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Acoustic Characteristics of Coconut Leaf Beetle, *Brontispa Longissima* (Coleoptera: Chrysomelidae)

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Abstract

The coconut beetle, *Brontispa longissima* (Coleoptera: Chrysomelidae), is a serious pest of coconut trees, where the larvae and adults feed on coconut leaves. This activity produces vibrations that can be detected by acoustic equipment. This study aimed to identify the sound features between larvae and adults using temporal and spectral acoustic detection. Insect samples were collected from infested coconut trees in May 2021 in Penang, Malaysia. Acoustic recording activities were carried out at the Applied Entomology Laboratory using an AED-2010 sensor-preamplifier module. Parameters such as average impulse time, number of impulses, and average activity rate were recorded to examine the temporal aspect. Two parameters used in the spectral analysis were frequency range and dominant frequency (kHz). An Independent two-sample T-test was conducted to compare the mean differences in acoustic parameters between adult and larvae of *B. longissima*. The results showed that adult *B. longissima* was more active than larvae. It had higher mean impulse interval time (ms), mean number of impulses, and mean activity rate (impulses/s) than the larvae. However, the results showed that the difference in activity between larvae and adults was insignificant. Furthermore, this acoustic study is critical to understanding the behavior of destructive insects and helps develop more curative and sustainable methods to control *B. longissima*. Using acoustic methods could assist in evaluating the level of infestation and damaging activity of the insect pest.

Keywords: Acoustics, adult, *Brontispa longissima, Cocos nucifera*, impulse

Introduction

The coconut leaf beetle, *Brontispa longissima* (Coleoptera: Chrysomelidae), is a major pest of coconut (*Cocos nucifera*) and other palm species in Southeast Asia. This insect, native to Indonesia and Papua New Guinea (Tang, 2019 in Li et al., 2021). The distribution of this insect pest nowadays includes Malaysia, Indonesia, Singapore, Vietnam, Nauru, Thailand, Maldives, Japan, and Hainan Island (China), all of which have experienced spread in recent years (Singh and Rethinam, 2005; Takasu et al., 2010). The spread of *B. longissima* between regions and countries is caused by its spread through the transportation of infested coconut trees by humans (FAO, 2004).

The population density of *B. longissima* varies based on habitat conditions. Lumentut et al. (2018) found 128.57 - 253.67 individual of *B. longissima* per leaf sheath at different heights in North Sulawesi, Indonesia. Galicia et al. (2023) found 10.1 - 164.9 individuals *B. longissima* per bearing and non-bearing palm in Albay, Philippines. Wilco and Chapman (2006) state that this pest attack can target up to 17 palm trees, including oil palm, betel, nipah, and other ornamental plants. Larvae and adults feed on the unopened coconut leaf bud tissue (Takasu et al., 2010). Beetle attacks cause leaves to turn brown and reduce fruit yield. A series of severe leaf shedding will eventually lead to tree death (Nakamura et al., 2006; Cabelin and Ceniza, 2021a).

Current management strategies rely heavily on chemical insecticides. However, their excessive use poses environmental risks and health hazards (FAO, 2004). Biological control has been explored through the introduction of parasitoids, such as *Ooencyrtus podontiae* (Hymenoptera: Encyrtidae) and *Tetrastichus brontispae* (Hymenoptera: Eulophidae), as well as entomopathogenic fungi (*Metarhizium anisopliae*) and bacteria (*Serratia marcescens*) (Liu et al., 2016; Hoe, 2018; Alouw et al., 2020; Yang et al., 2024). While these methods show promise, they require more time for population suppression and may not provide immediate results.

An alternative and non-invasive approach for monitoring *B. longissima* infestations is acoustic detection. Insects generate acoustic signals during various activities such as foraging, movement, and feeding (Balakrishnan, 2016; Romer, 2019; Aliyah-Ahmad & Jalinas, 2023). Signaling via substrate vibration is one of the most common and ancient forms of insect communication. In crickets, the production and detection of acoustic and vibration signals are closely linked functionally and evolutionarily (Stritih-Peljhan et al., 2021). Insects that bore and hide inside trees show different acoustic characteristics (Mankin et al., 2008; Khudri et al., 2021). The movement and feeding or chewing activity of larvae inside trees produce sounds with specific frequencies and spectra, which can help in the early diagnosis of pest attacks for immediate remedial action to prevent severe damage (Jalinas et al., 2017).

Analysis of temporal and spectral patterns of insect larvae sounds has been used to distinguish them from background noise in both field and laboratory settings (Aliyah-Ahmad & Jalinas, 2023; Mankin et al., 2016). Key spectral factors include dominant frequency (kHz) and frequency range (Aliyah-Ahmad & Jalinas, 2023). In *B. longissima* beetles infesting coconut leaves, the sounds produced by both larvae and adults vary in ways that reflect their feeding activity. Despite the potential of acoustic monitoring, research on the acoustic characteristics of *B. longissima* remains limited. While previous studies have focused on population dynamics and biological control, little is known about the specific spectral and temporal properties of their feeding sounds.

Analysis of temporal and spectral patterns of sounds produced by insect larvae has been used in the field and laboratory to distinguish these sounds from background noise (Aliyah-Ahmad and Jalinas, 2023; Mankin et al., 2016). The dominant frequency (kHz) and frequency range have been used as two factors in spectral analysis (Aliyah-Ahmad and Jalinas 2023). The spectral and temporal patterns of sounds produced by adult beetles and larvae of *B. longissima* on coconut leaves can show essential variations in signals indicating their feeding behavior activities.

Despite the potential of acoustic monitoring, limited studies have investigated the acoustic characteristics of *B. longissima*, little is known about the specific spectral and temporal properties of sounds produced by larvae and adult beetles during feeding. Understanding these acoustic signatures could offer an innovative, eco-friendly method for early detection and monitoring. This study aimed to study the temporal and spectral acoustic characteristics of adult beetles and larvae of *B. longissima* that reflect their damaging activities on coconut leaves.

Methods

The study was carried out in Kampung Padang Tembusu, North Seberang Perai, Penang, Malaysia, and the Laboratory of Applied Entomology, Universiti Kebangsaan Malaysia, during May 2021.

Method

Insect Samplings

Larvae and adult were conducted in Kampung Padang Tembusu, North Seberang Perai, Penang, Malaysia (5°32'23.1"N 100°23'18.3"E) (Figure 1). Samples were collected from coconut trees with visible symptoms of infestation. The identification was based on the morphology characters (Ayri and Ramamurthy, 2012; Ali et al., 2018; Cabelin and Ceniza, 2021b). To ensure that larvae and adult stay alive, insect samples collected were placed and maintained in separate containers with ventilation openings (Figure 2).

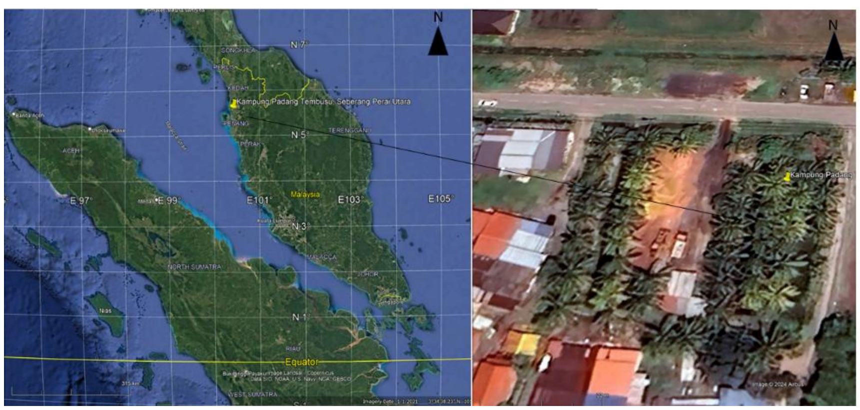

Figure 1. The location of insect samplings for *B. longgissima* at the coconut orcard in Kampung Padang Tembusu, North Seberang Perai, Penang, Malaysia.

Figure 2. Samples of larvae and adult of *Brontispa longissima* were collected from coconut trees: a. visible symptoms of infestation, b. larvae, c. adult

Acoustic Recordings

Acoustic recordings of healthy larvae and adults of *B.longissima* were recorded for 180 seconds at the Laboratory of Applied Entomology with a sensor-preamplifier module (SP-1L) connected by a magnetic attachment to the signal waveguide screw, as in Jalinas et al. (2015) and Dosunmu et al. (2014) (Figure 3a and 3b). The signals were fed from the sensor module through an amplifier (AED-2010, Acoustic Emission Consulting, Inc., Sacramento, California) to a digital audio recorder (model DR-05 TASCAM) at a 44.1-kHz digitization rate (Jalinas et al., 2017) (Figure 3c). During acoustic recording, the acoustic signals were monitored with headphones to avoid faulty readings or periods of loud background noise. Precautions were taken to minimize contact by wires and sensors with palm leaves and other surfaces (Jalinas et al., 2019).

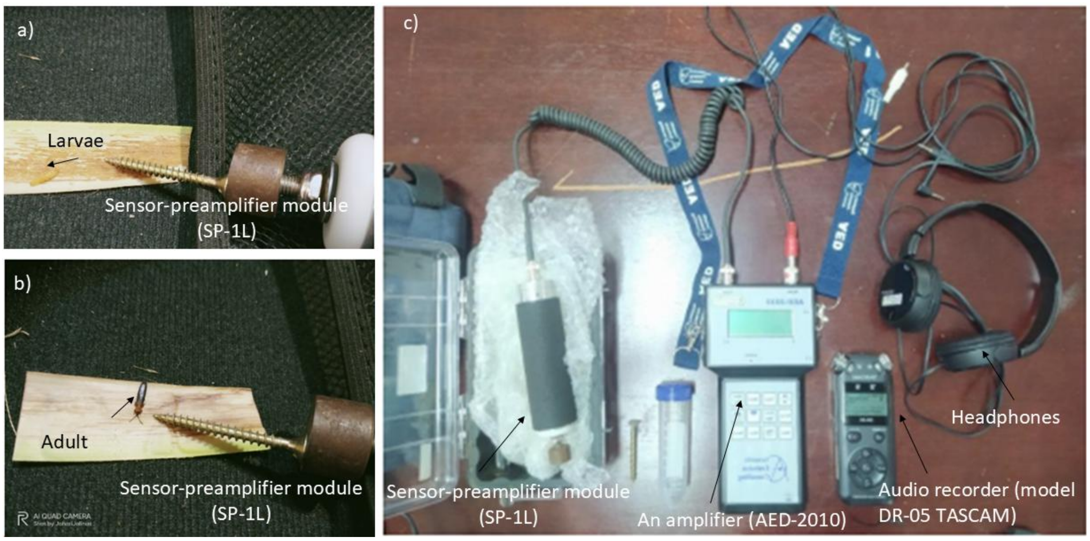

Figure 3. Acoustic recording of *Brontispa longissima*: a. larvae, b. adult, c. acoustic recording equipments - sensor equipment, preamplifier module and digital audio recorder (TASCAM model DR-05)

Analysis of Acoustic Temporal and Spectral Features

Oscillograms and spectrograms of the sound recordings were screened with Raven Pro Software 13.0 (Charif et al., 2010) to identify relatively noise-free intervals containing *Brontispa* beetle's signals.

Variable observed

Several acoustic parameters for temporal analysis were used based on methods (Aliyah-Ahmad and Jalinas, 2023 and Jalinas et al., 2017). All the parameters were recorded and observed 10 times.

- Duration impulse**:** Time of individual impulse produced by larvae or adult, unit in time (ms)
- Number of impulses in selected, unit number.
- The rate of impulses (impulse/s) was identified and recorded to study the temporal characteristics based on acoustic recordings of larvae and adults.

Two parameters for spectral analysis were used based on methods (Aliyah-Ahmad and Jalinas, 2023 and Jalinas et al., 2017): The dominant frequency (kHz) and the frequency range (kHz)

Data and Statistical Analysis

The two-sample unpaired T-Test for the mean difference between parameters of the acoustic signals produced by adult and larvae of the *Brontispa* beetle by using R-Studio software.

Results

Acoustic detection of *B. longissima* activity

Acoustic recordings of *Brontispa* beetle larva and adult have been successfully recorded using the acoustic devices AED 2010. The acoustic signals were based on movement and feeding activities on coconut leaf. The acoustic signals can be analyzed and displayed in the oscillogram using Raven Software (13.0) (Figure 4).

Larvae and adult *Brontispa* beetles produce different impulses and amplitudes on the oscillogram with more frequent impulses and stronger sound impulses for adult than larvae. Larvae and adults *Brontispa* beetles produce different impulses and amplitudes on the oscillogram. *Brontispa* beetle adults were found to have a higher number of impulses and a louder sound of impulses than *Brontispa* beetle larvae during the recording activity (Figure 5).

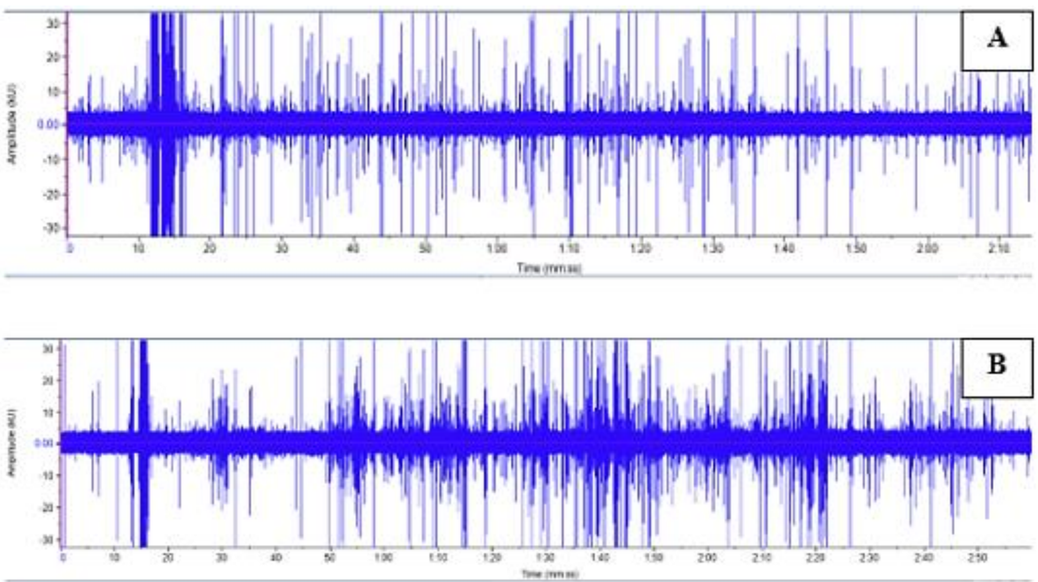

Figure 4. Acoustic detection of *Brontispa longissima* on Oscillogram: A. Larvae, B. adult

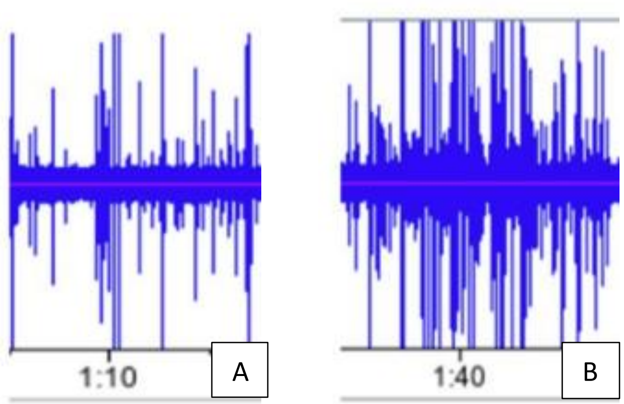

Figure 5. Comparison of acoustic impulses produced by *Brontispa longissimi*: a. larvae, adult

Acoustic Impulse Time, Number, and Rate

The average impulse time (ms) produced by adult *B. longissima* was higher than that of the larvae, which was 13.026 for adults and 7.315 for larvae. Furthermore, it was discovered that adults produced more impulses than larvae, with the average for adults being 4.234 and the average for larvae being 4.091. Additionally, the adult's mean impulse rate (impulses/s) is 0.424, while that of the larvae is 0.409 (Table 1).

Table1. Impulse time (ms) larvae and adults of *Brontispa longissima*

Samples	Mean Impulse Time (ms)*	Mean Number of Impulse**	Mean activity rate (impulses/s)***
Larvae	7.32 ± 0.45	4.091 ± 0.80	0.409 ± 0.15
Adult	13.03 ± 0.55	4.234 ± 1.50	0.424 ± 0.15

Notes: *n= 10 observations for individual impulse within 10 seconds of acoustic recording, **n= 10 observations for each 10 seconds of acoustic recording, ***n= 10 observations for number of impulses within 10 seconds of acoustic recording.

All three parameters had P values > 0.05. The value of P is 2.542 for the mean of the impulse time; next, the value of P is 0.7713 for the mean number of impulses, and the P value is 0.7713 for the mean rate of impulse. These findings indicate that there is no significant difference in the temporal characteristics produced by *B. longissima* larvae and adults.

Spectral characteristic of acoustics

For spectral analysis, there are two amplitude peaks for larvae, dominantly located on 4 - 10 kHz with a frequency range of 0.3 - 0.8 kHz. There are four amplitude peaks for adults, dominantly located on 4 -19 kHz with a frequency range of 0.3 - 0.9 kHz (Figure 6 and Table 2).

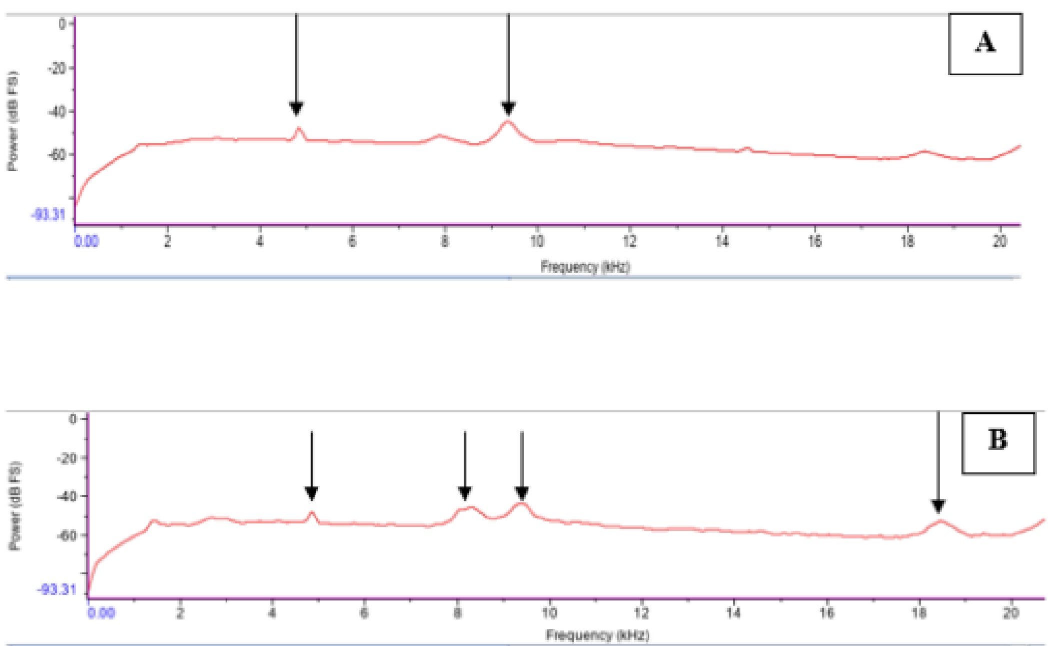

Figure 6. Spectral profile of *Brontispa longissimi:* A. Larvae, B. Adult

Table 2. Dominant frequency and frequency range of larvae and adult *Brontispa longissima* spectral profile

Sample	Dominant Frequency (kHz)	Frequency Range (kHz)
Larvae	4.83	0.34
	9.31	0.80
Adult	4.88	0.33
	8.25	0.85
	9.34	0.70
	18.46	0.90

Discussion

This report discusses using bioacoustic equipment to analyze plant health and structural characteristics (Mankin et al., 2018). Both larvae and adults typically feed on the abaxial and adaxial epidermis of leaves, strip tissues from leaflets, and damage the growing points of palm trees (Ayri and Ramamurthy, 2012). Acoustic techniques can be used to identify the vibrations that generate their movements and feeding activities (Banga et al., 2019).

A study by Mankin (2012) reported that using modern acoustic equipment has increased the automation and efficacy of the acoustic recording process and helped researchers monitor the level of insect infestation. In addition to monitoring insect movement, feeding activity, and mating on host plants, entomologists use vibration and sound sensors to reveal hidden infestations of invasive insect species (Mankin et al., 2018; Mueller-Blenkle et al., 2018).

In this study, these acoustic techniques successfully detected and identified acoustic features specific to *B. longissima* larvae and adults. Their movement and feeding activities on coconut leaves reflected specific acoustic signal patterns. Adult beetles were found to have more impulses and louder impulse sounds than Brontispa beetle larvae during recording activities (Figure 4, Figure 5). The average impulse time produced by adults (13,026) was higher than that of larvae (7,315) (Table 1). Adult beetles produce more acoustics than larvae because they are stronger, have stiffer legs, and have more developed mouthparts and heads. All acoustic parameters of adult beetles were higher than those of larvae. Adult beetles showed higher frequency levels than larvae (Figure 6, Table 2). More acoustic activity was recorded in adults because the external body structure of adults is stronger and more complex than that of larvae. Both larval and adult stages of insect pests that inhibit plant growth have been effectively identified by acoustic technology, which is especially useful in determining the impact of early attacks on food crops (Jalinas et al., 2015). It is helpful to use temporal characteristic analysis to separate insect impulse sounds from background noise, especially in areas with high levels of auditory diversity (Mankin et al., 2008; Khudri et al., 2023).

In terms of spectral characteristic analysis, it was found that the dominant frequencies produced by adult *B. longissima* were higher, ranging from 4 to 19 kHz with a frequency range of 0.3 to 0.9 kHz, while the dominant frequencies produced by *B. longissima* larvae were between 4 and 10 kHz with a frequency range of 0.3 to 0.8 kHz (Figure 6 and Table 2). Adult *B. longissima* produced sound impulses with higher amplitudes than larvae, as evidenced by the spectral profile with a higher number of prominent frequencies for adults than for larvae. The acoustic signals produced by adult and larval beetles, *Prostephanus truncatus*, and *Sitophilus zeamais* have different frequencies and time patterns (Njoroge et al., 2016). Variation in the spectral and temporal patterns of insect signals has been associated with variation in behavioral activities such as feeding and movement (Jalinas et al., 2015; Njoroge et al., 2016).

Conclusion

The results showed that adult *B. longissima* was more active than larvae. It had higher mean impulse interval time (ms), mean number of impulses, and mean activity rate (impulses/s) than the larvae. However, the results showed that the difference in activity between larvae and adults was insignificant. Furthermore, this acoustic study is critical to understanding the behavior of destructive insects and helps develop more curative and sustainable methods to control *B. longissima*. Using acoustic methods could assist in evaluating the level of infestation and damaging activity of the insect pest.

Declaration

Author contribution

Ganeshwari Selvaraj is the first author. Johari Jalinas is corresponding author for this paper. Both authors read and approved the final paper.

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Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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