Abstract

In this paper, details on the techniques used towards analyzing the acoustic signals generated by Red Palm Weevil RPW are presented. Besides, the acoustic signals generated by RPW in the palm and in the laboratory have been taken for this analysis. This paper describes in detail the great significance pertaining to the analysis of acoustic signals of red palm weevil recorded. The spectrum obtained for RPW is stored for analysis. The frequency in Hz and sound level in dB for both signals are determined. The frequencies are also of low range. Adequate number of spectrum has been displayed for easy understanding. Movement of RPW signal could not be compared with that of the eating and biting signature since no evenness existed for evaluation.

Keywords: Acoustic activity; Data acquisition; Red Palm Weevil (RPW); Spectra;

1. Introduction

1.1 Different Pests on Palm (coconut trees)

The different pests on coconut palms, their biological name and their effect on infestations have been listed below Leffroy H.M 1906, Daniel Blumberg (2008), Nirula et al( 1953) and Abraham et al (1998).

1. Rhinoceros beetle (RB) (Oryctes Rhinoceros)-feeds on tender open of leaves.
2. Leaf eating caterpillar (Opirina Arenosella walk)-deestructs leaves.
3. Red Palm Weevil (RPW) (Rhynchophorus Ferrugineus)- feeds on tissues of trunk.
4. Eriophyid Mite (Aceria Guerreronis)-affects nut surface.
5. Coconut white grub (Leucopholis Coneophora)-affects growing roots of coconut palm.
6. Mealy bugs and Scales (Pseudo Coccus longispinus and Aspidiotus destructor)-infest spindle, unopened spathe.
Coreid Bug (Paradasynus Rostratus)-sucks sap from developing buttons and causes immature nut fall and malformation of nuts.

Rats (Rattus Rattus Wroughtonni)-lives on palm crown and damages tender nuts.

Nematodes

In the above listed group of insect pests on palms, it has been found that the Red palm weevil (RPW) is the most influential pest and leads to the death of tree Walid Barakat Hussein (2009), Mankin et al (2000), Lever, R.J.A.W. (1979). The main objective of the research is to detect the red palm weevil which is the most deadly pest. Due to its high reproduction rate, RPW prefers to live with no other insects in one trunk. However, in the following section detection of Red Palm Weevil (RPW) is considered since it is considered to be the most destroying pest.

1.2 RPW and its Life Cycle

The Red Palm Weevil (RPW) also known as Asian palm weevil or sago palm weevil affects palm of 3-15 years of age Lefroy, H.M. (1906). As the name suggests they are red coloured, 2 to 4 cms long. The larva of red palm weevil tunnels through trunk of palms weakening the stem thereby causing mortality of tree trunk. RPW originated in Asia which later spread to Africa and Europe finally reached Mediterranean in 1980’s. In Asia, it covered regions of Bangladesh, China, Iran, Iraq, Bahrein, Cambodia, India, Indonesia, Israel, Kuwait, Laos, Manmar, Oman, Pakistan, Philippines, Qatar, Saudi Arabia, Singapore, Srilanka, Taiwan, Thailand, UAE and Vietnam. It also spread throughout Africa and Spain. It affected coconut palms in India, Srilanka and affected oil palms of Kerala. Malaysia had damage on its Sago palms. The scientific classification of RPW (Rhynchophorus Ferrugineus) is listed as follows.

- Kingdom- Animalia
- Phylum- Arthropoda
- Class- Insecta
- Order- Coleoptera
- Family- Curclionidae
- Genus- Rhynchophorus
- Species- Rhynchophorus Ferrugineus

The Life Cycle of RPW is now described. The weevil infests the palms of age 3-15 years. More than the adult the larva burrows into heart of palm that causes greatest mortality of trunk. Figure 1. shows the life cycle of red palm weevil Richard W. Mankin et al (2004). The larva of about 5 inches feeds on the soft fibers and terminal buds penetrating deep into the tissues of the tree within a month. At pupation, the larva shelters itself into a network of fibers to form cocoon. The total life cycle gets completed in 4 months. The larvae are yellowish white, segmented legless and have chitinous head capsule, dark brown in colour. It burrows from the axils of the leaves to the crown using its conical jaws.

Fig. 1. Life cycle of red palm weevil
1.3 Appearance of RPW

The male RPW is characterized by the presence of a series of black hairs on the dorsal, frontal parts of snout. Female RPW do not exhibit hairs Vidyasagar, P.S.P.V. and S. Keshava Bhat. (1991). The maximum span of adult RPW for female is 76 days and 113 days for male. The RPW has 3 generations/year. The shortest generation is of 100 days and longest of 127 days. Figure 2 shows the image of RPW.

![Fig.2 Image of Red Palm Weevil](image)

In the next section, we will discuss some aspects on various methods of detection of RPW and analyze the acoustic samples particularly their frequency ranges which can be used to determine the presence of the particular species.

1.4 Objectives of the Research

- The proposed research work would also focus its main objective viz., to develop a novel system to detect in-situ the RPW in the field. The technique proposed essentially comprises of the following three modules:
  - Acquiring the acoustic data pertaining to the suspected RPW
  - Comparing (correlating) the same with the known acoustic data of known RPW
  - Taking the appropriate decision based on statistics concerning its presence or not.
- Now the details of these techniques will be described in the following sections.

2 Materials and Methods

2.1 Acquiring acoustic data and analysis

As mentioned, in this research an acoustic technique has been used to record signals of the pest infested palm tree trunk by placing the sensor on the stem base, on the leaf axil and on the palm crown. The attack of symptoms is visible at a stage, when the tree is highly infested by the pests and the tree outwardly appears rot in the extremely affected areas. In such cases, sensor is placed on the affected portions of the stem. Recordings were done on the pest infested trunk and non infested trunks. The acoustic signals were played employing sound editing software and the analysis is made. The spikes or bursts pertain to infected trees and blank files for non-infested ones. The spikes appeared continuously but in intervals for suspected palms. Playing the recorded file, the spikes with different widths and amplitude levels would enable different interpretations. However these signals can be classified according to their pattern and the corresponding frequency range could be determined. Using the frequency pattern thus observed, one could then classify these spikes as sound emanating from insect species. It may be mentioned here that an experienced trained listener could easily spot the sound of insects by simply hearing the recorded file.

2.2 Data acquisition

Data acquisition in our context involves sampling of analog signals recorded in the tape and then digitizing it for digital signal analysis as needed. This entire work is automatically carried out in the digital tape recorder used. The digital data so acquired are then processed by appropriate software programs available in general purpose
programming languages such as BASIC, C, JAVA etc. The specifications of the data recorder used for the purpose of acoustic data acquisition are given in a later section.

The basic concept used in the digital recording or processing system employed is shown in Figure 3.

The input low pass filter (Anti aliasing filter) shown in Figure 3, is required to eliminate all frequency above $fs/2$ where $fs$ is equal to sample frequency to avoid aliasing distortion for original $fs/2$. ADC is required for conversion. Storage of data can be performed on magnetic tape discs or RAM. DAC converts back to analog signal. The conversion speeds are 2 kHz to 200 MHz. The output of low pass filter should eliminate all frequencies above $fs/2$ which are generated during D/A conversion.

### 2.3 Data Acquisition Hardware

An input sensor used for detecting the acoustic signal, is a type of transducer that converts the physical property viz., the acoustic signals, into the corresponding electrical signal output. Appropriate signal conditioners, enable, filtering and amplifying of signals as necessary to finally get done digitization. Once the signal is digitized the signal can then be encoded appropriately to reduce and correct transmission errors Betty Martin, Vimala Juliet,(2013). The digitized audio data so captured by the sensor now needs to be interfaced with the PC. For this purpose a data acquisition hardware is essential and it could be in the form of modules that can be connected to computer ports (parallel, serial, USB etc.) DAQ cards contain multiple components (MUX, ADC, DAC, TTL-IO, high speed timers, RAM). The digital voice recorder (DVR) used in this research work is Cenix VR W 2170 n, with 512 MB as in built memory and can be used continuously for 17 h in the field. The salient features of DVR are that, it stores the erased files for future use, works in multi recording mode. It has SHQ/HQ/LP, micro SD card, voice operated recording facility, and various clock functions. It has an internal microphone with signal to noise ratio 40dB. Its dimensions are 33 mm X 96 mm X 15 mm (W/H/T). Figure 4 shows the DVR along with the sensor microphone, used for the study.

2.4 Acquiring the acoustic waveform of RPW in infested palms

The pest enjoys its whole generation inside the trunk throughout its life time and it can be observed that the tree has lots of tunneling through the tissue, forming a pathway for the movement of the pests. Thus the whole tree gets infected and suffers damage. Taking cautious steps towards the complete capture of the acoustic patterns of
the pest, the DVR along with the microphone has been placed in three different locations as shown in Figure 5. The three main locations of interest are the affected area of stem in its base, the axil of leaf and the palm crown. The placement of sensors played a significant role during recording.

![Fig.5 Placement of sensor in three different locations](image1)

The microphone being handy can be placed and focused towards suitable points on affected parts of the palm trunk. The microphone can be placed in a horizontal as well as vertical to the trunk orientation position as shown in Figure 6. An additional flexible mike which is covered with the headset cap is also used to avoid air gap.

![Fig.6 The microphone in horizontal and vertical positions](image2)

Once the sound is recorded during tests in the hotspot, it could be immediately played back for check. The infested and non-infested sounds are segregated and blank records are discarded. Only the sounds of interest are stored in the laptop for further analysis and comparison with the known acoustic format of RPW.

### 2.5 Acquiring Acoustic Format of RPW In The Lab

For the proposed method of analysis, the acoustic wave form of live RPW is needed. For this purpose the acoustic wave form generated by live RPW is recorded in the lab using a sound insulated chamber to maintain low levels of back ground noise. The recorder is stuck inside the sound proof box in a switched ON condition. Figure 7 shows the voice recorder along with the box used for this purpose.
The recordings of the weevil activity are done by pasting the DVR on the wall of the acoustic box using tapes. The elements of the acoustic box consisted of rectangular glass box, thermocol, chart paper, rock wool, cotton cloth and rough paper. The outer dimension of the glass box is 34cm in length and 16 cm in width. It consisted of thermocol filling, the walls of the box with 2 pieces each of 38 cm for top and bottom respectively and chart paper of 2 pieces 18cm each is used to cover the thermocol. A cotton cloth of ¼ meter total is used with rock wool to make it completely sound proof as shown in Figure 7. Care is taken that any machinery nearby are turned off. The recording period ranged from 20 min to 60 min, per sample Betty Martin, Vimala Juliet, (2011). These recordings were done on seven small grubs and one small weevil of RPW.

3 Results and Discussion

As stated earlier, the acoustic activity of the species RPW is recorded inside the sound proof chamber separately. From the transparent side of the sound proof box the grubs and the adult weevils are observed and its activity is been keenly watched. Later from the observation, the sound actions were categorized as eating, biting and moving. The classified acoustic signals are considered for analysis. Hence using this finding, detection of RPW can be made simple. This study can be used to design and develop a novel system for detection of RPW L.R. Rabiner and B.H. Juang, (1993). Betty Martin et al (2013), Betty Martin et al (2014)

3.1 Categorisation of Acoustic Pattern of RPW from Laboratory Recordings

During recording in laboratory the acoustic activity of RPW actions inside the sound proof chamber, is vigilantly watched continuously. The acoustic activity recorded in the sound proof box is classified as biting, eating and moving. Biting action is sorted into normal biting and slow biting. Eating action is further divided into clear eating and slow eating. Crawling is again classified as normal, slow and lengthy movements. In these sorting methods, the sound level and frequency of each spectrum are the key factors which decide the presence of RPW. Further analysis has been given in the next section.

3.2 Acoustic analysis on biting pattern of RPW

Biting is the process of breaking the food substance into smaller pieces when the upper and lower mandible meets each other. Biting action is further divided into

- Normal Biting
- Slow Biting
With normal biting, the observed frequency peak in the spectra displayed is 1651 Hz at a sound level of –19.6 db, and at a frequency peak of 1588 Hz with -24.2 db the spectrum exhibited slow biting as tabulated in Table 1. Figure 8 and Figure 9 show the biting patterns of RPW.

Table 1 Frequency of Biting pattern of RPW

| S.No. | Activity     | Frequency (Hz) | Sound Level (dB) |
|-------|--------------|----------------|------------------|
| 1     | Normal biting| 1651           | -19.6            |
| 2     | Slow Biting  | 1588           | -24.2            |

Fig.8 Spectrum for Normal Biting

Fig.9 Spectrum for slow biting
From these observations, it is clear that from the spectrum of Figure 8 and Figure 9 the sound level of slow biting signal is -24.2 dB lesser than the normal biting signal which is -19.6 dB. This infers that slow biting signal has lesser sound level than normal biting signal.

3.3 Acoustic analysis on eating pattern of RPW

Eating can be defined as the process of chewing the food substance and collectively swallowing it into the mouth which is subsequent to biting action.

Eating action is divided into

- Clear Eating
- Slow Eating

At a frequency peak of 2219 Hz with -17.2dB the spectrum exhibits clear eating, the spectrum presented a frequency 1163 Hz at -15.2 dB for slow eating and is tabulated in Table 2. Figure 4.5 - Figure 4.6 show the spectrum for different eating patterns of RPW.

Table 2. Frequency of eating pattern of RPW

| S. No | Activity     | Frequency (Hz) | Sound Level (dB) |
|-------|--------------|----------------|------------------|
| 1     | Clear Eating | 2219           | -17.2            |
| 2     | Slow Eating  | 1163           | -15.2            |

Fig.10 Spectrum for clear Eating
From these observations, it is clear that from the spectrum of Figure 10 and Figure 11 the sound level of clear eating signal is -17.2 dB less than the slow eating signal which is -15.2 dB. This infers that clear eating signal generates less sound than slow eating signal.

3.4 Acoustic analysis on movement pattern of RPW

Movement of an insect is the process of crawling or changing position or moving from one place to another. Movement action is further divided into

- Normal movement
- Slow movement
- Lengthy movement

While in normal movement the observed frequency peak in the spectrum displayed a range of 1652Hz - 2168 Hz at a sound level of + 9.9 db, and at a frequency range of 1651 Hz to 2201 Hz with +10.5db to 9.7 dB the spectrum exhibited slow movement, the spectrum presented a frequency range of 1003 Hz to 1600 to 2151 Hz at 0.5 db for lengthy movement as tabulated in Table 3. The spectrum for movement did not exhibit consistent frequency pattern. Figure 12 – Figure 14show different patterns of movement of RPW.

| S.No. | Activity            | Frequency (Hz) | Sound Level (dB) |
|-------|---------------------|----------------|-----------------|
| 1     | Normal movement     | 1652-2168      | 9.9             |
| 2     | Slow movement       | 1651-2201      | 9.7             |
| 3     | Lengthy movement    | 1600-2151      | 0.5             |
Fig. 12 Spectrum for crawling movement

Fig. 13 Spectrum for slow movement
From the observed spectrum, comparison of movement signal cannot be made on biting and eating signal since there is no uniformity in the results obtained. But it can be concluded that the sound level of eating signal produces more sound than that of biting signal. This study made on sound level emanating from the red palm weevil could help in the design and development of a system to detect red palm weevil.

4 Conclusion

The presence of the insect pest could be detected by its unique traits namely eating, biting or crawling actions. Hence these activities have been categorized as biting, eating and movement. Among these actions the sound level for eating signal is high when compared to the biting sound signal. But movement of RPW signal could not be compared since no evenness existed for evaluation. Comparison between the sound level of RPW’s signal activity, helped in detecting the presence of hidden RPW inside the trunk.

5 Summary

The study made on the categorization of acoustic activity of RPW along with its respective spectra and sound level is being compared. From this analysis it can be concluded that the sound level of eating signal generated from RPW is greater when compared to its biting sound signal. Besides, the biting and eating sound signals emanating from RPW cannot be compared with the movement sound signal of RPW while crawling. The biting and eating patterns of sound signal maintained constancy in sound level obtained but it is not observed in the movement signal of RPW.

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