Acoustic Detection and Identification of Insects in Soil

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Abstract: There is considerable practical need for user-friendly, inexpensive devices that detect and quantify insect populations in environments hidden from visual observation. One approach used with varying success is to detect the insects through the sounds or vibrations they generate for communication or through noises that are produced incidentally during feeding and general movement. This paper describes experiments using different sensors and analysis techniques for detection of insects in soil in an agricultural environment. Results from different sensors and different sensor placements are compared, and the spectral and temporal patterns that can be used to distinguish the target insects from noise and nontarget soil organisms are discussed. The ability to precisely monitor soil insect populations and identify specific pests is limited by the high rate of attenuation of sound in soil, and a lack of species-specific features in the typically broad-band spectrum of movement-generated signals. Nevertheless, the use of accelerometers attached to 20-30-cm spikes appears to be a low-cost, user-friendly method to locate and monitor the size of infestations of major pest insects that tend to group together in clumps of restricted area.

INTRODUCTION

Soil insects are difficult to detect and study, but some species cause billions of dollars of damage yearly to turf, agricultural crops, trees, and golf courses (1,2). Growers and managers need new tools to assess infestation and reduce management costs, while researchers must develop basic knowledge about life cycles, behavior, and population distributions, and determine the efficacy of management strategies for soil insect pests. Acoustic technology offers some potential as a means of identifying and targeting populations that can be found now only by laborious, destructive techniques.

The usefulness of acoustic techniques for detection of soil insects depends on several biophysical factors, including the signal-to-noise ratio of the insect sounds compared with background noise in the frequency range of the signal, the amount of distortion and attenuation as the sounds travel through the soil, the distinguishability of sounds made other organisms, and the fraction of the measurement period during which signals are generated. Sound attenuation is greater in soil than in air (~600 dB m^{-1}, compared with ~0.008 dB m^{-1}, 3, 4). However, there is evidence that low frequency sounds (<5 kHz) traveling through sandy soil can be detected over distances of 5–50 cm, and detectable sound transmission has been reported through plants and leaf mats for distances of up to 8 m (5).

We have begun a study to determine the feasibility of acoustic methods for detecting and monitoring soil insect behavior, and targeting the locations of pest insect populations. To determine detection distances, signal characteristics and background noise characteristics, we measured sounds in a sheltered laboratory environment and under field conditions with different noise backgrounds and wind speeds, comparing feeding and movement sounds made by particular pest insects with those from other soil organisms.

METHODS

Standard Microphones. Insects were placed on a thin piece of St. Augustine turf in an anechoic chamber and their burrowing or feeding movements were recorded with a microphone (Brüel and Kjær [B&K] model 2639, Nærum, Denmark) suspended ~1 cm overhead. The signals from the microphone were bandpass filtered between 0.2 and 15 kHz (Krohn-Hite model 3100, Avon, MA) after amplification with a B&K model 2639 preamplifier and a B&K model 2610 amplifier. The processed signals were stored on a digital audio tape recorder (Panasonic model SV-255 DAT, Matsushita Electric, New York, NY). Custom-written software, DAVIS (6), and a personal computer system were used to perform spectral and temporal analyses. Acoustic signal levels were expressed in dB re 20 μPa.

Piezoelectric Microphones. A piezoelectric microphone (MuRata Erie model PKM28-2AO, Smyrna, GA) connected to a B&K Model 2610 measuring amplifier was used to detect the movement of insects in the field or in a laboratory observation arena constructed from two parallel transparent plastic sheets, 0.64 cm apart, filled with potting soil or builders sand. Signal storage and analysis procedures were the same as for the B&K microphones. After field recordings, 15 x 31-cm diameter soil cores were removed at the recording site and examined for visible organisms.

Accelerometers. Steel spikes, 20 or 30 cm in length, or 3 x 31.5 x 0.5 cm stakes were driven into soil in field tests or into 3.8-l pots filled with potting soil or builder's sand in laboratory tests. An accelerometer (B&K model 4382) was attached magnetically to the head, ~ 5 cm above the soil surface. In several tests with citrus root stock, the accelerometer was attached to the tree trunk instead of a spike. The signals were passed to a B&K model 2635 charge amplifier and band-passed filtered between 2-1000 Hz. Signal storage and analysis procedures were the same as for the acoustic and piezoelectric microphones. Accelerometer vibration levels were measured in dB re 10^{-6} ms^{-2}.

RESULTS AND DISCUSSION

With a few exceptions, insects within ~20 cm of the acoustic sensors were detected easily in the field or the laboratory. In the laboratory, the suspended microphone recorded signals ~10 dB above background from burrowing *Phyllophaga* beetle grubs. Outside, the accelerometers recorded signals in the range of 80-90 dB (e.g., Fig. 1) compared to a background of 60-70 dB. In the example shown, an accelerometer attached to the trunk of a small orange tree records more wind noise than an accelerometer attached to a stake, but the ~400-Hz sounds from a *Diaprepes* citrus root weevil grub digging in the soil under the tree can be detected at either position. Both the piezoelectric and the accelerometer system were portable and operated for 2-3 h between battery changes or recharging. The piezoelectric microphone was very sensitive and less expensive than the accelerometer, but was more susceptible than the accelerometer to background noise in the field. Moderate to high levels of pump, worker activity, or traffic noise strongly affected the signal to noise ratio. The signals from the accelerometer were less affected by the acoustic background in the field, and reliably predicted when subsequently collected soil cores did or did not contain digging organisms.

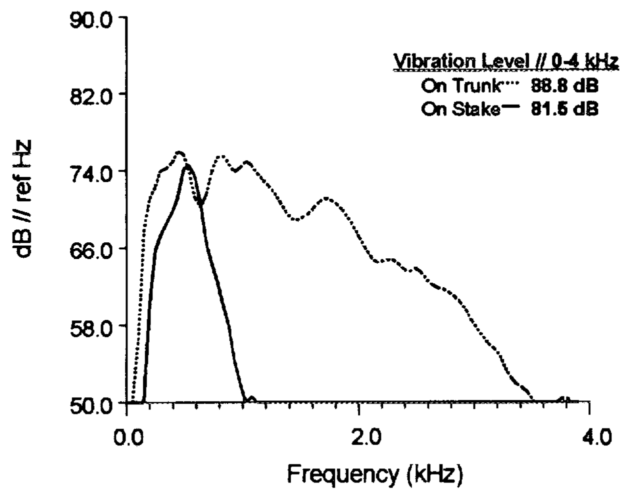

FIGURE 1. Citrus root weevil sounds detected with accelerometer attached to orange tree trunk or stake.

The recorded signals were analyzed to identify features that could be used to distinguish among insect species or to distinguish insects from other soil inhabitants. In general, slithering sounds made by earthworms were similar in frequency to the digging or chewing sounds made by large *Phyllophaga* or *Diaprepes* beetle grub pests (300-600 Hz, 5-10 ms in duration), but a trained ear could distinguish them by signal pattern. Ants generated low-frequency clicks (~125 Hz) that could be distinguished from grubs.

Portable acoustic detection systems have considerable potential as pest mapping tools and as early warning devices for turf, crop, and grove managers. Sampling is less difficult and labor intensive than present digging and flushing techniques, and the sounds of the largest, most destructive soil insects can be acoustically distinguished from many non-pest soil inhabitants.

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