cause of the forced proximity of host and parasite, larvae from the unselected strain were more often successfully parasitized than were larvae from the selected strain.

It is plain when one compares the data for the rearing pan exposure tests that the selected larvae can avoid attack and therefore have a lower infection rate and a lower nematode-to-host average than larvae from the unselected strain. This is the 1st report of a mosquito developing resistance to a biological control agent.

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EVALUATION OF TWO MOSQUITO-REPELLING DEVICES

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ABSTRACT. Two electronic devices emitting sound waves which, according to label and advertised claims, ward off most female mosquitoes, for a distance of 0.9 to 2.5 ms (3–8 ft) were tested to ascertain their effectiveness as mosquito repellents. Evaluations were conducted in a chamber under practical-use conditions as defined by Soltavatta (1947) to be a distance of 10 in. The results of all evaluations indicated that the devices did not afford protection against the bites of *Aedes aegypti* mosquitoes as claimed by the manufacturer under the conditions used in this study. Only one species of mosquito was used in this study because it has been observed by Soltavatta (1947) that the flight sound pitch is practically the same for all species of mosquitoes.

INTRODUCTION

For about a century, insect control has meant primarily chemical control as well as biological and cultural control. Compared with studies on insecticidal chemicals and means for applying them, research on physical control of insects has not been extensive. Even most of the new non-insecticidal controls such as sterilants or hormones are, with rare exceptions, chemical. Among the many types of energy that could be used in insect control—electricity, heat, light, ionizing radiations, radio-frequencies, pressure, and sound—I tested only sound.

Sound is used by many insects for courtship, mating, and echolocation (Wigglesworth 1969). The acoustical vocabulary of invertebrates is relatively small because of highly specialized emitting organs and limitations of the nervous system. The hearing organ in the mosquito is located in the antennae. One of the specialized organs that responds to pressure oscillations is the Johnston's organ, a chordotonal organ lying in the 2nd segment of the antenna with its distal insertion in the articulation between the 2nd and 3rd segments. The Johnston's organ perceives movements of the antennal flagellum, and most of the sensillae comprising the organ give phasic responses, potentials only developing during and immediately after the movement so that a single to and fro movement of the flagellum produces an "on and off" response.

Flies and mosquitoes offer opportunities for acoustical control. In fact, reports of pilot-scale tests of mosquito control have been published (Roth 1948). It is known that the wing-sounds of female mosquitoes act as sexual signals to males, bringing about attraction and mating. There have been a number of critical studies on the function of these organs and on acoustical behavior of mosquitoes. Thus a good core of fundamental information exists (Clements 1963).

The manufacturers of the devices tested claimed to have achieved sound repellency and further claimed to repel female mosquitoes for a distance of 3 to 8 ft. The devices are powered by 9-volt batteries, and, in the directions for use, it is stated that the repeller should be carried or attached to the outer clothing so as not to muffle the sound.

The objective of this article is to report the results of laboratory evaluations of the repellers. Measurements of the physical characteristics of the sound emitted by the repellers were made. Testing of these devices has been reported by Kutz (1974) and by Johns (1975). Both researchers concluded that presently-available devices are ineffective.

The physical characteristics of the sound produced by these devices were measured by standard procedures in a laboratory utilizing a sound level (db) meter. The measurements were made by holding the repeller to the microphone, and readings were taken at 1, 2, and 3 or more cm from the microphone. The waveform was determined on an oscilloscope to be a sine wave.

TEST CHAMBER and PROTECTIVE CAGE

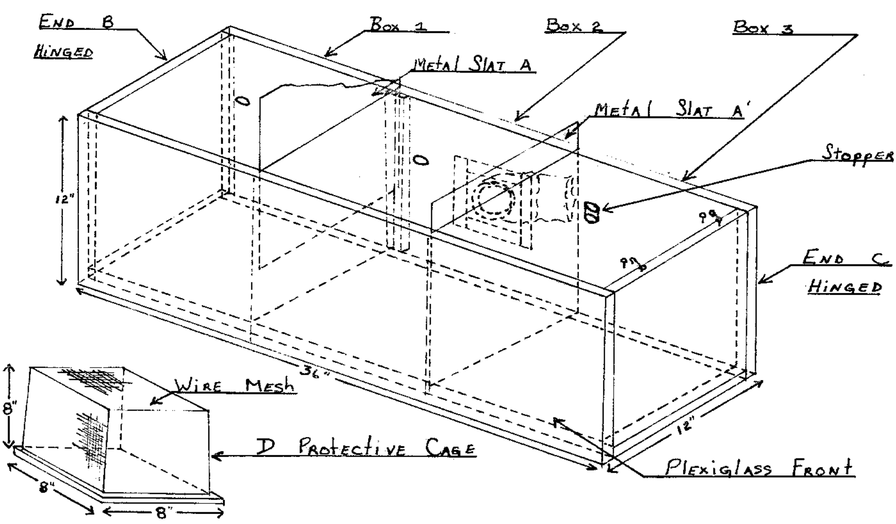

DIAGRAM A

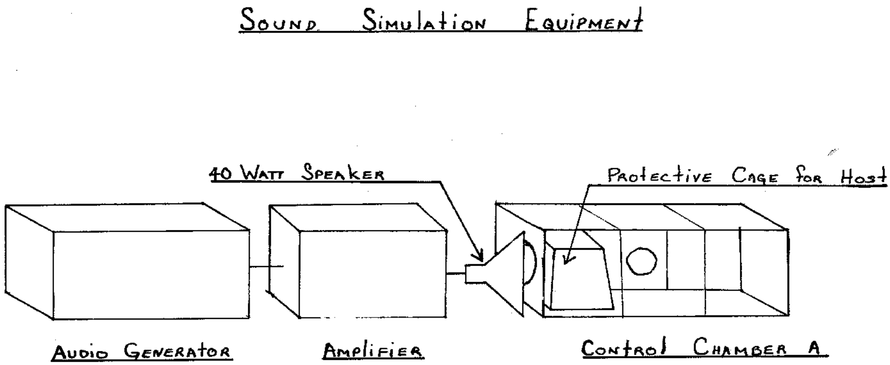

DIAGRAM B

MATERIALS AND METHODS

Aedes aegypti mosquitoes were used, and a test chamber was constructed with the dimensions 12" x 12" x 36" (see Diagram A). The rearing procedure which was followed is that reported by Trembley (1944), and the devices tested were the Electronic Mosquito Repeller manufactured by Progressive Electronics in Dallas and the Buzz-Off Mosquito Repeller manufactured by the Palm Company in New York. Simulation equipment included an audio generator, an amplifier, a 2½", 8-ohm tweeter, a 5" speaker also 8-ohms, and connecting wires (see Diagram B). A guinea pig was used for a live host. Mosquitoes used were 6–9 days old.

Two identical repelling devices were received from the manufacturer of Buzz-Off Mosquito Repeller and two from the manufacturer of the Electronic Mosquito Repeller. The measurements and physical characteristics of the sound emitted by the

Table 1. Physical measurements of the sound produced by the Electronic Mosquito Repeller and the Buzz-Off Mosquito Repeller.

	Device Number	Frequency (CPS)	Decibels & Distance (0″)	(1″)	(2″)	(2+″)	Waveform
Electronic Mosquito Repeller	1	5024	83db	64db	61db	unreadable	sine
	2	5024	83db	64db	61db	unreadable	sine
Buzz-Off Mosquito Repeller	1	5024	82db	64db	61db	unreadable	sine
	2	5024	82db	64db	61db	unreadable	sine

Table 2. Tests to determine distribution of mosquitoes with and without a live host present. Test A was performed without a repelling device, and Tests B, C, and C1 were performed with devices present and operating.

Test #	Sum of replicates $\bar{x}$	Box 1	Box 2	Box 3	Total # Mosq.
Test A—control. Normal distribution.	7	Empty $\bar{x}16.71 \pm 2.38$	Mosq. released $\bar{x}15.85 \pm 2.26$	Empty $\bar{x}17.14 \pm 2.44$	$\bar{x}48.28 \pm 6.89$
Test B—no device Normal attraction. Live host.	7	Host $\bar{x}30.71 \pm 4.38$	Mosq. released $\bar{x}10.28 \pm 1.46$	Empty $\bar{x}10.15 \pm 1.45$	$\bar{x}52.14 \pm 7.44$
Test C—device present. Normal attraction. Live host.	7	Empty $\bar{x}8.85 \pm 1.26$	Mosq. released $\bar{x}12.00 \pm 1.71$	Host & device $\bar{x}28.85 \pm 1.71$	$\bar{x}50.00 \pm 7.14$
Test C1—device present Normal attraction. Live host.	7	Host & device $\bar{x}30.71 \pm 4.38$	Mosq. released $\bar{x}12.57 \pm 1.79$	Empty $\bar{x}8.85 \pm 1.26$	$\bar{x}52.14 \pm 7.44$

Table 3. Sound simulation repellency tests.

Test #	db level	Sum of replicates	Box 1	Box 2	Box 3	Total # Mosq.
Test D Host present	70	5	Host present $\bar{x}25.20 \pm 5.04$	Mosq. released $\bar{x}11.60 \pm 2.32$	Empty $\bar{x}13.00 \pm 2.26$	$\bar{x}49.80 \pm 9.96$
Test E Host present	90	5	$\bar{x}29.40 \pm 5.88$	$\bar{x}8.80 \pm 2.24$	$\bar{x}8.80 \pm 1.76$	$\bar{x}49.20 \pm 9.85$
Test F Host present	110	5	$\bar{x}32.40 \pm 6.48$	$\bar{x}9.00 \pm 1.80$	$\bar{x}8.00 \pm 1.60$	$\bar{x}49.00 \pm 9.80$

repellers were similar and are shown in Table 1.

Test A. Test A was performed to determine the normal distribution of female mosquitoes within the chamber. The chamber was constructed so that the distribution of mosquitoes released could be counted after the test. Partitions were slid into place dividing the chamber into 3 compartments, and the mosquitoes in each were anaesthesized with chloroform. These compartments were labeled Box 1, Box 2, and Box 3. Fifty female mosquitoes were released into the chamber through a stockinette sleeve located in Box 2 which was midway between either end of the chamber. The results were as follows: the mosquitoes distributed themselves equally throughout the chamber (see Table 2). Test A was utilized as a control for Tests B, C, and D.

Test B. The experiment was designed to determine the distribution of mosquitoes when a live host (in this case a guinea pig) was in the chamber with the mosquitoes. The host was placed in Box 1 in a protective cage which prevented biting. Approximately 50 female mosquitoes were used per replicate and each replicate lasted 15 minutes. The results showed that the mosquitoes were attracted to the host regardless of which end of the chamber the host was present.

Test C. The experiment was designed to determine the repellency of sound to mosquitoes by testing the 2 mosquito repelling devices previously mentioned. The female mosquitoes were not repelled by the sound devices. Approximately 50 female mosquitoes were used per replicate and each test lasted 15 minutes.

Tests D, E, and F. To see if higher db at the same frequency would repel mosquitoes a sound simulator was used in place of the repelling devices. I determined the repellency of the sound frequency 5,000 CPS at intensities of 70db, 90db, and 110db with a live host present. Approximately 50 female mosquitoes per replicate, with 5 replicates per test were used. Each test lasted for 15 min. and was conducted in Chamber A. Diagram B shows the arrangement for the sound simulation equipment test. The results of the testing were negative, and the frequency tested did not repel the female mosquitoes.

DISCUSSION

The object of this study was to examine and test the idea that since mosquitoes respond to sound, a device could be manufactured that would utilize sound as a repellent, affecting the behavior of mosquitoes. The devices that are being marketed claim to repel female mosquitoes but testing has shown that they do not.

The frequency generated at different intensities through the simulation equipment was accurate, but the equipment used to do the simulation testing was not adequate to test other frequencies. Because of this limitation I was unable to determine if a frequency exists which will repel female mosquitoes.

The results of this testing were negative, but there has been some success in using sound as a repellent with dogs, birds, and some insects, though these uses still lack validation and verification (White 1971). The future use and application of sound as an effective means of controlling pest behavior is still open to exploration and experimentation.

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