Acoustic Detection of the Red Date Palm Weevil

Mohammed A. Al-Manie, Mohammed I. Alkanhal

Abstract**——** In this paper, acoustic techniques are used to detect hidden insect infestations of date palm tress (Phoenix dactylifera L.). In particular, we use an acoustic instrument for early discovery of the presence of a destructive insect pest commonly known as the Red Date Palm Weevil (RDPW) and scientifically as Rhynchophorus ferrugineus (Olivier). This type of insect attacks date palm tress and causes irreversible damages at late stages. As a result, the infected trees must be destroyed. Therefore, early presence detection is a major part in controlling the spread and economic damage caused by this type of infestation. Furthermore monitoring and early detection of the disease can asses in taking appropriate measures such as isolating or treating the infected trees. The acoustic system is evaluated in terms of its ability for early discovery of hidden bests inside the tested tree. When signal acquisitions is completed for a number of date palms, a signal processing technique known as time-frequency analysis is evaluated in terms of providing an estimate that can be visually used to recognize the acoustic signature of the RDPW. The testing instrument was tested in the laboratory first then; it was used on suspected or infested tress in the field. The final results indicate that the acoustic monitoring approach along with signal processing techniques are very promising for the early detection of presence of the larva as well as the adult pest in the date palms.

Keywords**—** Acoustic emissions, acoustic sensors, non-destructive tests, Red Date Palm Weevil, signal processing..

I. INTRODUCTION

THERE has been a growing interest in finding and implementing non-destructive methods for the objective of detecting the presence of insect species living in the interior parts of plants or trees. For instance, Mankin et al. [1] used acoustic systems with vibration sensors to monitor the activities of hidden insects on soil and interior structures of plants in the laboratory as well as in field conditions.

Manuscript received November 30, 2004. This work was supported by king Abdulaziz city for Science and Technology (KACST) under research project number EI-23-01.

M. A. Al-Manie is with the Computers and Electronics Research Institute (CERI) of King Abdulaziz City for Science and Technology (KACST), Riyadh, Saudi Arabia. Phone: (++966-1)-481-3330; fax (++966-1)-481-3764; e-mail: manie@kacst.edu.sa.

M. I. Alkanhal is with the Computers and Electronics Research Institute (CERI) of King Abdulaziz City for Science and Thecnology (KACST), Riyadh, Saudi Arabia. Phone: (++966-1)-481-3747; fax (++966-1)-481-3764; e-mail alkanhal@kacst.edu.sa.

Some other researchers such as Shade et al. [2] used acoustic techniques to monitor and detect hidden insects infestation of some plants in the laboratory. Other examples of these methods include Lemaster et al. [3], where acoustic emissions of termites were employed to detect their presence in wood structures. The same approaches were also implemented in Mankin et al. [4] paper to detect termite's infestation inside trees, and Mankin et al. [5] to look for black Vine Weevil larval infestation in nursery containers. Similar investigations with the same technique have also been conducted by other researchers [6,7].

Unlike traditional methods that are time consuming and labor intensive, these types of procedures offer the advantages of keeping the plant intact; reduce cost, as well as saving time in the process of pest's infestation detection. Acoustics methods also have a number of different applications such as machine condition monitoring and diagnosis [8, 9].

In this paper, acoustic emissions produced by the Red Date Palm Weevil (RDPW), a destructive pest that infects date palm trees (Phoenix dactylifera L.) are recoded with special sensors and analyzed using signal processing methods. Acoustic sensors such as special probes are inserted in the Palm tree trunk in order to record sounds produced by the insect especially in the early stages of its life known as larval stage where the feeding and other activities of the insect are at their maximum. Once the sound produced by the pest is available through the usage of acoustic sensors, the next step is to try to find a method for identifying a unique signature of these pests. As it is well known, time series representation of the acoustic emissions is not enough by itself to identify the presence of the pest through visual inspection. Furthermore, many other factors must be taken into consideration such as the possibility of other insects living in the same tree that may also produce similar sounds. Other physical factors include environmental noise, distortions, and attenuation by the tree trunk, which will reduce the strength of the received signal and make it harder to detect.

Therefore, it is necessary to devise a procedure that makes it possible to visually recognize the acoustic emissions produced by these particular pests and ultimately identify the infected trees. In this experiment, signal processing methods are utilized to analyze the different sounds recoded by the special sensors inserted in the tree trunk. In particular, time-frequency analysis approach is implemented by calculating the time-frequency distribution (TFD) of the collected signals.

These methods include for instance the common Spectrogram, while other time-frequency methods can also be used. The main purpose is to be able to recognize the acoustic signature of the RDPW through visual inspection of the time frequency plane. The procedure of time-frequency analysis also offers the advantage of representing the signal, in this case sound, as a function of time and frequency making it possible to relate the spectral frequencies available in the signal to the time of occurrence. This approach is used for a number of applications such as speech processing, biomedical, and machines diagnosis-prognosis purposes.

The needed data was collected from the laboratory as well as from the field in environmental conditions, which include some of the previously mentioned difficulties. The acquired acoustic signal may also need to be processed first to remove background noise through filtering before applying time-frequency estimation. A number of trials were repeated by collecting data from different infected trees as well as healthy ones. The lab work was completed in the Computer and Electronics Research Institute (CERI) at King Abdulaziz City for Science and Technology (KACST), while the fieldwork was conducted in infected farms of Al-hasa region located in the eastern part of Saudi Arabia. The suitability of time-frequency analysis to the detection of the RDPW unique sounds for this type of application is evaluated in terms of clarity and ease of recognition.

The second Section of this paper outlines the theoretical background of the time-frequency techniques for the purpose of the pest signature identification. The experimental procedure and set up followed in this experiment including the hardware used, sampling rate, and length of the recorded signal are outlined in the third Section. In the fourth Section, the results obtained using the different methods are analyzed in terms of their abilities to represent and resolve the acoustic signal under study. This section also includes related figures used to illustrate findings of the experiment. The fifth Section provides final discussions of results and conclusions on the field and laboratory work conducted for this paper.

II. TIME-FREQUENCY METHODS

The conventional Fourier transform can only indicate the particular frequencies that exist in a specific signal and their relative strengths; however, the time-frequency analysis approach has the capability to represent the energy density simultaneously in time and frequency. This feature could be very important and advantageous in a number of "real world" applications such as speech, biomedical, and machines diagnosis. Furthermore, time-frequency techniques make it possible to determine whether the analyzed signal is a mono or a multicomponent. Therefore, these procedures were utilized in this experiment in order to define a unique signature for the acoustic signal of the pest during the feeding process of the pest under study.

This Section outlines the proposed time-frequency procedure used to calculate the distributions of the acquired data from the field of the RPDW activities inside the date palm. The approach used in this project to find the time-frequency distribution (TFD) is the well-known Spectrogram that can be implemented by breaking the signal into small segments in time then using the short time Fourier transforms to find the existing frequencies in the data under study. More specifically, this method is calculated by multiplying the analysis signal by a selected window function. The resulting energy density spectrum at a particular time n can then be represented in a discrete mathematical form as follows [10]:

$$S_{sp}(n,\omega) = \left| \frac{1}{N} \sum_{m=0}^{N-1} x(m) h(m-n) e^{-j\omega m} \right|^2 \qquad (1)$$

Where $S_{sp}(n,\omega)$ is the energy density spectrum at a time n, N is the total number of sampling points, $x(m)$ is the input signal, and $h(m-n)$ is a chosen window function. The Spectrogram method does not produce the cross terms interference associated with the Wigner-Ville estimate, which may make results interpretation more difficult in the time-frequency plane. However, the spectrogram has the limitation of the well defined propriety of time frequency trade off, that can be interpreted as the inability to simultaneously produce a high time and high frequency resolutions for any chosen window.

III. EXPERIMENTAL PROCEDURE

This Section describes the hardware used to conduct the experiment in the laboratory as well as in the filed. The type of equipments used include the acoustic sensors attached to a special probe, a hand held instrument with a display that provides the ability to adjust different factors such as the gain of the signal, a digital tape recorder, and a portable PC. This part of the report will also include the systematic procedure carried out to setup the used hardware to perform the testing. The fieldwork that includes data collection and criteria for selecting the palm tress to be tested for presence of the disease will also be discussed. This Section also outlines a detailed step-by-step method for conducting the research, which includes the number of attempted trials at different date palm tree farms in Al-Ahasa area, and how measurements were taken.

3.1 Hardware and experimental setup

The main equipments used to carry out the laboratory and fieldworks are comprised of a special probe with a sensor designed to detect acoustic emissions produced by hidden insects. This type of device is known as an SP-1 probe, manufactured by Acoustic Emission Consulting (AEC) [11]. A hand-held instrument model # AED-2000 also made by AEC with a digital display that includes keys to adjust the gain of the signal and provide digital filtering to reduce distortions produced by the wind or other factors. A portable digital audio tape recorder type Sony model # TCD-D10 Pro II was utilized in the field and in the laboratory for digital storage of the collected data. A portable personal computer with special software installed was used to store the acoustic signal of the pest. Matlab software programs were later implemented to perform analysis and calculations of the acquired filed data. The recorded signal of he RDPW can also be monitored with a headphones set.

3.2 Data acquisition

In the first part of the experiment, the RDPW acoustic emissions were recorded inside and outside the laboratory using a sensitive microphone system. To perform lab work, a part of the palm tree trunk with adult and larva insects feeding inside was used to collected data by means of the microphone. The collected data was then stored in the digital audio recorder for later processing. This procedure was repeated for a number of trials. Next, the SP-1 probe was used to collect the data, which is capable of providing high audio sensitivity. The probe was affixed on a special nail, and then inserted in the infested date palm trunk.

The acoustic signals produced by the RPW were then amplified to reasonable amplitudes; digitized and finally stored in the provided digital audio tape recorder. The total length for each of the acquired digital signals is 88200 samples or 8 seconds with a sampling rate of 44 kHz. A headphone set was also used to listen to the acoustic signal before being stored in the audio recorder. The procedure used in this experiment for signals analysis is the time-frequency distribution method. A personal computer with (Matlab) software installed was used for data analysis and implementations.

IV. RESULTS AND DISCUSSION

In this Section, analysis and discussion of the results obtained through experimental laboratory and fieldwork carried out in this project are outlined. As mentioned in the previous Section, data was collected in the laboratory from trunks of data palm tress with the insects living inside by the acoustic sensors described earlier. The acoustic emissions of the RDPW were also collected in the field from infected date palms in Al-Ahasa region located in the eastern part of Saudi Arabia using the special hand held instrument and the portable PC. After data acquisition was completed, signal-processing techniques were then implemented to analyze the collected signals for identifying the special acoustic signature produced by the pest under study. In particular, a time-frequency procedure was used to identify any unique features present in the RDPW acoustic signals. The Spectrogram technique was selected for this purpose

Consequently, the time-frequency estimates of the above method was calculated for the acquired data with the obtained results displayed in the following Figures. The first illustration of Fig. 1 shows the acoustic signal produced by RDPW in the time-domain as a spike that was recorded in the field using the sensitive probe and instrument. On the other hand, Fig. 2 depicts the power spectral density for one of the collected acoustic signal. The next one, Fig 3, displays the calculated time-frequency distribution (TFD) for the collected data using the Spectrogram method implemented with a Hamming window of 16 sampling points in length, chosen due to the short duration of the analysis signal. The x-axis and y-axis represent time and frequency respectively. The recorded "click" representing feeding sound of the RDPW inside the date palm trunk seen as a spike is displayed clearly in the time-frequency plane with the background noise indicated as low frequencies.

Hence, as can be seen from the results, the time-frequency technique was quite capable of identifying acoustic emissions of the RPDW and may be used for detecting the best presence. We can also conclude that the above method was able to separate the special clicks produced by the feeding process of the pest from background noise.

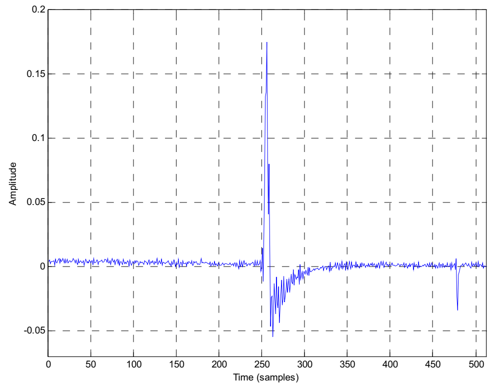

Figure1. Time-series plot of the RDPW acoustic signal from an infested date palm acquired with the acoustic probe.

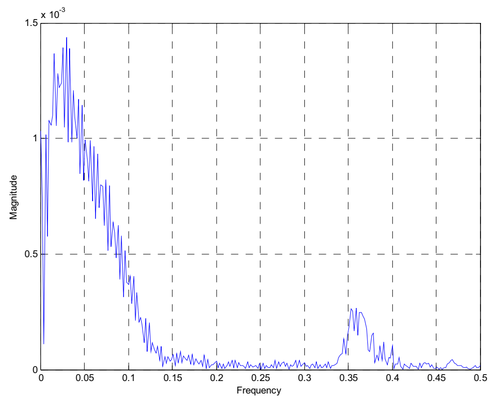

Figure2. Power spectral density for the RDPW acoustic signal.

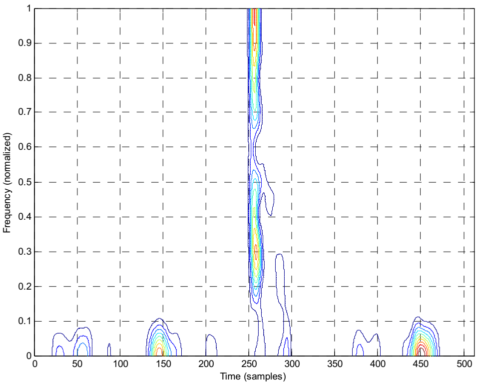

Figure 3. Time-frequency distribution for the RDPW signal.

V. Conclusion

In this project, the acoustic emissions produced by the RDPW inside the date palm tree were successfully recorded and identified using special sensors. The power spectral density for the collected data was calculated representing one main frequency in the RDPW acoustic signal. Time-frequency technique was implemented in order to find a unique signature of the pest activities. The applied method was the common Spectrogram approach. The resulting TFD distinctly separated the true signal from background noise.

Acknowledgment

The authors would like to thank the General Directorate of Agriculture in Al-Hasa region for their help and cooperation during field data collection. We also would like to thank the Institute of Environmental and Natural Resources Research at KACST for supplying the specimen of infected tress to conduct lab work.

References

[1] Mankin, R.W.. Brandhorst-Hubbard, J.,Flanders, K. and et al. "Eavesdropping on Insects Hidden in Soil and Interior Structures of Plants". *Journal of Economic Entomology,* Vol. 93 No 4, pp.1173-1182, Aug. 2000.

[2] Shade, R.E., Furgason, E.S. and Murdock, L.L. "Detection of Hidden Insect Infestations by Feeding-generated Ultrasonic Signal". *Am. Entomol.,* Vol. 36, pp.231-234, 1990.

[3] Lemaster, R.L., Beall, F.C., and Lewis, V.R. "Detection of Termites with Acoustic Emissions". *For Pro. Journal*, Vol. 47, pp.75-79, 1997.

[4] Mankin, R.W., Osbrink, F.M., OI, and Anderson, J.B. "Acoustic Detection of Termite Infestation in Urban Trees." *Journal of Economic Entomology,* Vol. 95 No 5, pp.981-988, Oct. 2002.

[5] Mankin, R.W. and Fisher J.R. "Acoustic Detection of Black Vine Weevil, *Otiorhynchus sulcatus* (Fabricius) (Coleoptera: Curculionidae) Lavral Infestation in Nursery Containers". *Journal of Environ. Hort.,* Vol. 20 No 3, pp.166-170, Sept. 2002.

[6] Shuman, D., Coffelt, J.A.,Vick, K.W., and Mankin, R.W. "Quantitative Acoustical Detection of Larvae Feeding Inside Kernels of Grain". *Journal of Economic Entomology,* Vol. 86, pp.993-938, 1993.

[7] Hagstrum, D.W., Flinn, P.W., and Shuman, D. "Automated Monitoring Using Acoustical Sensors for Insects in Farm Stored Wheat". *Journal of Economic Entomology,* Vol. 89, pp.211-217, 1996.

[8] Wang, W.J. and McFadden, P.D. "Application of Orthogonal Wavelets to Early Gear Damage Detection". *Mechanical Systems and Signals Processing,* Vol. 9 No 5, pp.497-507, Sept. 1995.

[9] Wang, W.J. and McFadden, P.D. "Application of Wavelets to Gearbox vibration Signals for Fault Detection". *Journal of Sound and Vibration*, Vol. 192 No. 5, pp.927-939, May 1996.

[10] Cohen, L. *Time-frequency Analysis*, Prentice-Hall, N.J. 1995.

[11] Specifications of probes and instrument for acoustic detection available: http://www.aeconsulting.com/body.html .