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INFLUENCE OF PHENOLOGICAL STAGES AND WEATHER ON PESTS AND DISEASES INCIDENCE IN DURIAN (*Durio zibethinus*) IN MALAYSIA

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ABSTRACT

Durian, often called the "king of fruits," holds significant economic importance for Malaysia, particularly with the country's recent 2024 launch of fresh durian exports to China. However, pest infestations and diseases pose serious threats to this revenue stream. Effective management of pests and diseases is essential, which requires identifying the factors influencing their occurrence in durian crops. This study aimed to evaluate the impact of durian's phenological stages and weather conditions on pest infestations and disease incidences. Conducted over a year (January–December 2023), the research utilized sticky traps, light traps, and visual inspections to monitor pest and disease activity across the plantation. A total of 10 pests and four diseases were identified. Among the pests are *Allocaridara malayensis* (Hemiptera: Psyllidae), *Mudaria magniplaga* (Lepidoptera: Noctuidae), and *Amrasca* spp. (Hemiptera: Cicadellidae) showed significant interactions with durian phenological stages, while *Platypus* spp. (Coleoptera: Curculionidae) and *Tiraleurodes* spp. (Hemiptera: Aleyrodidae) had a strong positive correlation with rainfall (r=0.82) and (r=0.71), respectively. Disease pathogens such as *Phytopthora palmivora* and *Phomopsis durionis* also correlated with increased rainfall, while *Rhizoctonia solani* showed a positive correlation with higher temperatures and humidity (r=0.64) and (r=0.50), respectively. These findings underscore the influence of both plant growth stages and weather on pest and disease occurrence. The study's insights offer practical value to durian farmers, enabling targeted pest and disease management strategies aligned with growth stages and seasonal weather patterns. By implementing informed control measures, farmers can mitigate the risks associated with pest and disease pressures, thereby enhancing productivity and economic outcomes for Malaysia's durian industry.

Keywords: Durian; pest infestation; disease of durian; weather; phenological stages

ABSTRAK

Durian, yang sering dipanggil sebagai "raja buah," mempunyai kepentingan ekonomi yang besar bagi Malaysia, terutamanya dengan pelancaran eksport durian segar ke China pada tahun 2024. Namun, serangan perosak dan penyakit menimbulkan ancaman serius kepada aliran pendapatan ini. Pengurusan yang berkesan terhadap perosak dan penyakit adalah penting, yang memerlukan pengenalpastian faktor-faktor yang mempengaruhi kemunculannya dalam tanaman durian. Kajian ini bertujuan untuk menilai kesan peringkat fenologi durian dan keadaan cuaca terhadap serangan perosak dan kejadian penyakit. Dilaksanakan sepanjang tahun (Januari–Disember 2023), kajian ini menggunakan perangkap lekit, perangkap cahaya dan pemeriksaan visual bagi memantau aktiviti perosak dan penyakit di seluruh ladang. Sebanyak 10 perosak dan empat penyakit telah dikenal pasti. Di antara perosak, *Allocaridara malayensis* (Hemiptera: *Psyllidae*), *Mudaria magniplaga* (Lepidoptera: Noctuidae) dan *Amrasca* spp. (Hemiptera: Cicadellidae) menunjukkan interaksi yang signifikan dengan peringkat fenologi durian, manakala *Platypus* spp. (Coleoptera: Curculionidae) dan *Tiraleurodes* spp. (Hemiptera: Aleyrodidae) mempunyai korelasi positif yang kuat dengan hujan (r=0.82) dan (r=0.71). Patogen penyakit seperti *Phytopthora palmivora* dan *Phomopsis durionis* juga berkaitan dengan peningkatan hujan, manakala *Rhizoctonia solani* menunjukkan korelasi positif dengan suhu dan kelembapan yang lebih tinggi (r=0.64) dan (r=0.50). Hasil kajian ini menekankan pengaruh kedua-dua peringkat pertumbuhan tanaman dan cuaca terhadap kejadian perosak dan penyakit. Dapatan kajian ini memberikan nilai praktikal kepada pekebun durian dengan membolehkan pelaksanaan strategi pengurusan perosak dan penyakit yang lebih terarah, selaras dengan peringkat pertumbuhan tanaman serta corak cuaca bermusim. Melalui pelaksanaan langkah kawalan yang berasaskan maklumat, pekebun dapat mengurangkan risiko yang berkaitan dengan tekanan perosak dan penyakit, seterusnya meningkatkan produktiviti dan pulangan ekonomi bagi industri durian di Malaysia.

Kata kunci: Durian, serangan perosak; penyakit durian; cuaca; peringkat fenologi

INTRODUCTION

Durian (*Durio zibethinus* L.), referred to as the "king of fruits," is indigenous to Southeast Asia and has emerged as a commercially significant crop in Malaysia. In 2023, durian has emerged as the most extensively cultivated fruit in the country, with the total planted area rising from 87,278 hectares in 2022 to 87,365 hectares in 2023. Production volumes have increased to 471,672 metric tons (MT) in 2023, up from 455,458 MT in 2022. Johor was identified as the foremost producing state (Department of Agriculture 2022, 2023). Malaysia is pivotal in the international durian trade, with principal export markets being China, Singapore, Hong Kong, Vietnam, and the United States. In 2024, Malaysia secured a significant success by signing a memorandum of understanding with the General Administration of Customs of China (GACC), permitting the export of fresh durians under a newly instituted phytosanitary regulation. The protocol mandates that orchards and packing houses register with the Ministry of Agriculture and Food Security (MAFS) and adopt Good Agricultural Practices (GAP), Integrated Pest Management (IPM), traceability, and quality management systems (DOA 2024).

Notwithstanding these advancements, pests and illnesses continue to pose major barriers to durian production, with crop losses surpassing 50% in extreme instances (Ahmad et al. 2022). Principal diseases encompass patch canker induced by *Phytophthora palmivora*, fruit rot, Rhizoctonia foliar blight, anthracnose, and white root disease. Furthermore, *Fusarium solani* and *F. incarnatum*, while not yet documented in Malaysia, have been implicated in the death of durian in Thailand (Pongpisutta et al. 2023).

Environmental factors, particularly rainfall and humidity, facilitate disease transmission, while pest activity is closely linked to the phenological phases of durian. Psyllids specifically infest young leaves, while fruit borers typically deposit their eggs on growing fruits and flower buds (Ahmad et al. 2022; Visutsak 2021). While the distinct influences of weather and phenology on durian pests and diseases are acknowledged, there is an absence of thorough research examining their synergistic impacts, particularly under Malaysian field circumstances. Although research on durian is limited, investigations have been conducted on oil palm to assess the influence of abiotic factors on bagworm in Malaysian oil palm (Nur Robaatul Adhawiyah et al. 2025). Understanding the interaction of these elements is essential for devising efficient and timely pest and disease management strategies. This study aims to investigate the impact of meteorological circumstances and durian phenological stages on the occurrence and severity of pest and disease infestations on durian. Precipitation and humidity significantly influence disease outbreaks, pest populations vary with phenological stages, and their interaction can guide more precise, stage-specific control measures.

MATERIAL AND METHODS

Study Location and Duration

This research was performed at Top Fruits Plantation in Batu Pahat, Johor (2.0625915°N, 102.8873924°E), situated on a 500-acre estate, where durian has been the predominant crop for more than thirty years. The plantation is segmented into multiple areas, each exhibiting diverse exposure to environmental elements, facilitating thorough research on durian growth under changing conditions. The study duration extended from January 2023 to December 2023, encompassing the complete cycle of durian cultivation, insect invasion, and disease manifestation.

Pest Surveillance Methods

Pest surveillance in the durian orchard was conducted using three primary methods to monitor pest populations.

Yellow Sticky Traps

Heinz et al. (1992) said that yellow sticky traps were deployed around the orchard to attract and capture diverse pests. Approximately 20 traps per hectare were randomly distributed across the orchard. The traps were inspected manually and substituted weekly to ensure their effectiveness. The traps were systematically positioned at various positions inside the orchard to guarantee a representative sampling of pest populations from distinct areas of the plantation.

Light Traps

Light traps, as described by Ramamurthy et al. (2010), were employed to lure nocturnal pests. Approximately 5 UV light traps per hectare were randomly distributed across the orchard, ensuring the light source was adequate to attract insects from adjacent regions. The light traps were inspected and recalibrated bi-daily, and pest captures were documented scrupulously to track variations in pest activity.

Visual Inspections

Visual inspections were conducted utilizing systematic field-walking patterns to ensure thorough coverage of the entire area. Three conventional sample trajectories ie. X-pattern, zigzag (M-pattern), and circular pattern were employed according to field dimensions, crop arrangement, and topographical conditions. In each pattern, specified sampling points were evaluated, and plants within a consistent radius were examined for insect presence, feeding damage, unusual symptoms, and environmental conditions. The X-pattern involved diagonal movement across the plot from corner to corner to capture variations within the field. The zigzag, or M-pattern, provided a more stringent linear assessment by alternating movement across rows, hence increasing the likelihood of detecting early infestations. The circular layout was utilized in centrally planted plots, allowing inspectors to navigate a circular route from the perimeter to the centre for uniform coverage. Monitoring was conducted at least once or twice weekly, with increasing frequency in expectation of heightened pest population pressure due to favourable environmental conditions such as elevated humidity, rainfall, or warm temperatures. At each sampling site, the number of damaged plants, type of pest activity, and severity of symptoms were recorded using standardized data sheets. This systematic approach enabled the swift detection of pest infestations and supported the timely execution of management plans.

Record Keeping and Maintenance in Pest Surveillance

To ensure data accuracy, traps were cleaned regularly to eliminate accumulated dirt and were then inspected for damage or malfunction. Monthly reviews of monitoring data were conducted to discern patterns in pest populations in relation to the phenological stages of the durian crop and the seasonal variations in pest activity.

Phenological Stage of Durian

The durian season in the orchard consists of two minor seasons and one major season, each contributing significantly to the trees' development. The minor seasons occur from January to March 2023 and again from October to November 2023, while the major season extends from May to July 2023. The seasonal differences are essential for comprehending the distinct phenological stages that durian trees experience annually, with each season uniquely affecting the growth and development of the fruit. The timing of these seasons influences the tree's flowering, fruiting, and vegetative cycles, affecting the overall productivity and health of the plantation. Throughout the year, we observed several recurring phenological stages (Figure 1) produced by the seasonal variations in durian growth. In January, the tree reaches the crab-eye stage, which is characterized by the appearance of early flower buds. The period advances into February, during which a transitional phase occurs, leading to the blooming of mature flower buds and the simultaneous presence of both buds and open flowers. In March, during the minor season, full fruits from the preceding flowering cycle may still be present while fresh flowers emerge, succeeded by the chicken-feet stage and the formation of little marble-sized fruits, contingent upon successful pollination. As development progresses into April, these immature fruits evolve from the small marble stage to the duck-egg stage, and in May, they further expand to the guava-size stage, indicating the onset of the immense season. Fruits attain their fullest size in June and July, maturing completely and being picked during the peak season. Post-harvest, from August to October, the tree transitions into a vegetative growth phase, during which the canopy rejuvenates and the tree readies itself for the subsequent reproductive cycle. In November, the crab-eye stage re-emerges, signifying the commencement of the subsequent flowering cycle, succeeded by the development of fresh flower buds that bloom in December. Overlapping cycles are evident: mature fruits can be found in October and November, signifying the commencement of another minor season; in June, crab-eye structures and flower buds re-emerge, signalling the initiation of the subsequent minor-season cycle; by July, mature flower buds commence blooming; in August, the chicken-foot and small marble fruit stages reappear; and in September, developing fruits attain the duck-egg and guava-size stages, approaching maturity before the cycle recommences. Figure 1 illustrates these phenological stages and their visual indicators.

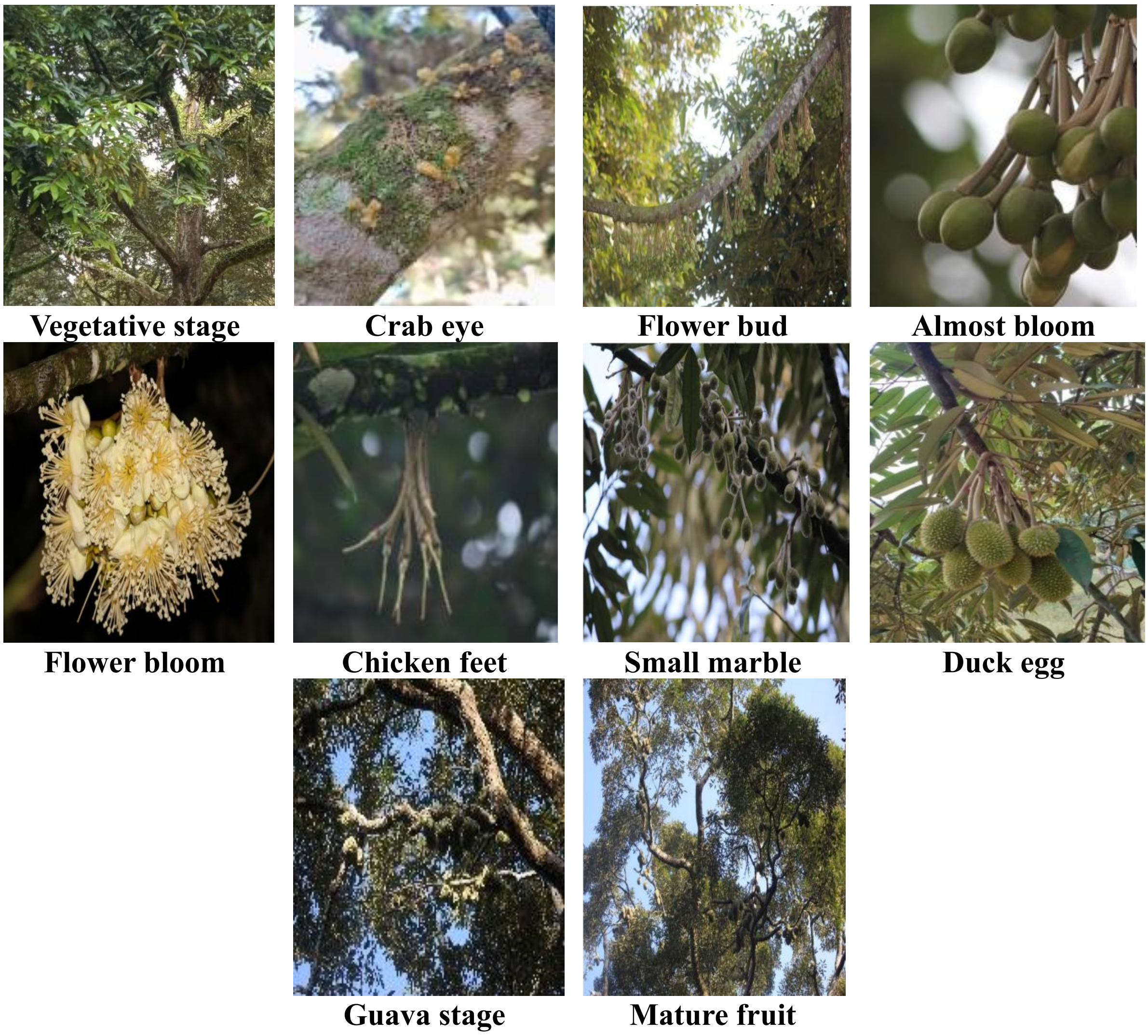

Figure 1. Visual cues of phenological stages of durian

Species Identification

Pest specimens were collected via the previously indicated methods. All insects were allocated to labelled containers, with soft-bodied taxa preserved in 70% ethanol to maintain morphological integrity, while hard-bodied beetles and moths were pinned for examination of external structures. The insects were further examined for diagnostic traits, including wing venation, antennal segmentation, setae distribution, and cuticular characteristics, following accepted identification techniques for Hemiptera and related species. All diagnostic structures were obtained using calibrated microscopic equipment and subsequently juxtaposed with published morphological descriptions to guarantee accurate and dependable identification (Bickerstaff et al. 2020; Gimpel & Miller 1996; Laštůvka & Laštůvka 2025; Mally 2018; Patel et al. 2022; Pellinen et al. 2018; Qin et al. 2014; Sabado et al. 2005; Wesa 2021; Wood 1993; Xu et al. 2017).

Recording of Weather Conditions

The relationship between pest and disease data and meteorological variables, including temperature, humidity, and precipitation, was examined to evaluate the impact of environmental conditions on pest and disease dynamics. A Davis™ Vantage Pro2 Plus weather station (Davis Instruments, USA) was utilized to record microclimatic variables, with measurements evaluated according to the sensor accuracy asserted by the maker. The integrated temperature probe provides an accuracy of ±0.3°C, while the relative humidity sensor operates with a precision of ±2% RH. A tipping-bucket rain gauge with a precision of 0.2 mm was employed to quantify precipitation. The accuracy is specified as ±3% of the total measurement or ±0.2 mm (equivalent to one bucket tip), whichever is greater, for rainfall intensities up to 250 mm h^{-1}. These figures represent optimal performance within the installation limits outlined by the manufacturer. This weather station is classified as automatic.

Data Analysis

The research utilized a randomized complete block design (RCBD) with phenological phases as the primary variables and rainfall, temperature, and humidity as secondary variables, each replicated four times. Statistical analysis utilizes Analysis of Variance (ANOVA) in SAS version 9.4 (SAS Institute, Cary, NC). Mean comparisons were performed utilizing the Tukey Honestly Significant Differences (Tukey's HSD) test at a significance threshold of $P = 0.05$. Pearson's correlation analysis (r) was conducted at $P = 0.05$ to investigate the correlations among all measured variables in this study.

RESULTS AND DISCUSSION

The Symptoms of Pest and Disease Infestation on Durian Tree

Pest infestations, especially by fruit borers (*Conogethes punctiferalis* (Lepidoptera: Crambidae) and *Mudaria magniplaga* (Lepidoptera: Noctuidae), psyllids (*Allocaridara malayensis* (Hemiptera: Psyllidae), and stem borers (*Platypus* spp. (Coleoptera: Curculionidae) and *Synanthedon* spp. (Lepidoptera: Sesiidae)), inflict considerable economic harm. Pests like *Amrasca* spp. (Hemiptera: Cicadellidae), *Microtermes* spp. (Blattodea: Rhinotermitidae), *Pseudococcus* spp. (Hemiptera: Pseudococcidae), *Tiraleurodes* spp. (Hemiptera: Aleyrodidae) and snail are recorded in this study. The identification of the seed borer, *M. magniplaga* is marked by a small hole on the durian's surface, serving as the entry point for the borer (Figure 2a). The entry point is saturated with frass, signifying the presence of the borer. *Conogethes punctiferalis* is a fruit borer; its presence is indicated by an entry hole filled with black frass (Figure 2b). The *Platypus* spp. is recognized as the stem borer. A small orifice is consistently obscured with white frass. The *Platypus* spp. consistently assaults in significant numbers, resulting in the stem exhibiting numerous perforations obscured by white frass. A severe infection may lead to leaf desiccation and tree mortality (Ahmad et al. 2022). *Synanthedon* spp. infects trees already afflicted by stem canker as a secondary infection. The entry location may be identified by black or brownish-red frass. *Allocaridara malayensis* is a psyllid that infests young shoots (Figure 2c). The psyllid nymph extracts plant sap and secretes honeydew. The psyllid's extraction of plant sap can result in leaf desiccation and abscission, adversely impacting tree growth. *Amrasca* spp. is recognized as the leafhopper. The leaf afflicted with leafhoppers exhibits bending or deformation (Figure 2d). *Microtermes* spp. are classified as termites. These termites impact the tree's root or stem (Figure 2e). The presence of termites can be determined by the trails on the branches of trees. A severe termite infestation can result in the death of the tree. *Pseudococcus* spp., commonly referred to as a mealybug is frequently observed infesting fruits and tree twigs (Figure 2f). The mealybugs extract the cell sap from the fruit and excrete honeydew, resulting in the fruit becoming coated with sooty mould.

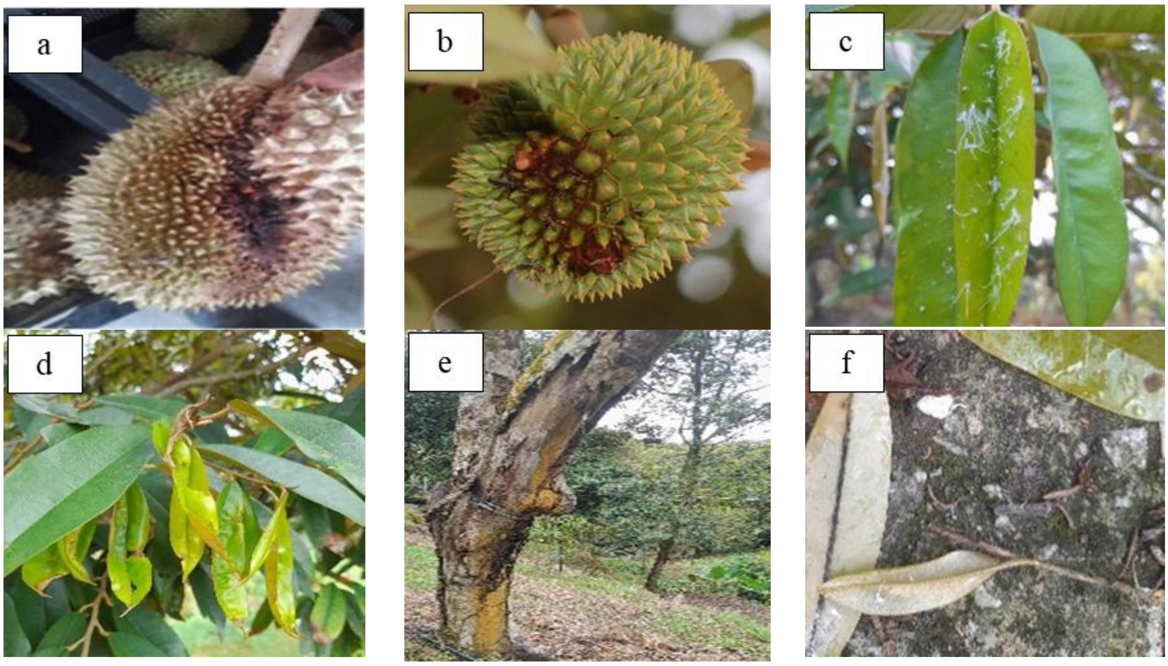

Figure 2. Symptoms of various pest infestation symptoms (a) *M. magniplaga*, (b) *C. puncteralis*, (c) *A. malayensis*, (d) leaf hopper, (e) termite, and (f) mealybugs

Leaf blight, predominantly induced by the fungus *Rhizoctonia solani*, presents as reddish lesions at the apices and margins of affected leaves (Figure 3a). As the disease advances, these lesions may expand, ultimately resulting in leaf abscission. In instances of severe infection, considerable defoliation may transpire, profoundly affecting the general health and output of durian trees. Lim and Sijam (2015) indicate that the first symptoms of leaf blight manifest as moist, diminutive spots on the leaf surface that progressively enlarge into larger, irregular patches. Gradually, these lesions desiccate and transform into a light chocolate to red tint, with the peripheries exhibiting dark red to brown tones. Moreover, impacted leaves frequently start to bend or deform as the disease progresses. These signs were equally noted in our investigation, corroborating the standard development of leaf blight.

High infection rates can lead to an uneven tree canopy due to substantial leaf loss, impairing the tree's photosynthetic ability and general vitality. Pascual et al. (2000) depict infected leaves as exhibiting pinkish-brown regions with necrotic spots ranging from 2 to 4 cm in diameter, typically featuring uneven borders. This description underscores certain discrepancies from our data, indicating diversity in symptoms that may be influenced by environmental factors, host plant circumstances, or individual strains of *R. solani*.

Durian patch canker, caused by *P. palmivora*, is regularly discovered in durian orchards. This infection is recognized as the most severe illness affecting durian (Ketsa et al. 2020). The symptom manifests on the stem's surface as a brownish to red colouration, accompanied by blackish patches on the epidermis. The skin surface feels moist to the touch. The infection typically originates in the root and base of the tree (Figure 3b). The diseased tree shows symptoms on its leaves, which start to fall off. Leng et al. (2024) noted that infected trees have dark, moist patches, with reddish-brown lesions present in the interior tissue upon removal of the external bark, consistent with this study’s findings. If the illness persists, it will result in browning leaves, further defoliation, and ultimately the death of trees. Ahmad et al. (2022) assert that the infected tree will exhibit an abundance of fruits and blossoms relative to typical conditions. The appearance indicates that the tree is experiencing stress, and if the condition persists, it may ultimately perish. This fungus not only induces patch canker but also other ailments, including fruit rot, root rot, and leaf blight.

Anthracnose is an ailment induced by *Colletotrichum gloesporioides*. The manifestation of this disease commences with a diminutive necrotic spot that progressively enlarges, creating a circular pattern (Figure 3c). This pattern is observable in both juvenile and older foliage. As the ailment progresses, the leaf may wither and fall. Ahmad et al. (2022) noted analogous symptoms. Anthracnose also impacts more fruit crops, such as banana, mango, avocado, papaya, dragon fruit, and guava.

Leaf spot induced by *Phomopsis durionis* is distinguished by diminutive, needle-like punctuations surrounded by yellow halos on the leaf surface (Figure 3d). The spots are dispersed throughout the leaves, creating a unique appearance. This observation diverges from the findings of Tongsri et al. (2023), who indicated that the dots on the leaves exceeded 1 mm in size. In our investigation, the diameters of the spots ranged from 1 to 10 mm, with the mean size being less than that reported by Tongsri et al. (2023). Our data coincide with those of Ahmad et al. (2022) and Lim and Sijam (2015), who identified analogous traits of leaf spots induced by P. durionis. This size gap underscores the possible heterogeneity in the disease's expression, which may be affected by factors such as environmental conditions, the individual pathogen strain, or the physiological status of the durian trees. Understanding these variances is essential for effective disease management and can direct strategies for monitoring and controlling leaf spot in durian crops.

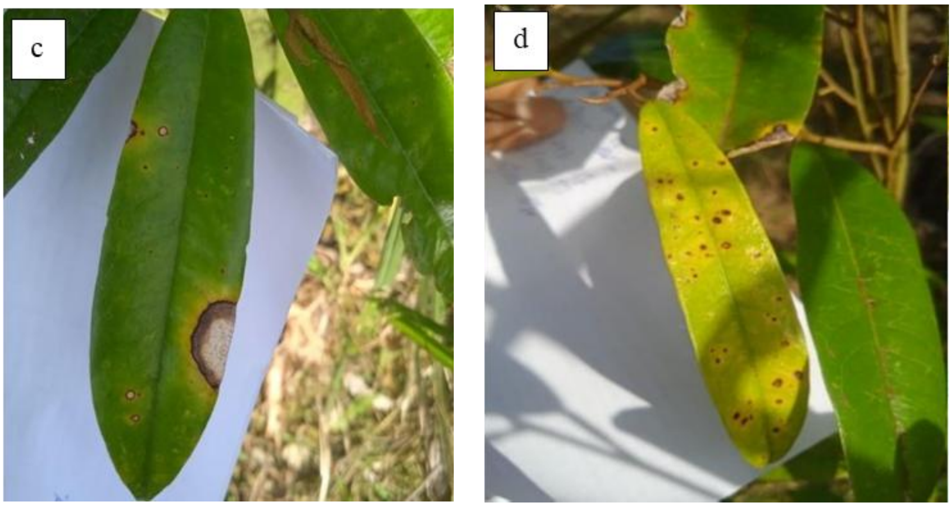

Figure 3. Symptoms of various disease infection (a) leaf blight caused by *Rhizoctonia solani*, (b) patch canker caused by *Phytophthora palmivora*, (c) anthracnose caused by *Colletotrichum gloersosporioides* and (d) leaf spot caused by *Phomopsis durionis*

The Impact of Phenological Phases on Durian Pests and Diseases

Over the course of the year, ten pests were identified in the plantation. A significant difference is seen between the prevalence of *A. malayensis* and the phenological phases of durian (*P<0.05*) (Figure 4). The *A. malayensis* was most prevalent during the flowering phase, recorded at a frequency of seven, followed by the vegetative and crab eye stages, each noted at four. *A. malayensis* were spotted throughout the year, perhaps due to the persistent development of new shoots. *A. malayensis* are commonly found on the new foliage of the tree. The presence of these *A. malayensis* on the foliage impedes leaf growth, yielding fewer leaves than normal. Ultimately, the leaf will curl and detach (Wiangsamut et al. 2024). The honeydew produced by *A. malayensis* can result in the development of black sooty mold (Ahmad et al. 2022). The mould is considered a secondary illness in the tree. Mould presence negatively affects photosynthesis. Consequently, it is essential to guarantee that the trees are free from pest infestations, as these might result in secondary diseases that undermine the tree's overall health and reduce the market value of the fruit.

A significant difference is observed between the prevalence of *M. magniplaga* and the phenological stages (*P<0.05*) (Figure 4). *M. magniplaga* had the highest frequency of 37 during the guava fruit's development stage. The adult lays eggs among the thorns of the growing durian tree (Ahmad et al. 2022). Upon emergence, the larva will infiltrate the food source and devour the fruit. Frass on the apple indicates the larval entry location. There is a significant difference between *Amrasca* spp. (leafhoppers) and the different stages of durian's life cycle. Statistical analysis shows a significant difference (*P<0.05*) (Figure 4). *Amrasca* spp. was persistently observed on the durian trees year-round, highlighting its continual presence. *Amrasca* spp. was predominant at full maturity, indicating the possible development of new shoots in anticipation of the vegetative phase. No substantial differences were detected among other insect pests and the various phenological stages of the durian (*P>0.05*) (Figure 4). *Amrasca* spp. may interact with the durian exclusively during specific growth stages.

Conogethes spp., identified as a fruit borer, exhibits behavior similar to *M. magniplaga*, since it is seen at multiple stages of fruit development, ranging from small, marble-sized fruits to fully ripe specimens. The adult moth lays its eggs on flower buds or among the crevices of fruit thorns. Upon hatching, the larvae penetrate the fruit, forming a small entry point discernible by the presence of black frass, the waste produced by the larvae. Infected blossoms or small marble-sized fruits are susceptible to deterioration and eventually detach from the tree, resulting in significant yield reduction (Ahmad et al. 2022). The occurrence of borer infestations may vary according to the phenological stage of the durian, indicating that the timing of infestation could be linked to the fruit's developmental state. Adult *Conogethes* spp. were discovered utilizing light traps, which are effective for monitoring moth populations in relevant to the fruit development.

Platypus spp. and *Synanthedon* spp. are recognized as stem borer species that can significantly affect durian trees. The statistical analysis of our study revealed no significant differences in the infestation levels of these borers at various phenological stages of durian ($P>0.05$) (Figure 4). This research indicates that the presence and activity of these stem borers are not significantly influenced by the growth stages of the durian, suggesting they can infest plants at any developmental time.

The behavior of *Platypus* spp. and *Synanthedon* spp. as secondary pests is particularly noteworthy. Typically, they focus on trees that have previously had multiple afflictions, including patch canker disease. Patch canker disease, often caused by fungi, diminishes the vigor of the durian tree, making it more susceptible to secondary infestations. The existence of these stem borers may exacerbate the tree's health troubles, since they infiltrate the stem or branches, potentially altering vascular tissues and further diminishing the tree's ability to transport nutrients and water. The presence of these pests can reduce tree vigor, resulting in diminished fruit production and quality. The absence of a substantial association between their infestation and the phenological stages indicates that management techniques should not exclusively concentrate on the growth phases of durian but should also consider the overall health of the trees.

Effective pest control measures may include monitoring for signs of patch canker disease and other stressors that could increase the vulnerability of durian trees to stem borer infestations. The orchard utilizes an integrated pest management (IPM) approach to combat insect infestations. The Integrated Pest Management (IPM) strategy begins with cultural measures, including orchard sanitation. Consistently removing infested plant detritus and fallen fruits can accomplish this objective by interrupting the insect life cycle.

Pruning and canopy management are included as cultural control techniques. We trim excess branches to improve ventilation and light penetration, ultimately creating a less favorable environment for pests. Ultimately, mulching and weed control were implemented in the orchard. Preserving a pristine and weed-free orchard floor reduces habitats and breeding sites for pests. Biological control is often utilized in orchards to alleviate pest infestations. *Bacillus thuringiensis* is frequently employed as a bacterial biopesticide to combat pests such as fruit borers. *Metarhizium anisopliae* operates as an entomopathogenic fungus that targets soil-dwelling pests. Chemical controls are utilized as a last resort in the management of pest infestations in the orchard. The task is accomplished through the careful application of pesticides according to threshold values to avert the development of resistance

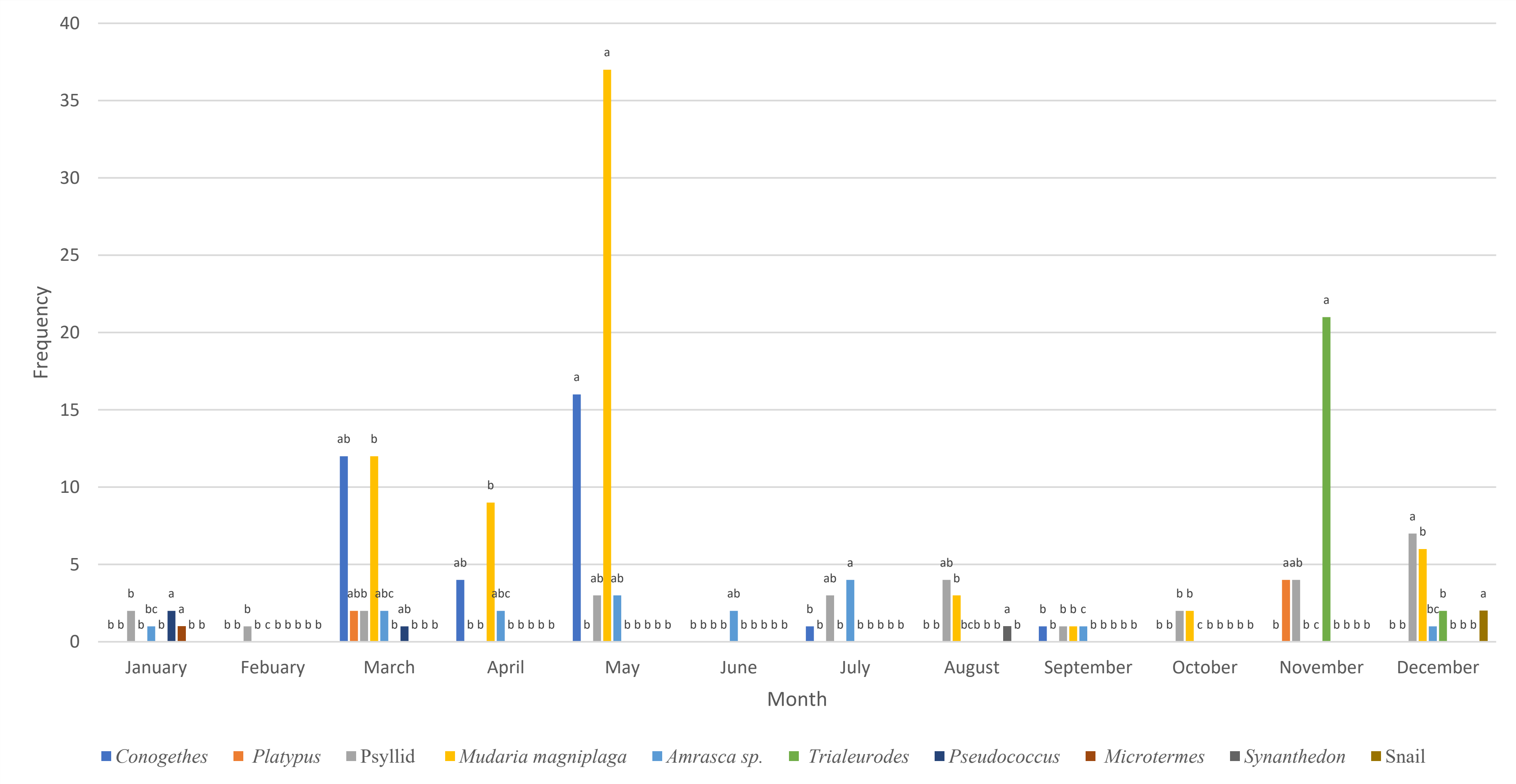

Figure 4. Frequency of pests in durian orchard based on the phenological stages of durian. Means with same alphabet are not significantly different between the months (Jan-Dec) for each pest at P = 0.05 by using Tukey's HSD test

This study identified four diseases in the durian plantation: leaf blight caused by *R. solani*, patch canker from *P. palmivora*, leaf spot from *P. durionis*, and anthracnose from *C. gloeosporioides*. Statistical analysis revealed no significant differences in the prevalence of these diseases throughout the various phenological stages of the durian trees (Figure 5). *Rhizoctonia solani* was much more common during the fruit maturation stages than at other times (Figure 5). *Phomopsis durionis* was most common during the crab eye stage in November, and *C. gloeosporioides* was most common during the flowering phase in December (Figure 5). External factors, particularly meteorological conditions, can significantly impact the progression of sickness. Variations in temperature, humidity, and precipitation can create conditions conducive to the proliferation of infections, thereby exacerbating the severity of the illness. Furthermore, the presence of these diseases may make durian plants vulnerable to secondary infestations by pests such as stem borers. Ahmad et al. (2022) contend that diseases might compromise the overall health of trees, making them more vulnerable to secondary infections and pest infestations. This interaction underscores the imperative for comprehensive management strategies that include disease prevention and pest control to maintain the health and production of durian crops.

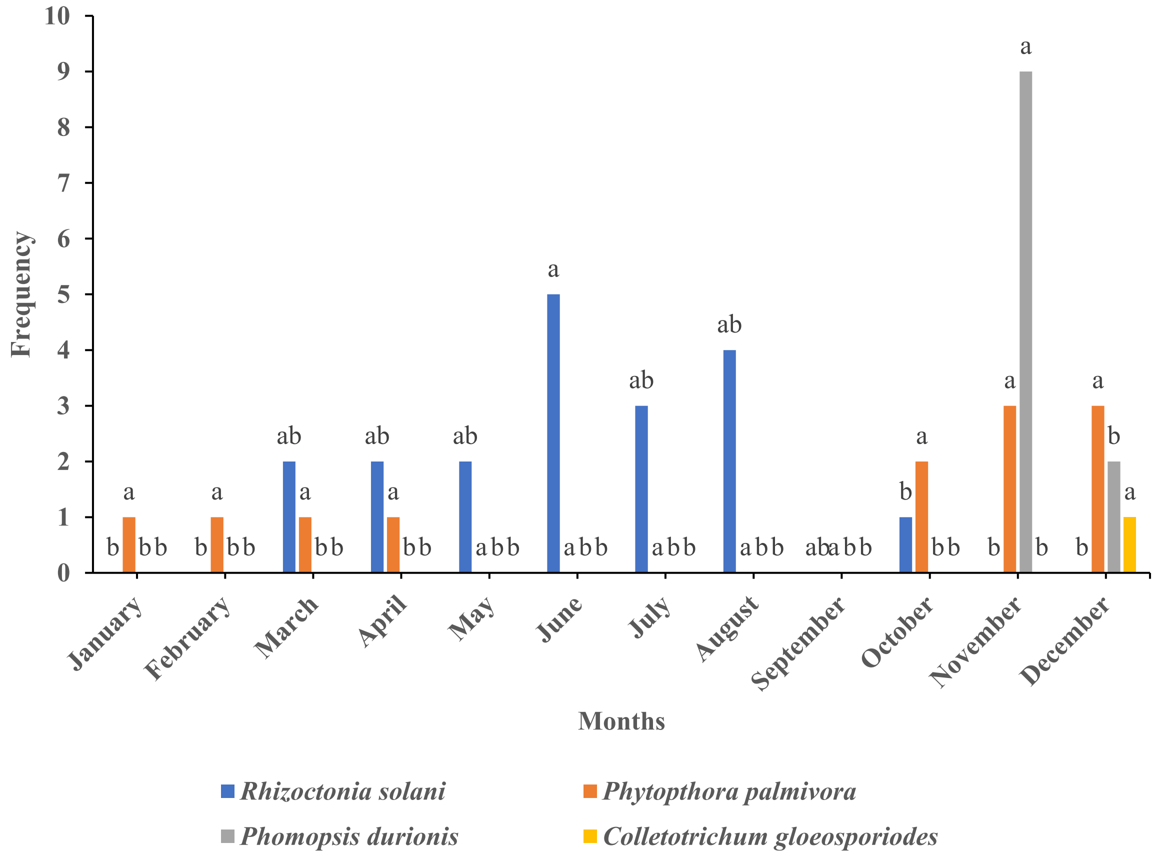

Figure 5. Frequency of disease affected in the durian orchard based on the phenological stages of durian. Means with same alphabet are not significantly different between the months (Jan-Dec) for each disease at P= 0.05 by using Tukey's HSD test

Correlation Between Pest and Disease Infestation and Meteorological Parameters in Durian Orchards

Substantial positive associations were identified across different pest species linked to durian agriculture, suggesting possible connections and common environmental preferences. Strong correlations were established between *Conogethes* spp. and *Mudaria* spp. (r = 0.911), *Platypus* spp. and *Tiraleurodes* spp. (r = 0.878), *A. malayensis* and snails (r = 0.731), and *Pseudococcus* spp. and *Microtermes* spp. (r = 0.877) (Table 1; Figure 6). *Conogethes* spp. and *Mudaria* spp., both recognized as fruit borers, have coordinated life cycles with the durian tree. In the initial phase of fruit development, specifically the "guava stage" when the fruits remain pliable, the larvae are capable of infiltrating the fruit's surface. The synchronicity of their life cycles increases their abundance throughout the initial stages of the durian fruiting season. *Platypus* spp. and *Tiraleurodes* spp. have a significant association, perhaps with their propensity to infest stressed trees, which may also render the plants susceptible to secondary fungal infections. Moreover, both pests demonstrated a positive correlation with precipitation, suggesting that increased moisture levels may enhance their proliferation (Figure 7).

Their shared preference for humid habitats seems to affect the connection between *A. malayensis* and snails. This study regularly noted the concurrent presence of multiple pests, thereby underscoring their vulnerability to analogous climate influences. Moreover, infestations of *Pseudococcus* spp. were found to increase the susceptibility of durian trees to *Microtermes* spp., as evidenced by the notable correlation between these two pests. Infestations by *Pseudococcus* spp. undermine the structural integrity of the tree, particularly the branches; hence, they enable colonization by *Microtermes* spp. This connection highlights the cascading impacts of pest infestations on tree health, as primary pests facilitate the emergence of secondary pests. Understanding these pest dynamics is vital for creating integrated pest management strategies that account for both direct insect harm and the environmental factors influencing their prevalence.

A significant negative connection was seen between *R. solani* and *P. palmivora* (r = -0.606), while a robust positive correlation was found between *P. palmivora* and *P. durionis* (r = 0.679) (Table 2; Figure 8). *R. solani* and *P. palmivora* are soil-borne pathogens whose infections are influenced by climate conditions. The prevalence of *R. solani* rises with heightened humidity, whereas *P. palmivora* infection has a positive connection with higher rainfall (Table 3). The observed negative correlation between *R. solani* and *P. palmivora* suggests a potential antagonistic interaction, whereby the presence of one pathogen may inhibit the growth or impact of the other under particular environmental conditions. The favorable association between *P. palmivora* and *P. durionis* is due to their shared preference for elevated humidity, which promotes the proliferation of both pathogens (Table 3, Figure 7). The similarity in environmental requirements likely enables their concurrent existence and increased co-infection risks. However, little research has been done on how these infections interact, especially if one worsens or causes the other. Further investigation is necessary to elucidate the dynamics of these pathogen interactions and their cumulative impact on durian tree health, which is vital to establishing integrated disease management strategies.

Table 1. Correlation studies between incidence of insect pests of durian

	Conogethes	***Platypus***	**A. malayensis**	***Mudaria***	***Amrasca***	***Tiraleurodes***	***Pseudococcus***	***Microtermes***	***Synanthedon***
Platypus	0.095^{ns}								
Psyllid	-0.052^{ns}	0.204^{ns}							
Mudaria	0.911^{*}	-0.076^{ns}	0.108^{ns}						
Amrasca	0.512^{ns}	-0.225^{ns}	-0.130^{ns}	0.439^{ns}					
Tiraleurodes	-0.181^{ns}	0.878^{*}	0.323^{ns}	-0.174^{ns}	-0.331^{ns}				
Pseudococcus	0.095^{ns}	0.059^{ns}	-0.093^{ns}	-0.076^{ns}	$-4.4E-17^{ns}$	-0.139^{ns}			
Microtermes	-0.165^{ns}	-0.127^{ns}	-0.066^{ns}	-0.173^{ns}	-0.081^{ns}	-0.100^{ns}	0.887^{*}		
Synanthedon	-0.165^{ns}	-0.127^{ns}	0.252^{ns}	-0.084^{ns}	-0.322^{ns}	-0.100^{ns}	-0.127^{ns}	-0.091^{ns}	
Snail	-0.165^{ns}	-0.127^{ns}	0.731^{*}	0.005^{ns}	-0.081^{ns}	0.004^{ns}	-0.127^{ns}	-0.091^{ns}	-0.091^{ns}

Correlation coefficients (r) with four replications. ^{ns} = non-significant, * = significant at P = 0.05

Table 2. Correlation studies between incidence of disease of durian

	Rhizoctonia solani	***Phytopthora palmivora***	***Phomopsis durionis***
Phytopthora palmivora	-0.606^{*}		
Phomopsis durionis	-0.351^{ns}	0.679^{*}	
Colletotrichum gloeosporiodes	-0.288^{ns}	0.558^{ns}	0.131^{ns}

Correlation coefficients (r) with four replications. ^{ns} = non-significant, * = significant at P = 0.05.

Table 3. Correlation studies between durian disease and weather parameters.

Weather	***Rhizoctonia solani***	***Phytopthora palmivora***	***Phomopsis durionis***	***Coletotrichum gloesosporioides***
Rainfall (mm)	-0.20^{ns}	0.63*	0.72*	0.11^{ns}
Temperature (°C)	0.64*	-0.40^{ns}	-0.13^{ns}	-0.01^{ns}
Humidity (%)	0.50*	0.15^{ns}	0.19^{ns}	-0.19^{ns}

Correlation coefficients (r) with four replications. ^{ns} = non-significant, *= significant at P = 0.05.

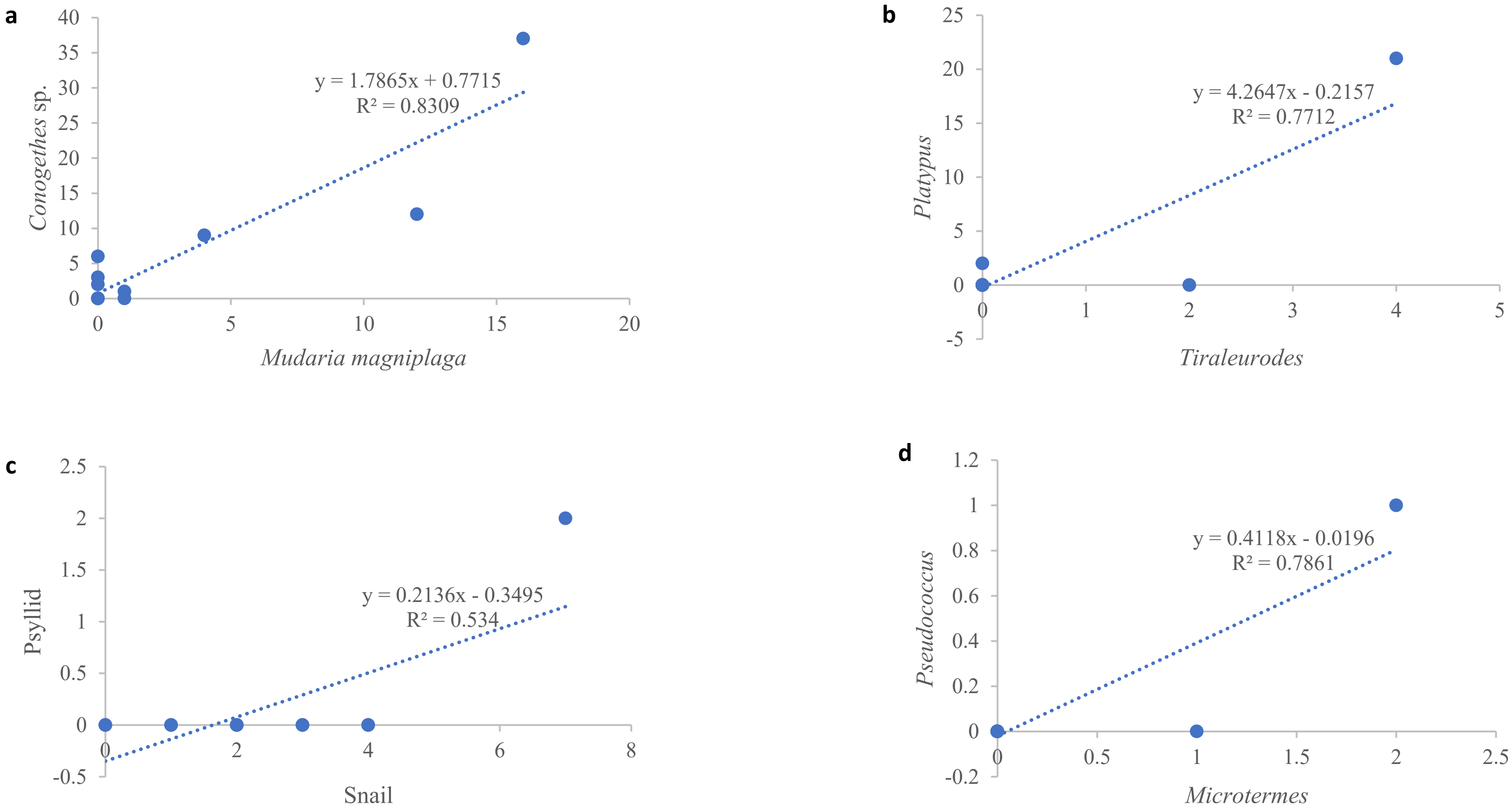

Figure 6. Scattered diagram and regression line showing the relation between abundance of insect pest of durian (a) *Conogethes* vs *Mudaria*, (b) *Platypus* vs *Tiraleurodes*, (c) *A. malayensis* vs Snail and (d) *Pseudococcus* vs *Microtermes*

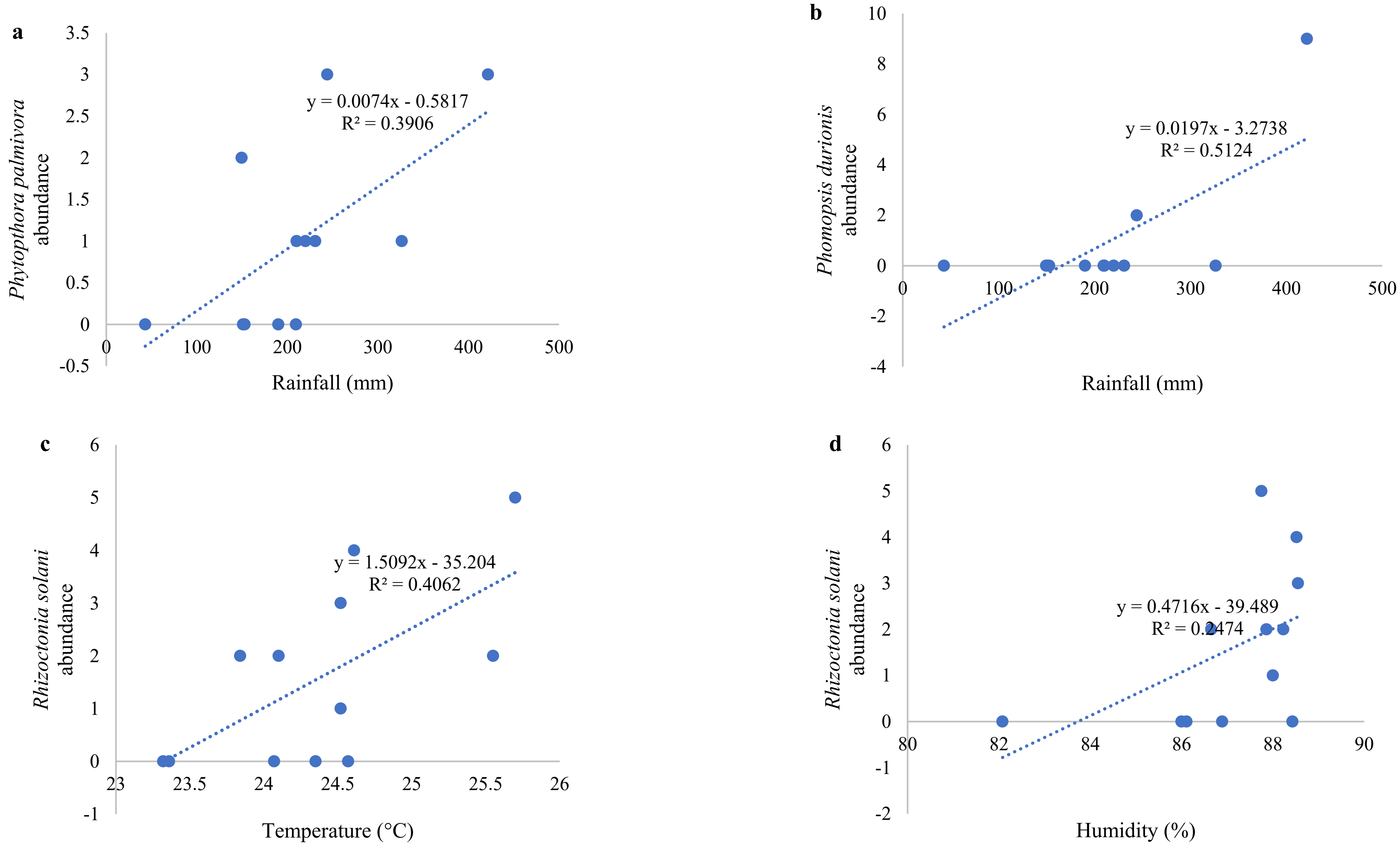

Figure 7. Scattered diagram and regression line showing the relation between abundance of disease of durian and significant weather parameters (a) *P. palmivora* against rainfall, (b) *P. durionis* against rainfall, (c) *R. solani* against temperature and (d) *R. solani* against humidity

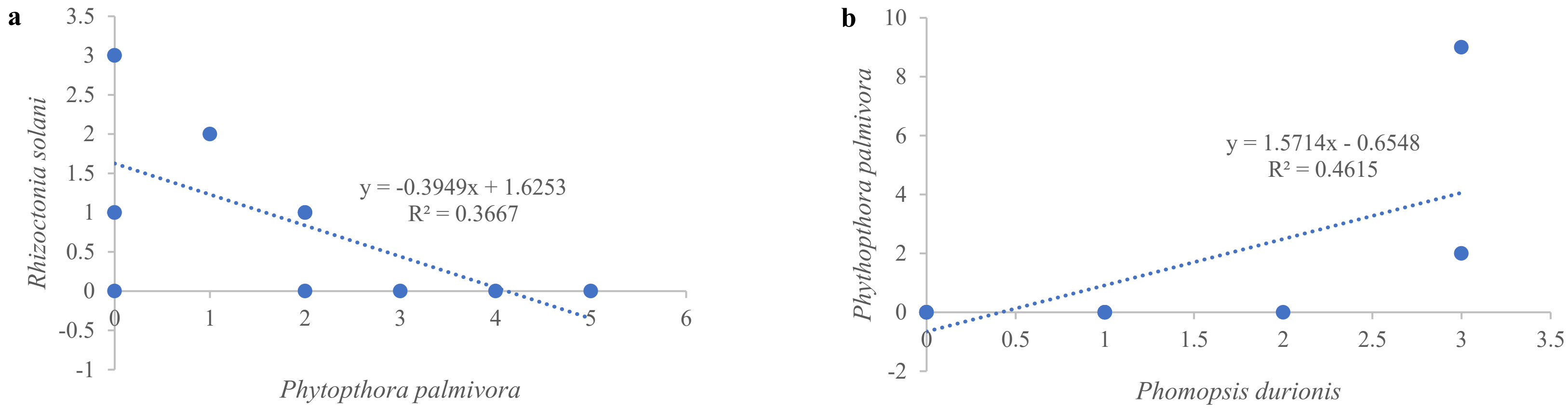

Figure 8. Scattered diagram and regression line showing the relation between abundance of disease of durian (a) *R. solani* against *P. palmivora*, and (b) *P. palmivora* against *P. durionis*

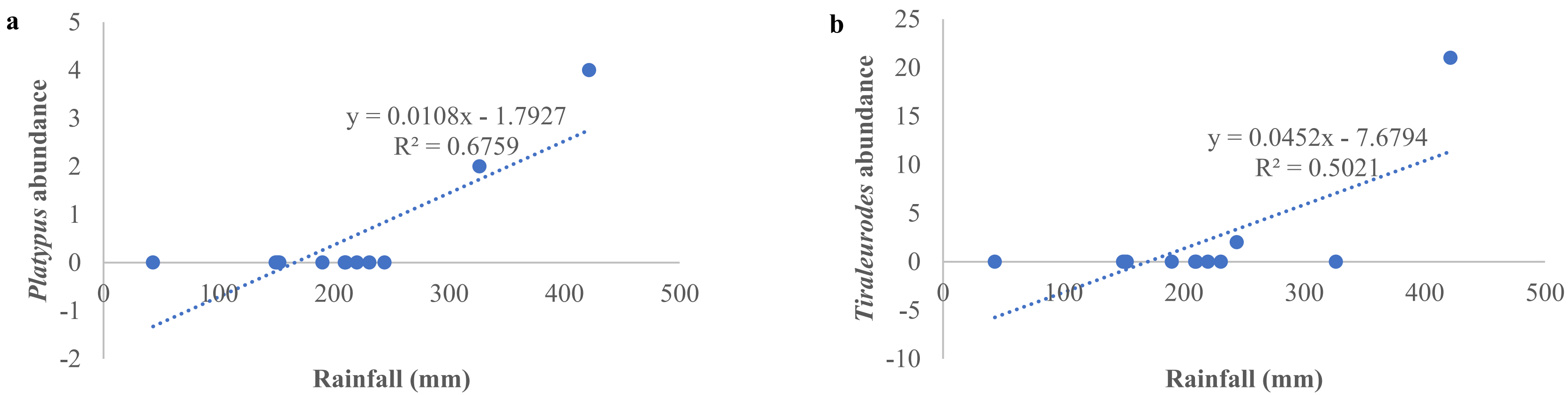

Figure 9. Scattered diagram and regression line showing the relation between abundance of insect pest of durian and significant weather parameters (a) *Platypus* and (b) *Tiraleurodes*

The Relationship Between Durian Pests and Diseases

In the durian plantation, *Platypus* spp. (r = 0.82) and *Tiraleurodes* spp. (r = 0.71) show a strong positive relationship with rainfall (Table 4; Figure 9). These results are consistent with Devi et al. (2019), who observed that cold, humid conditions can intensify insect infestations. Namni et al. (2017), observed a rise in mango hopper populations during the rainy season, while Dassou et al. (2018), reported a positive link between mango seed weevil infestations and rainfall. This study demonstrates that the populations of *Platypus* spp. and *Tiraleurodes* spp. increased with elevated rainfall; nevertheless, excessive precipitation may sporadically reduce pest populations by shifting eggs and larvae (Pandey et al. 2003; Shrestha 2019). However, not all pests exhibited strong connections with climatic variables; many showed moderate or negligible associations with temperature and humidity (Table 4). This diversity highlights the differing reactions of insect pests to environmental conditions, as documented by Pathak et al. (2012), who found that small-bodied pests like aphids and mites demonstrate increased vulnerability to heavy rains.

Table 4. Correlation studies between durian pest and weather parameters

Weather	*Conogethes*	*Platypus*	A. malayensis	*Mudaria*	*Amrasca*	*Tiraleurodes*	*Pseudococcus*	*Microtermes*	*Synanthedon*	Snail
Rainfall (mm)	0.04^{ns}	0.82*	0.36^{ns}	-0.09^{ns}	-0.16^{ns}	0.71*	0.20^{ns}	0.03^{ns}	-0.07^{ns}	0.11^{ns}
Temperature (°C)	0.27^{ns}	-0.23^{ns}	-0.01^{ns}	0.42^{ns}	0.40^{ns}	-0.13^{ns}	-0.53^{ns}	-0.46^{ns}	0.10^{ns}	-0.01^{ns}
Humidity (%)	0.03^{ns}	0.28^{ns}	0.09^{ns}	-0.01^{ns}	0.13^{ns}	0.21^{ns}	0.03^{ns}	-0.03^{ns}	0.25^{ns}	-0.19^{ns}

Correlation coefficients (r) with four replications. ^{ns} = non-significant, * = significant at P = 0.05

In durian plantations, the identified diseases are *P. palmivora*, which induces patch canker (r = 0.63), and *P. durionis*, responsible for leaf spot (r = 0.72), both demonstrating significant positive correlations with rainfall (Table 3, Figure 8). Ahmad et al. (2022) indicated that *P. palmivora* proliferates rapidly during the rainy season, aided by rain splash and wind-dispersed spores, a process similarly observed in oil palm plantations (Misman et al. 2022). *P. durionis*, regarded as a minor durian affliction (Zakaria 2022), is disseminated by precipitation and wind, indicating that increased rainfall accelerates its propagation (Campoverde et al. 2017). This pattern mirrors global trends, since pathogens like *Phytophthora* spp. thrive in conditions of heavy precipitation, leading to root rot in forest trees (Jung 2009). Abundant rainfall facilitates the dissemination of diseases in numerous crops, such as downy mildew in grapes (Elad & Pertot 2014) and phoma stem canker in the UK (Elad & Pertot 2014). In addition to precipitation, temperature and humidity significantly influence the prevalence of sickness. *R. solani*, the causative agent of leaf blight, had positive correlations with temperature (r = 0.64) and humidity (r = 0.50) (Table 3; Figure 7), supporting the findings of Yáñez-López et al. (2012). *R. solani* thrives at high humidity, whereas *Phytophthora* spp. showed no notable correlation with humidity in our study, underscoring the complex and varied responses of pathogens to environmental factors

CONCLUSION

Pest infestations and diseases jeopardize vital durian production for Malaysia's economy. This study discusses the importance of comprehending the elements influencing pest and disease prevalence to enhance management techniques. The results indicate that pest populations, especially *A. malayensis*, *M. magniplaga*, and *Amrasca* spp., are intricately associated with the phenological phases of durian, with fluctuations in population dynamics correlated to their feeding habits. Conversely, the incidence of disorders remained uniform throughout all phenological stages, indicating that disease prevalence is less affected by developmental stages and more by environmental factors. Weather parameters, rainfall, temperature, and humidity were identified as key drivers of both pest infestations and disease outbreaks. *Platypus* spp. and *Tiraleurodes* spp. showed strong positive correlations with rainfall, while *P. palmivora* and *P. durionis* were similarly influenced. Additionally, *R. solani* exhibited significant correlations with temperature and humidity. These insights emphasize the need for integrated pest and disease management strategies that consider both the phenological stages of the crop and prevailing weather conditions. By adopting targeted interventions based on these factors, farmers can enhance durian yields, ensuring sustainable cultivation and contributing to the sector's long-term economic viability.

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No ethical issue is required for this research.

Data Availability Statement:
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author's Contributions
The authors contributed to this study as detailed below: Tan Xue Yi conceptualized and designed the study, acted as the corresponding author, and was chiefly accountable for composing and revising the manuscript. Vinailosni Amirthalingam performed the data analysis, aided in the interpretation of results, and engaged in paper composition. Tan Sue Sian supplied

financial assistance and conducted a critical assessment of the work. Mohamad Baharudin Mohd Sinon facilitated data collecting. All authors have reviewed and endorsed the final version of the text. For correspondence, please reach out to Tan Xue Yi at tanxy@ucsiuniversity.edu.my.

Statement on permission from owner/authority
The authors confirm that formal permission to conduct experimental work within the study area was obtained from *Top Fruits Plantation*, the legal owner and managing authority of the site. All research activities were undertaken in accordance with the plantation's regulations and with the full knowledge and approval of its management.

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