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RESEARCH PAPER

Pattern distribution and epidemic factors of stem canker disease caused by *Neoscytalidium dimidiatum* on pitahaya in Banyuwangi Regency, East Java, Indonesia

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ABSTRACT

Neoscytalidium dimidiatum is an airborne pathogen that causes stem canker disease, characterized by small brown spots surrounded by a yellow halo on the plant stem. These spots expand and darken from brown to dark brown and eventually black. In addition to attacking the plant stem, this disease can also infect the fruit. This research aims to understand the distribution pattern model of stem canker disease and to identify the factors contributing to the epidemic caused by *N. dimidiatum*. The study was conducted through the collection of secondary data, field observations of disease severity, assessment of farmers' cultivation practices via questionnaires, isolation of phyllosphere and rhizosphere microbes, and soil chemical analysis. The results showed that this pathogen initially exhibits a random distribution pattern but later develops into infection patches with two possible dissemination modes based on the observed distribution pattern: airborne transmission and vegetative planting materials. Environmental factors influencing the stem canker epidemic include rainfall exceeding 98 mm/month, a temperature of 27 ºC, and humidity of 78.3%. Biotically, the diversity and abundance of phylloplane and rhizosphere microbes in low-severity areas are higher than in high-severity areas. From the abiotic aspect of soil chemistry, the elements P, Mg, Fe, and total N are associated with reduced stem canker intensity. Four aspects of cultivation techniques are closely related to the human role in the formation of the stem canker epidemic: the use of phytohormones, the control methods employed, the choice of pitahaya varieties, and yield losses.

Keywords: Airborne disease, phyllosphere, random distribution, rhizosphere, soil

INTRODUCTION

Pitahaya (*Hylocereus* sp.) is a tropical cactus plant that thrives in warm climates. It grows optimally at temperatures between 20–30 ºC, tolerates maximum temperatures of 38–40 ºC, and requires annual rainfall ranging from 500–1500 mm. The crop performs well at altitudes above 800 meters above sea level (masl), with sufficient year-round sunlight and slightly acidic to neutral soil (pH 6.5–7.0) (Muas et al., 2016). In Indonesia, pitahaya production in 2022 reached 367,300 tons, a decrease from 484,083 tons in 2021 (BPS-Statistics Indonesia, 2025). This consistent decline indicates that national production has not yet met the growing domestic demand. According to Imang et al. (2019), the local market in Indonesian market is increasingly supplied by imported pitahaya from Thailand and Vietnam, amounting to 200–400 tons annually.

The decline in pitahaya production has been largely attributed to fungal infections, particularly by *Neoscytalidium dimidiatum* ((Penz.) Crous & Slippers), the causal agent of stem canker disease. Poor cultivation practices, such as the use of monoculture systems with dense plant spacing, also create favorable conditions for the pathogen's development. Monoculture planting over large areas with close spacing (2 × 2 m or 2 × 2.5 m) has been associated with high disease incidence, with spot infection on pitahaya cladodes reaching up to 99.5% (Syafnidarti et al., 2013). *N. dimidiatum* is an airborne pathogen that causes stem canker characterized by small brown spots surrounded by a yellow halo on the stems. These lesions gradually darken, progressing from brown to dark brown and eventually black. In severe cases, the disease can also infect the fruit (Yi et al., 2015).

Neoscytalidium dimidiatum was first reported in Asia in 2009 in Israel (Chuang et al., 2012) and was subsequently reported for the first time in Indonesia in 2014, affecting pitahaya plantations in Pariaman, and Batam, Indonesia with disease intensities ranging from 72.5% to 95.56% (Jumjunidang et al., 2014). In several

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countries, control of this disease remains limited and still relies on chemical pesticide, several fungicide (e.g., Cu_2O-cunanoparticles stabilized by alginate, Floupyram+Tebuconazole, Cyprodinil + Fludioxonil) have shown promising results in vitro (Oksal, 2021).

Efforts to develop safe, effective, and sustainable control strategies for *N. dimidiatum* are ongoing, but progress has been constrained by limited understanding of the pathogen's bioecology and the presence of other potential pathogens causing similar symptoms (Jumjunidang et al., 2019). Effective disease management requires a clear understanding of epidemic components and the factors influencing disease development (Bowen et al., 2004). It remains uncertain whether the occurrence of stem canker epidemics is primarily driven by pathogen presence, environmental conditions, or human management practices.

This study aims to identify the factors contributing to the *N. dimidiatum* stem canker epidemic in Banyuwangi, the largest pitahaya-producing region in Indonesia, and to determine the distribution pattern of *N. dimidiatum* in pitahaya fields. The findings are expected to support the development of effective and sustainable management strategies against stem canker disease in pitahaya.

MATERIALS AND METHODS

Research Site. This study was conducted in major pitahaya production areas of Banyuwangi Regency, East Java, Indonesia, covering four sub-districts: Tegaldlimo (-8.520623, 114.309188), Siliragung (-8.5630489, 114.1247213), Bangorejo (-8.5308720, 114.3389450), and Purwoharjo (-8.563978, 114.244148). Laboratory work was carried at the Mycology Laboratory, IPB University.

Collection of Secondary Data. Secondary data were obtained from the Pest and Disease Observation Laboratory (LPHP) Tanggul of Banyuwangi Regency. consisting of stem canker incidence data from 2019–2024. Additional data on rainfall, temperature, and relative humidity were obtained from the Meteorology, Climatology, and Geophysics Agency (BMKG) Region III.

Field Observation of Disease Severity. Disease severity was assessed in the field using an M-shaped sampling method across 40 pitahaya plots distributed among the four sub-districts. Observations were made directly on plants showing visible symptoms, and disease severity was calculated using the following formula:

$$\mathrm{DS} = \frac{\sum(\mathrm{ni} \times \mathrm{vi})}{\mathrm{N} \times \mathrm{Z}} \times 100\%$$

DS = Disease severity;
ni = Number of plants in each symptom score category;
vi = Score value of each category (Table 1);
N = Total number of plants observed;
Z = Highest score category.

Distribution Pattern of Stem Canker. The disease distribution pattern was observed descriptively based on visible symptoms at early and advanced stages on the stems. Observations were conducted on 195 fruit-bearing plants in Tegaldlimo District using both drone imagery and direct ground observations to verify the accuracy of drone readings.

The disease distribution map was visualized using dots with specific color codes: No dot = healthy, plant; black dot= score 4; Dark gray dot= score 3; Light gray dot = score 2; Pale gray/white dot= score 1.

The observed patterns were compared with six disease distribution models described by Brown (1997): aggregated, random, regular, patch, steep gradient, and flat.

To support visual interpretation, a distribution index (DI) was calculated as follows:

$$\mathrm{DI} = \frac{\sigma^2}{\mu}$$

DI = Distribution Index;
σ^2 = Variance (measure of deviation from the mean);
μ = Mean number of infected plants per sampling unit.

Table 1. Scoring criteria

Score	Description
0	No visible symptoms.
1	White/orange necrotic spots on ≤50% of cladodes.
2	White/orange necrotic spots on ≥ 50% of cladodes.
3	Black to grayish necrotic spots with multiple holes on cladodes.
4	Cladodes appear blackish-brown within a 50 m radius and/or plant death.

Source: Sukmana et al. (2025)

Interpretation: DI ≈ 1 = Random distribution; DI > 1 = aggregated (clustered) distribution; DI < 1 = uniform (regular) distribution.

Cultivation Practices and their Relationship with Disease Severity. The role of cultivation techniques in the development of *N. dimidiatum* was assessed through field surveys and farmer interviews. A total of 40 farmers from the four sub-districts were interviewed using a structured questionnaire. Respondents were selected based on having at least five years of pitahaya cultivation experience.

The questionnaire included questions on: land size, variety used, major diseases, yield loss, cultivation techniques, disease control methods, use of growth regulators, herbicide application, and fertilizer usage (N, KCl, and SP).

The collected data were analyzed to determine their relationship with field disease severity using cross-tabulation analysis. If significantly different were observed, a Chi-square (χ^2) test was performed at a 5% significance level.

Weather and Climate. Secondary climatic data from 2019–2023, including monthly rainfall, temperature, and relative humidity, were obtained from the BMKG (Region III) to analyze their relationship with stem canker severity.

Diversity and Population of Phylloplane and Rhizosphere Microbes. Soil samples (for rhizosphere) and cladodes sample (for phylloplane) were collected using the M-shaped sampling pattern from fields representing the highest and lowest disease severity categories.

Microbial isolation was conducted using Potato Dextrose Agar (PDA) medium (HiMedia; containing potatoes, dextrose, and agar) for fungi, and Nutrient Agar (NA) medium (HiMedia; containing peptone, HM peptone B, yeast extract, NaCl, and agar) for bacteria.

For rhizosphere microbes, soil suspensions were prepared in sterile water, serially diluted (10^{-3} and 10^{-4}), and plated directly (Shikha et al., 2020). For phylloplane microbes, the method of Batool et al. (2016) was followed: 100 g of pitahaya vine samples were immersed in 1000 mL of 0.9% NaCl solution, shaken at 100 rpm for 12 hours, and serially diluted (10^{-3} and 10^{-4}) before plating on the respective media.

Soil Chemical Analysis. Four soil samples were collected from each disease intensity category (high and low) at a depth of 30 cm. Soil chemical analysis was conducted at the Soil Science Laboratory, Department of Soil Science, IPB University. Correlation matrix analyses were performed using the R statistical software to identify relationships between soil parameters and disease severity.

Data Analysis. The data was analyzed based on sub-chapters. Secondary data and microbial population & diversity were analyzed descriptively, disease distribution data were analyzed using Agrisoft application analysis, and soil chemistry analysis data were analyzed using R by creating a correlation matrix. For data on the relationship between cultivation factors using cross-tabulation analysis and if significantly different, a chi-square test was performed using Excel.

RESULTS AND DISCUSSION

Symptoms and Pathogen Identification. The pathogen *N. dimidatum*, which infects pitahaya in Banyuwangi, initially produces small white spots resembling needle pricks on the stems. These lesions gradually enlarge and turn yellow. As the disease progresses, the symptoms darken to blackish-brown, indicating the formation of pycnidia. Over time, the infected tissue dries, blackens, and causes stem thinning, eventually leading to stem death and loss of the affected segment. Field observations showed that *N. dimidiatum* infects nearly all parts of the pitahaya plant, including both stems and fruits (Figure 1).

Macroscopically, colonies of *N. dimidatum* grown on PDA appeared blackish-gray by day 3, intensifying with black pigmentation by day 9. The fungus formed dense, aerial mycelia that rapidly grew upward toward the lid of the Petri dish. Microscopically, the hyphae were septate, and the conidia exhibited various morphologies, including oval, round, and chain-like forms (arthroconidia) (Figure 2). These characteristics correspond to the description by Jumjunidang et al. (2019), who reported similar morphological and microscopic features of *N. dimidiatum* isolated from pitahaya plantations in Solok and Pariaman.

Disease Distribution Pattern. Monitoring of stem canker distribution caused by *N. dimidiatum* revealed a random distribution pattern, where disease symptoms appeared uniformly across the plantation without a distinct spatial pattern. The random distribution observed up to the third week suggests that *N. dimidiatum* is airborne, with its conidia dispersed by wind (Figure 3). Wind movement from

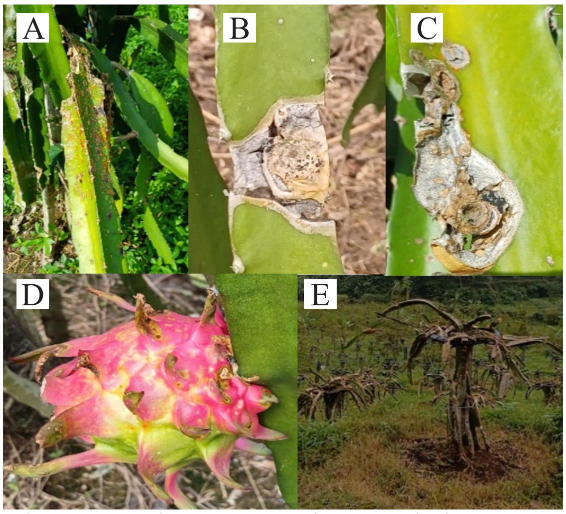

Figure 1. Symptoms of *N. dimidiatum* causing stem canker on pitahaya. A. Early symptoms; B–C. Advanced symptoms with pycnidia formation; D. Symptoms on fruit; E. Severe symptoms on pitahaya.

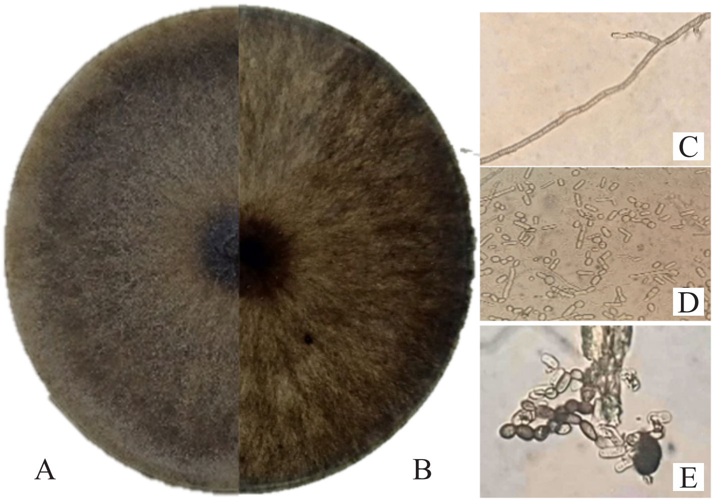

Figure 2. Colony characteristics of *N. dimidiatum* causing stem canker on pitahaya. A. Front view of *N. dimidiatum* growth on PDA; B. Back view of *N. dimidiatum* growth on PDA; C. Hyphae; D. Variation in *N. dimidiatum* spore shape; E. Phragmospore/arthroconidia.

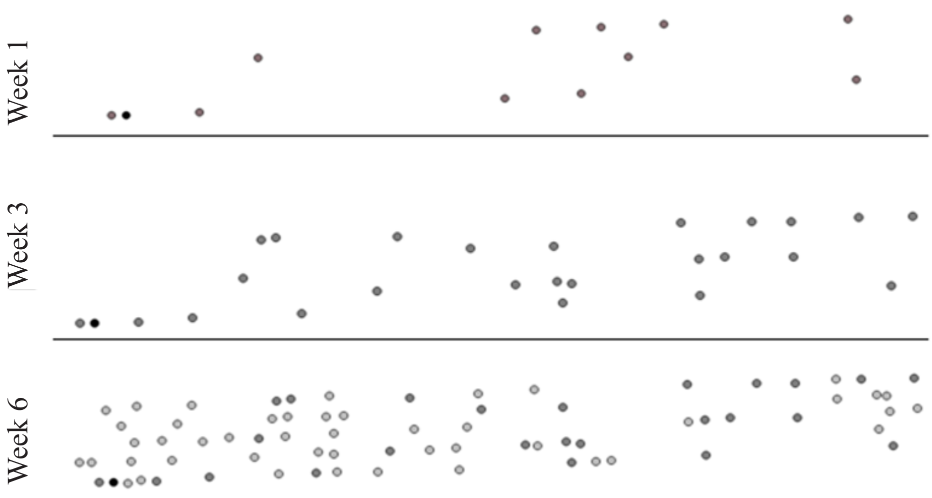

Figure 3. Random distribution pattern of stem canker disease on pitahaya plants (color gradation indicates severity level).

west to east likely carried mature pycnidia releasing pycnidiospores, which were subsequently deposited on nearby plants, causing varying disease severity levels across the field (Figure 3 and 4).

By the sixth week, however, the disease distribution shifted toward a clustered pattern, supported by the calculated distribution (Figure 3) index (DI = 13.640 > 1), indicating aggregation. Besides wind-borne dispersal, the clustered pattern may also result from the spread of infected vegetative cuttings, similar to seed-borne pathogen transmission. These findings agree with Brown (1997), who noted that random and aggregated patterns can result from seed-borne or airborne pathogens originating from distant sources. The observation that initial infections occurred in plants near the Kalipait River and irrigation

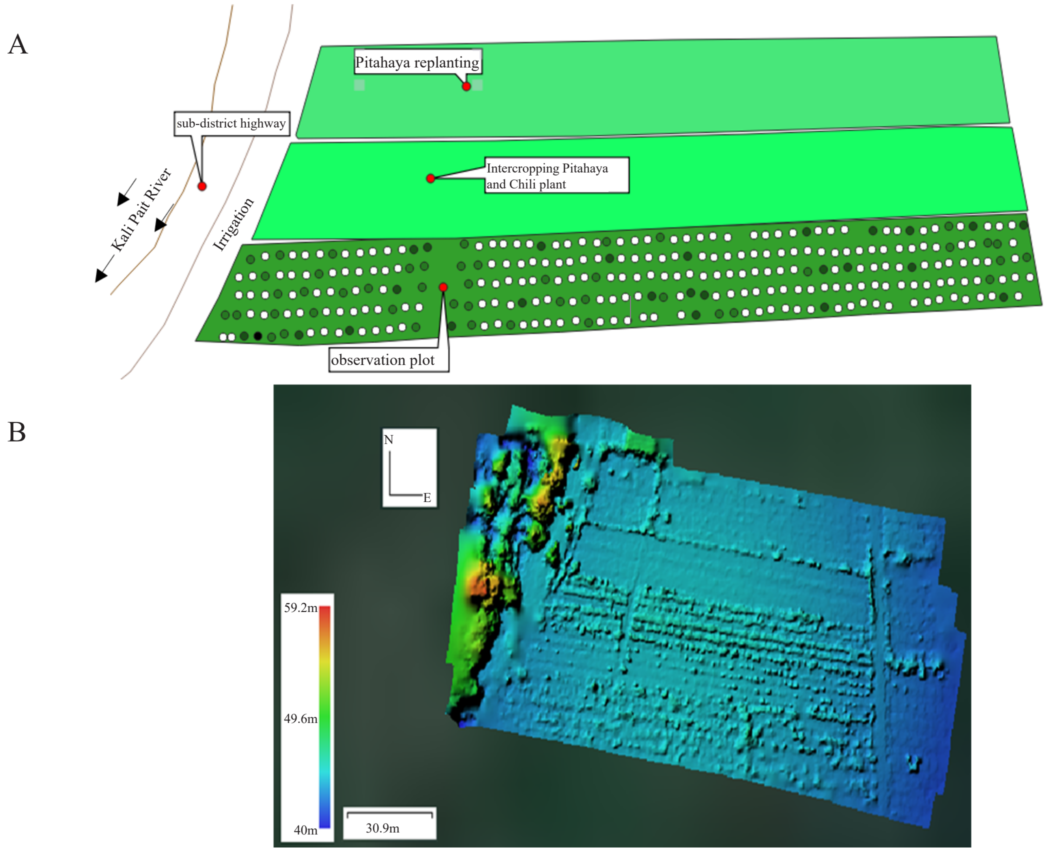

Figure 4. Illustration of distribution. A. Topographic levels; B. Observation area in Tegaldlimo Village, Banyuwangi (color differences indicate topographic levels).

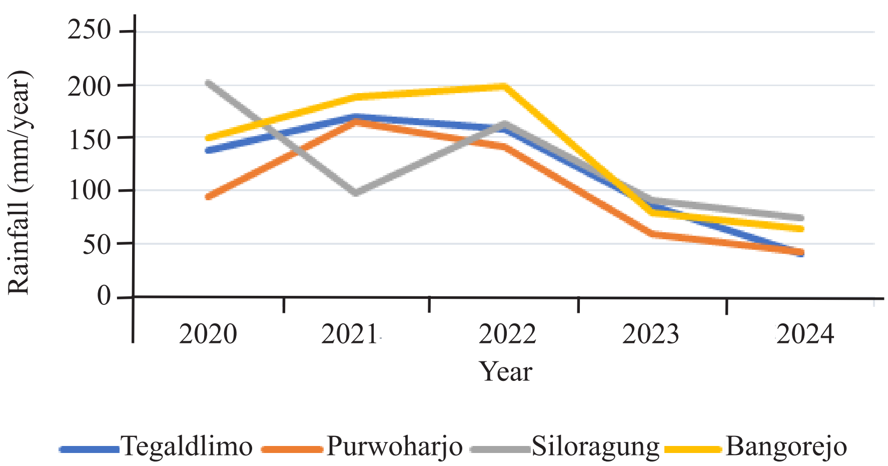

Figure 5. Average annual rainfall (mm) in four districts.

channels further suggests that *N. dimidiatum* thrives in areas with higher humidity (Figure 5 and 6).

Disease Intensity and Cultivation Factors. Surveys of 40 pitahaya plantations across four sub-districts, e main production centers of Banyuwangi Regency, revealed that most plantations were located in home gardens adjacent to houses and roads, at an elevation of approximately 43 m above sea level with flat topography. Disease intensity varied across locations. The highest plot-level severity was recorded in Purwoharjo (land code 1) at 36.11%, with a sub-district average of 20.52%. The lowest plot-level severity occurred in Siliragung (land code 25) at 2.43%, also representing the sub-district with the lowest average severity (14.09%). Other locations included Tegaldlimo (18.74%) and Bangorejo, which had the highest sub-district average severity of 21.72% (Table 2).

Differences in disease intensity across plantations were strongly influenced by the cultivation practices adopted by farmers (Table 2). Farmer knowledge and management practices significantly determine disease development and epidemic potential. Interviews with 40 farmers revealed that only 14 correctly identified *N. dimidiatum* as a fungal pathogen, while 26 mistakenly attributed the disease to bacterial infection. Misidentification leads to inappropriate control measures and reduced effectiveness in disease management.

Effect of Cultivation Practices on Disease Severity. The occurrence of disease epidemics in agricultural systems is closely associated with human cultivation practices, which serve as key drivers of plant production. Cultivation techniques that influence the pathogen life cycle, genetic modification of host plants through breeding and genetic engineering, large-scale monoculture systems, and environmental manipulations such as irrigation collectively determine the extent and spread of pathogen infections.

Results of the chi-square analysis assessing the relationship between farmers' cultivation practices and the severity of *N. dimidiatum* in Banyuwangi identified four key factors significantly influencing disease intensity in the field: (1) variety used, (2) yield losses, (3) control techniques, and (4) the application of growth hormones to increase fruit size (Table 3).

The use of growth hormones, particularly gibberellin (Gibro10), for fruit enlargement—applied three times per season (once monthly for three months)—significantly increased disease intensity, with infection levels exceeding 25%. This effect may be attributed to physiological changes in Pitahaya plants induced by gibberellin, which promotes cambium and xylem development without reinforcing the epidermal layer, thereby facilitating pathogen penetration and colonization by *N. dimidiatum*.

Another cultivation factor contributing to the stem canker epidemic is the control strategy adopted by

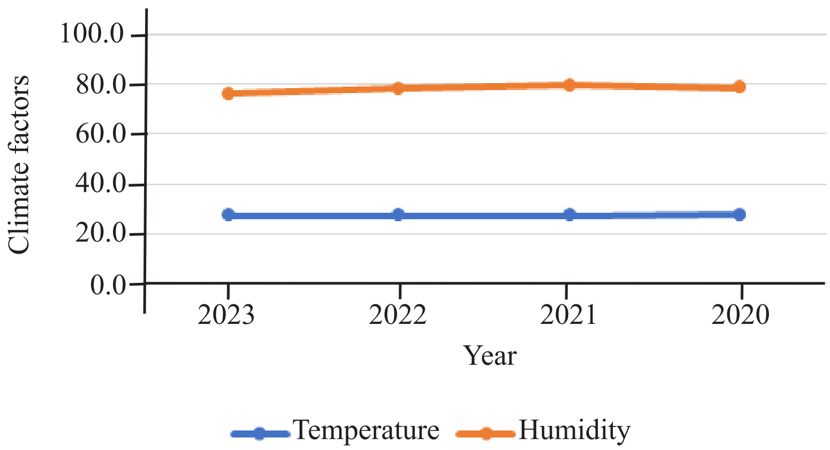

Figure 6. Annual temperature (°C) and Annual humidity (%) in Banyuwangi.

Table 2. Severity of stem canker disease caused by *N. dimidiatum* across 40 observation plots

Sub-District	Average disease severity (%)
Siliragung	14.09 ± 0.10
Bangorejo	21.72 ± 5.67
Tegaldlimo	18.74 ± 1.14
Purwoharjo	20.02 ± 0.06

farmers. The majority rely on synthetic pesticides for disease management. Although pesticide application can reduce yield losses to below 25%, extensive studies have documented the adverse long-term effects of chemical pesticide use, including the development of pathogen resistance, pesticide residues on fruit, and resurgence of resistant pathogen populations.

The final influential factor is the extensive use of a single variety over large production areas (monoculture). Continuous planting of the same variety increases the risk of *N. dimidiatum* infection, as Pitahaya is a perennial crop that provides a persistent host for pathogen survival. Field observations also indicate that the super red variety exhibits lower resistance to *N. dimidiatum* than the red (mawar) and white varieties, although this finding requires further experimental validation.

Environmental Factors Related to Disease Intensity. Understanding the relationship between environmental

Table 3. Contingency table analysis of pitahaya cultivation factors and the severity of *N. dimidiatum*

Cultivation factors		Disease severity		P	X^2
		< 25%	> 25%		
Land size	< 0.25	6	13	0.056955	5.730971
	0.25 – 0.5	9	4		
	> 0.5	2	6		
Status of land holding	Own farm	14	9	0.971216	0.001302
	Tenant	3	2		
Variety	Super red	14	10	0.042668	6.30861
	Red	3	12		
	White	0	1		
The major disease	Stem canker	15	11	0,209165	3.129268
	Anthracnose	1	2		
	Other	3	8		
Yield losses	< 25%	17	7	0.013692	6.077441
	> 25%	5	11		
Cropping system	Intercropping	10	2	0.161617	1.95903
	Without (monokultur)	17	11		
Controlling the disease	Cutting (sanitation)	0	1	0.016952	8.15476
	Spray with fungisida	15	3		
	Combination	9	12		
Application phytohormones	Low (0-1)	2	4	0.002237	12.2056
	Middle (2-3)	17	4		
	High (>3)	3	10		
Application herbicide	Yes	17	21	0.212242	1.55606
	No	0	2		
N fertilizer (ZA/Urea)	Low	0	1	0.499049	1.3901
	Middle	3	2		
	High	14	20		
KCl fertilizer	Low	0	2	0.164555	3.60902
	Middle	3	5		
	High	18	12		
SP fertilizer	Low	0	1	0.647727	0.86857
	Middle	2	2		
	High	13	22		

factors and the development of *N. dimidiatum* in Banyuwangi is essential for explaining the dynamics of the disease epidemic. Abiotic factors such as rainfall, temperature, and humidity strongly influence both pathogen distribution and host ecology. This finding is consistent with the report of Lopez et al. (2012), who stated that agroclimatic shifts significantly affect host distribution and the spatial spread of pathogens.

Based on agroclimatic data from Banyuwangi Regency, which indicate consistently high temperatures, moderate to high humidity, and seasonal rainfall, this lowland region provides favorable conditions for disease development. These environmental factors are positively correlated with the severity and spread of *N. dimidiatum* stem canker. For instance, areas with higher rainfall, such as Bangorejo, exhibit more severe disease incidence and intensity compared to regions with lower precipitation levels.

In addition to rainfall, temperature and humidity also play important roles in determining the intensity and spatial extent of *N. dimidiatum* infections. Across all observed sites, environmental conditions—average temperatures around 27.4 ºC and relative humidity near 78%—are conducive to pathogen growth and disease expression (Figure 6). Similar findings were reported by Hong et al. (2020) in Florida, who demonstrated that *N. dimidiatum* conidia germinate optimally at temperatures above 22 ºC, with optimum growth occurring at 32 ºC and relative humidity of approximately 78.3%. These results collectively suggest that the prevailing agroclimatic conditions in Banyuwangi directly favor the development and intensification of stem canker disease caused by *N. dimidiatum*.

Microbial Communities and Disease Intensity. Among the biotic environmental factors influencing *N. dimidiatum* intensity in pitahaya, the presence and composition of microbial communities play a crucial role. These microorganisms, which utilize plant exudates as energy sources, can affect pathogen development in positive, negative, or neutral ways depending on their interactions.

Analysis of microbial communities inhabiting the rhizosphere and phylloplane of Pitahaya revealed distinct patterns of diversity and dominance related to disease intensity. The phyllosphere—comprising all aerial parts of the plant—supports diverse microbial populations, some of which may exert antagonistic effects on pathogens. Microorganisms colonizing the phylloplane can benefit the host by preventing pathogen establishment, promoting plant growth, expressing antagonistic mechanisms, or inducing systemic resistance (Dees et al., 2015).

Fungal isolation from the phyllosphere of Pitahaya tendrils showed that microbial diversity and abundance were higher in low-disease-intensity fields in Siliragung compared to high-intensity fields in Tegaldlimo (Figures 7 and 8).

The predominance of white and brown (CF) phylloplane fungi in both regions is thought to influence stem canker severity. Although these genera were dominant in both environments, the greater diversity in low-intensity areas suggests that microbial heterogeneity may contribute to natural suppression of *N. dimidatum*. Variations in microbial community structure are commonly driven by environmental factors such as temperature and water availability, microbial interactions, and host plant genotype and phenotype.

Isolation of phylloplane bacteria indicated that bacterial diversity and abundance were similar between low- and high-intensity areas, with populations of 63 and 48 colonies, respectively. This similarity may be attributed to comparable temperature and sunlight exposure across locations, leading to analogous bacterial communities. Reisberg et al. (2013) similarly reported that environmental variables such as light intensity, season, geographic location, and sampling site significantly influence phyllosphere microbiota composition.

Microbial isolation from both phylloplane and rhizosphere samples demonstrated that the source of the isolate strongly affected microbial abundance and diversity. Rhizosphere samples consistently showed higher microbial populations than phylloplane Differences in soil microbial composition were also evident and may be related to land use, soil type, and fertilizer input. According to Lupatini et al. (2017), soils receiving higher chemical fertilizer inputs tend to exhibit reduced microbial diversity.

Overall, both fungal and bacterial communities displayed greater diversity in low-disease-intensity areas (Figures 7 and 8). The structure and activity of these communities are shaped by plant-associated and environmental factors, including soil type, moisture, pH, temperature, and plant age and condition (Rao, 1994; Freiberg et al., 1998; Morris et al., 2001; Reisberg et al., 2013). These findings indicate that diverse microbial assemblages—particularly within the rhizosphere—may contribute to the suppression of *N. dimidiatum* and reduced disease severity in Pitahaya fields.

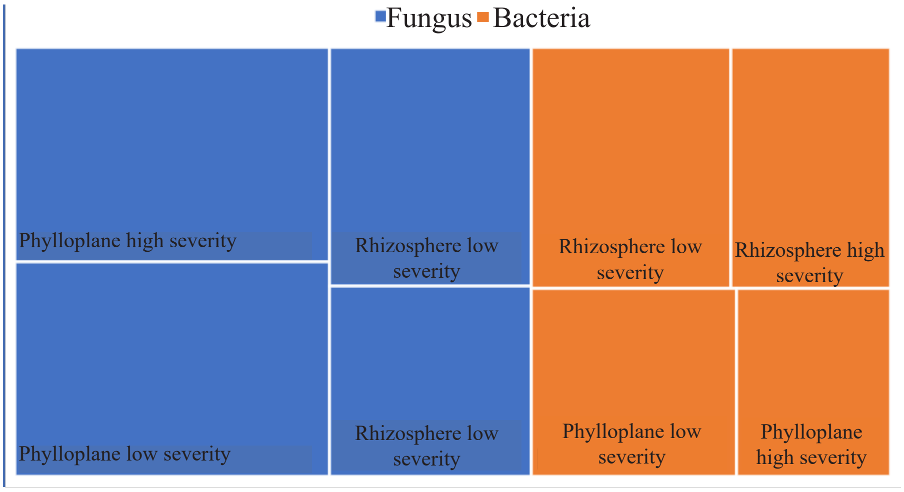

Figure 7. Treemap of phylloplane and rhizosphere diversity at two levels of stem canker disease in pitahaya (Box width indicates the number of microbial morpho-species).

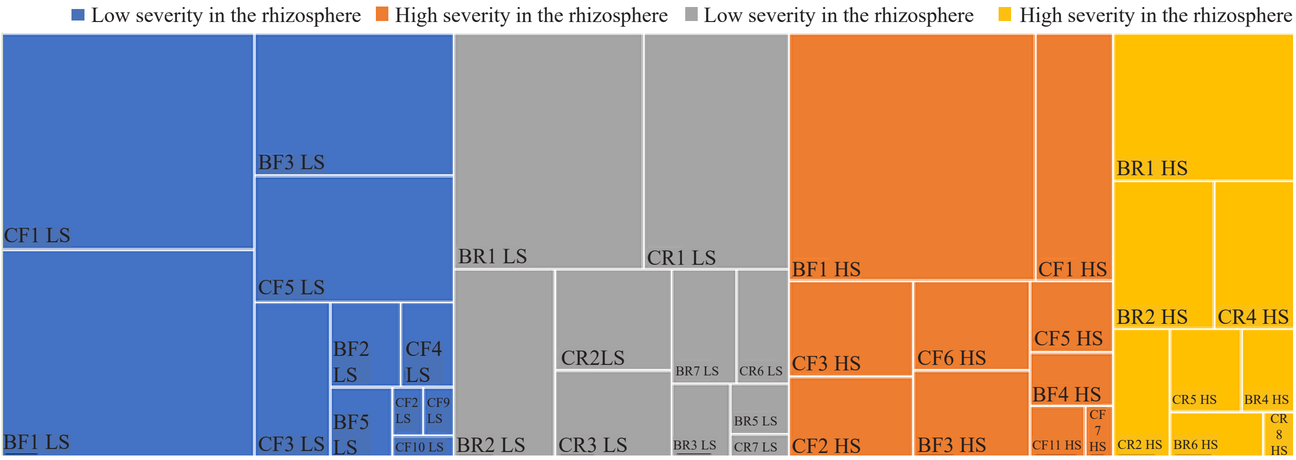

Figure 8. Treemap of phylloplane and rhizosphere microbes (fungus and bacteria) at two levels of stem canker disease in pitahaya (Box width indicates the abundance [CFU per 10 g] of microbial isolates, each labeled with a code based on their morpho-species).

Soil Nutrients and Disease Intensity. Nutrient availability strongly influences plant physiological processes, including defense activation against pathogens. Analysis of macronutrient content in soils from high- and low-disease-intensity areas revealed that, except for phosphorus (P), macronutrient levels—particularly potassium (K), calcium (Ca), and magnesium (Mg)—were generally lower in low-intensity areas than in high-intensity areas (Table 4). High concentrations of P and K are known to enhance plant vigor and reduce disease susceptibility. Phosphorus plays a key role in photosynthesis and energy transfer, while potassium contributes to cell wall strengthening and osmotic regulation. These findings are consistent with Hadiwiyono & Widodo (2008), who reported that sufficient P and K availability reduced stem rot incidence in garlic.

Magnesium (Mg) is another macronutrient closely linked to disease suppression. As a central component of chlorophyll, Mg is essential for photosynthesis, carbohydrate accumulation, and enzyme activation (Farhat et al., 2016). The higher Mg content observed in low-intensity areas suggests that adequate Mg availability supports plant growth and resilience against *N. dimidiatum* stem canker (Table 3). In addition, Mg facilitates the uptake and balance of other nutrients such as P and K (Harris et al., 2018).

Micronutrient analysis also indicated that elements such as iron (Fe), manganese (Mn), zinc (Zn), and carbon (C) influence disease dynamics. Among these, Fe showed a strong negative correlation with disease intensity, suggesting its importance in disease suppression. Iron functions as a cofactor in various enzymatic processes and is essential for chlorophyll synthesis and electron transport during respiration. Deficiency in Fe can impair enzyme activity and chlorophyll formation, weakening plant defense mechanisms. According to Tanaka et al., 1966, optimal Fe concentrations in plant tissues range from 100–200 ppm.

Soil pH, representing active (H_2O) and potential (KCl) acidity (Sulaeman et al., 2005), also affects nutrient availability and microbial activity. The organic carbon (C) content in both soil samples was relatively low (<2%), indicating reduced soil fertility (Setyorini et al., 2006). However, the C/N ratio suggested rapid organic matter decomposition and high nutrient availability, particularly in low-disease-intensity areas (Fitriyani et al., 2023). This condition supports better plant growth and enhances physiological defense against *N. dimidiatum* infection (Table 5).

Correlation analysis between soil chemical

Table 4. Soil chemical properties at two levels of *N. dimidiatum* infection in pitahaya in Banyuwangi

Soil chemical properties	Content in plots and level of attack by *N. dimidiatum* pathogen	
	Low intensity	High intensity
	General content	
pH H2O	4.02 ± 0.35	5.31 ± 0.53
C-Organik	1.80 ± 1.56	1.58 ± 0.24
N- total	0.26 ± 0.04	0.12 ± 0.01
C/N	6.37 ± 4.70	13.37 ± 3.58
	Macronutrients (cmol/kg)	
P	2177 ± 74.9	829.5 ± 47.3
K	135.2 ± 115	156.9 ± 113.2
Ca	6.18 ± 0	19.7 ± 0.36
Mg	2.64 ± 2.05	3.33 ± 3.26
	Micronutrients (ppm)	
Fe	120 ± 0.07	103.5 ± 31.7
Mn	50.1 ± 31.6	465.2 ± 422
Cu	2.08 ± 0.31	4.29 ± 2.80
Zn	0.55 ± 0.007	0.82 ± 0.24

Table 5. Correlation matrix between soil chemical properties and the intensity of stem canker disease caused by *N. dimidiatum*

Parameter	P	K	Ca	Mg	Fe	Cu	Zn	Mn	pH H_2O	C-Organik	N-total	C/N
K	-1											
Ca	-1	1										
Mg	1	-1	-1									
Fe	1	-1	-1	1								
Cu	-1	1	1	-1	-1							
Zn	-1	1	1	-1	-1	1						
Mn	-1	1	1	-1	-1	1	1					
pH H_2O	-1	1	1	-1	-1	1	1	1				
C-Organiks	-1	1	1	-1	-1	1	1	1	1			
N-Total	1	-1	-1	1	1	-1	-1	-1	-1	-1		
C/N	-1	1	1	-1	-1	1	1	1	1	1	-1	
DS	-1	1	1	-1	-1	1	1	1	1	1	-1	1

DS = Disease severity; 1 = indicates a positive correlation between parameters; -1 = indicates a negative correlation between parameters.

properties and stem canker intensity revealed both positive and negative associations. Positive correlations indicate that increased concentrations of certain elements correspond with higher disease intensity, whereas negative correlations indicate the opposite. The elements P, Mg, Fe, and total nitrogen (N) exhibited negative correlations with disease severity, suggesting their potential roles in mitigating *N. dimidiatum* infection and reducing stem canker intensity in pitahaya plantations (Table 5).

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CONCLUSION

The pathogen *Neoscytalidium dimidiatum*, which causes stem canker disease in pitahaya, initially exhibits a random distribution pattern but later develops into localized infection patches. In the epidemiological assessment of stem canker disease, environmental factors such as monthly rainfall exceeding 98 mm, temperatures around 27 ºC, and relative humidity of approximately 78.3% were found to significantly increase disease severity. Microbial diversity and population density in both the phylloplane and rhizosphere were higher in areas with low disease severity compared to high-severity areas. Soil chemical properties, including phosphorus (P), magnesium (Mg), iron (Fe), the carbon-to-nitrogen (C/N) ratio, and soil pH, were also associated with the severity of *N. dimidiatum* stem canker. Furthermore, four cultivation practices were identified as key factors influencing the development of the disease epidemic: yield loss, the use of plant growth hormones (phytohormones), disease management methods, and the selection of pitahaya varieties.

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AUTHORS' CONTRIBUTIONS

ASA, ETT, and SWI conceived and designed the research. ASA collected the data and performed the analyses. ETT and SWI provided input on data interpretation and discussion. All authors contributed to writing and revising the manuscript.

COMPETING INTEREST

The authors declare no potential conflict of interest.

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