scratching tree bark. These wounds provide entry points for pathogen infection in duku.

The isolates of *C. fimbriata* exhibited consistency in basic morphological characteristics, although variations were observed in specific dimensions and growth rates. All isolates possessed globose ascomatal bases and straight ascomatal necks, with divergent ostiolar hyphae. Similarly, the shape of chlamydospores was consistent across all isolates, ranging from globose to pyriform. These findings suggest that these general morphological features may represent stable traits of the species, regardless of isolate origin. Comparable characteristics were also consistent with previous descriptions of *C. fimbriata* (Piveta *et al.*, 2016; Syazwan *et al.*, 2021; Pratama *et al.*, 2025). Nevertheless, significant differences were observed in structural dimensions. For example, the OI isolate exhibited a wider range of ascomatal base diameters (136.8-343.2 μm) compared to MUBA (125.2-288.2 μm). Similar differences were also noted in ascomatal neck length, with the OKUS isolate showing the longest range (409.1-789.9 μm), which substantially exceeded that of MUBA (358.1-711.8 μm). These variations may indicate potential genetic differences or environmental adaptations among the isolates.

Analysis of growth rate showed that none of the isolates were able to grow at 10 °C. The optimal temperature for growth of all isolates was 25 °C, with growth rates ranging from 4.0 to 5.0 mm. The OKUS isolate exhibited the highest growth rate at both 25 °C and 15 °C compared with the other isolates, which may indicate that this isolate is more aggressive or adaptive to certain temperature conditions. The reduced growth rate at 30 °C suggests that temperatures above 25 °C do not support optimal growth of these isolates. Variation in growth rate across different temperatures is important to understand in the context of the epidemiology of diseases caused by this fungus (Stahr & Quesada-Ocampo, 2020, 2021). In this study, Ceratocystis isolates from duku (*L. domesticum*) in Indonesia (OI, OKUT, MUBA, and OKUS) were grouped into a single phylogenetic cluster of *C. fimbriata* sensu stricto based on partial β-tubulin sequences. Isolates within this cluster represent the aggressive genotype of *C. fimbriata*, which causes lethal wilt disease on economically important plants worldwide. This genotype corresponds to native populations of *C. fimbriata* on *Coffea arabica* (CBS14653) in Suriname, *Gmelina arborea* (CBS115173) in Brazil (Luchi *et al.*, 2013), *Acacia crassicarpa* (CMW21127) in Indonesia (Oliveira *et al.*, 2015), Eucalyptus hybrids in China (Chen *et al.*, 2013), *Mangifera indica* (CMW23634) in Pakistan (van Wyk *et al.*, 2007) and in Oman (CMW13851) (van Wyk *et al.*, 2005), *A. mangium* (CMW22563) in Indonesia (Tarigan *et al.*, 2011) and Vietnam (C1) (Trang *et al.*, 2018), *Eucalyptus grandis* (CMW38737) in Zimbabwe (Jimu *et al.*, 2015), and *Cupressus sempervirens* (CLL1) in Indonesia (Pratama *et al.*, 2025).

The diversity of disease incidence and severity across the four locations representing these varieties was observed during field

Table 1: Criteria for scoring disease intensity

Score	Field description of symptoms	Severity Criteria
0	The plant leaves are healthy and there is no wilting.	No symptoms
1	Plant leaves wilt and turn yellow with a percentage of 0.1-25%	Mild
2	Plant leaves wilt and turn yellow with a percentage of 25.1-50%	Moderate
3	Plant leaves wilt and turn yellow with a percentage of 50.1-75%	Severe
4	Plant leaves wilt and turn yellow with a percentage of >75.1%	Very severe

Table 2: Morphology of *C. fimbriata* on Malt Extract Agar (MEA)

Morphological characters	Isolates			
	OI	OKUS	OKUT	MUBA
Ascomatal bases Shape				
Shape	Globose	Globose	Globose	Globose
Ascomatal base (w)	136.8-343.2	134.3-327.1	140.8-319.3	125.2-288.2
Ascomatal base (l)	138.2-426.5	147.9-397.6	149.3-408.9	130.3-318.1
Ascomatal necks	Straight	Straight	Straight	Straight
Neck (l)	458.2-728.1	409.1-789.9	441.2-733.1	358.1-711.8
Neck (w) top	11.2-23.1	11.9-21.5	11.7-24.2	10.19-21.9
Neck (w) bottom	23.6-42.9	22.8-44.2	21.8-43.8	20.9-40.9
Ostiolar hyphae				
Shape	Divergent	Divergent	Divergent	Divergent
Ostiolar hyphae (l)	33.8-43.1	31.9-44.2	32.9-43.7	31.5-41.2
Ascospores				
Hat-shaped ascospores (l)	3.2-4.5	3.2-5.6	3.4-5.2	3.3-5.1
Ascospores (w) without sheath	3.3-4.2	3.3-4.5	3.4-4.7	3.2-4.3
Ascospores (w) with sheath	5.1-6.6	5.1-6.1	5.3-6.6	4.8-6.2
Primary conidia (l)	12.8-22.3	13.2-23.2	12.1-26.4	11.4-20.9
Primary conidia (w)	3.4-4.2	3.2-5.2	3.4-4.4	3.2-4.1
Secondary conidia (l)	6.2-11.7	6.8-11.9	7.1-11.2	5.9-10.2
Secondary conidia (w)	4.5-7.2	4.7-7.7	5.2-7.7	4.3-7.1
Chlamydospores				
Shape	Globose to pyriform	Globose to pyriform	Globose to pyriform	Globose to pyriform
Chlamydospores (l)	10.2-14.7	11.1-15.2	10.9-16.1	9.7-14.2
Chlamydospores (w)	5.3-8.8	6.2-9.1	5.4-9.6	6.3-10.2
Culture growth rate				
10°C	0	0	0	0
15°C	2.2-2.8	3.1-3.4	2.1-2.6	2.1-2.4
20°C	4.1-4.3	3.1-3.8	3.2-3.8	3.0-2.8
25°C	4.3-4.8	4.6-5.0	4.3-4.6	4.0-4.4
30°C	3.7-4.1	3.4-4.5	3.4-4.1	3.0-3.8

Table 3: Incidence and intensity of *Ceratocystis fimbriata* disease

Location	Number of Plants	Disease Incidence (%)	Disease Intensity	
			(%)	Criteria
East Ogan Komering Ulu				
Sukabumi	130	0	0	No symptoms
Harisan Jaya	131	0	0	No symptoms
Campang Tiga Ilir	132	0	0	No symptoms
Negeri Agung	115	73.04	66.30	Severe
Bantan	105	12.38	10.37	Mild
Bantan Pelita	17	94.11	89.70	No symptoms
Pulau Negara	33	90.90	81	No symptoms
Negri Agung	95	24.2	35.78	Moderate
Bantan	62	45.16	54.83	Severe
South Ogan Komering Ulu				
Muara Dua	40	37.5	31.25	Moderate
Bumi Agung	29	27.5	20.68	Mild
Tanjung Beringin	27	40.7	20.37	Mild
Buana Pemaca	14	100	100	Very Severe
Damarpura	60	100	97.08	Very Severe
Simpang Hadji	22	4.54	4.54	Mild
Gunung Tiga	21	28.57	15.47	Mild
Ogan Ilir				
Sirah Pulau Padang	76	0	0	No symptoms
Serdang Menang	69	0	0	No symptoms
Miji	82	0	0	No symptoms
Tanjung Lubuk	65	7.69	7.69	Mild
Musi Banyuasin				
Kasmaran	76	15.5	19.4	Mild
Babat Toman	78	32.05	30.45	Moderate
Bruge	82	43.9	42.07	Moderate
Sereka	82	48.7	45.7	Moderate
Sanga Desa	89	100	100	Very Severe
Tanjung Raya	82	100	100	Very Severe

assessments. The OKUT variety showed the highest incidence and severity of disease, while the OI variety exhibited the lowest levels observed. Interestingly, no moderate to severe infections were found in the OI variety; only mild symptoms were recorded. In contrast, disease outbreaks in the OKUT region showed broader development and spread compared to those reported in 2021. According to Muslim *et al.* (2022), in 2021, infections were reported only in Bantan Pelita District, with an incidence of 20.5%. However, by 2024, Ceratocystis infections had expanded rapidly to several additional districts, including Pulau Negara and Negri Agung, which reported the most severe levels of both incidence and intensity. For the OI variety, no Ceratocystis infection was recorded in 2021, but more recently, mild infections were detected, with one site showing symptoms and three other sites remaining uninfected. The OKUS variety showed an expansion of infected areas between 2021 and 2024: in 2021, infections were reported in only four districts, whereas by 2024, infections were found in seven districts, including newly affected areas. A notable increase in incidence was observed in Tanjung Beringin, rising from 11.1% in 2021 to 40.7% in 2024. The MUBA variety did not show expansion of infected areas from 2021 to 2024, with infections consistently found in six districts. Among these, Sanga Desa and Tanjung Raya both recorded the highest severity with 100% incidence. Three districts showed an increase in incidence, while one district, Kasmaran, consistently recorded the lowest incidence (15.5%) without change between 2021 and 2024 (Muslim *et al.*, 2022).

The variation in disease intensity caused by Ceratocystis is influenced by both biotic and abiotic factors. Several biotic factors support the development of this disease. Monkey pests can cause wounds on the stem, while squirrels induce defoliation in the canopy, creating favorable conditions for pathogen growth (Suwandi *et al.*, 2021; Muslim *et al.*, 2022). Insect pests, particularly beetles from the family Nidiludidae, such as *Hypocryphalus mangiferae*, facilitate pathogen entry by boring holes that serve as infection sites. Similar beetle species have also been reported attacking related plants such as acacia in Malaysia (Syazwan *et al.*, 2021). These two pest-related phenomena increase the vulnerability of duku trees, particularly in the stem, which is characterized by hard bark. The majority of duku orchards have moderately spaced canopies, neither too dense nor too open. This canopy arrangement enables monkeys and squirrels to move freely and attack the plants. In addition to animals, humans—acting as orchard owners and harvesters—often contribute negatively to plant resistance. Inadequate tool sterilization and improper maintenance further influence disease development (Chi *et al.*, 2019; Cassol *et al.*, 2024). The tropical climate also supports pathogen proliferation, as observed in *Metrosideros polymorpha* (flowering ʻōhiʻa tree) in Hawaii (Mortenson *et al.*, 2016). Internal plant factors may also affect disease intensity, particularly the presence of bioactive compounds. Secondary metabolites such as flavonoids, terpenoids, tannins, phenols, and saponins have been detected in bark tissue (Apridamayanti *et al.*, 2018). Research by Sinaga *et al.* (2023) further demonstrated antimicrobial and anticancer potential in duku bark extracts. These findings indicate that secondary metabolites play an important role in enhancing the resistance of duku trees.

CONCLUSION

C. fimbriata was identified as the cause of lethal wilt in duku (*L. domesticum*), with disease incidence and severity varying among varieties and locations. The highest infections occurred in OKUT, while OI showed the lowest. Disease development was strongly influenced by ambrosia beetles, monkeys, and squirrels, which created entry points for pathogen invasion, as well as orchard management practices and tropical climate conditions. Morphological and growth analyses confirmed all isolates as part of the aggressive *C. fimbriata sensu stricto* lineage known to infect many economically important crops worldwide. These findings highlight the epidemic potential of *Ceratocystis* wilt in duku and the need for integrated management strategies to reduce its impact.

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