EVIDENCE FOR A THERMALLY TRANSDUCED, SCANNING IR DETECTION SYSTEM IN THE MITE *LAELAPS ECHIDNINA*

WILLIAM A. BRUCE

Stored-Product Insects Research and Development Laboratory
Agr. Res. Serv., USDA, Savannah, Georgia 31403

ABSTRACT

The attraction of the spiny rat mite, *Laelaps echidnina* Berlese, to host-emitted infrared radiation (IR) is closely correlated with the vertical scanning motion of legs I. Based on theory and experimental data, it is concluded that the transduction mechanism for IR reception is probably thermal in mode of operation.

The attraction of ectoparasitic arthropods to their respective hosts is well-documented and has been attributed to a variety of stimuli. Until recently, IR irradiation has received little or no attention as a potential attractant for either parasitic or free-living arthropods (Laithwaite 1960, Evans 1964, Callahan 1967). The detectors of these emissions have received even less attention, but of the few organisms studied (Bruce 1971, Eldumiati 1971, Harris 1971), all have some of the following IR receptor characteristics: (1) capability of being moved or scanned, (2) high directionality, (3) cut-off/cut-on intensity, and (4) limited range of detectable wavelengths.

The spiny rat mite, *Laelaps echidnina* Berlese, a nidicolous ectoparasite, is known to distinguish among several intermediate IR wavelengths (3.6-7.0 μm) at a constant intensity of 1.6×10^{-4} w/cm^2; the probable receptors are the thin-walled setae at the tip of legs I (Bruce 1971). Investigation into the mechanism of host-finding behavior of this species revealed that standardized (Kanungo 1964) adult females were attracted to rat-emitted IR radiation within a distance of 4 cm when host odors and convected heat were eliminated (Fig. 1). Also, an artificial source of IR at the same temperature (38°) and surface area was as attractive to the mites as the rat (Bruce, in press), though it became less attractive as the transmission of IR radiation was reduced to 90 and to 0% (decreases of 25 and 100%, respectively). Thus, the process of attraction is certainly extremely complex, but host-emitted IR radiation is among the many parameters involved; moreover, it is a parameter that becomes operable only within a limited distance from the host.

According to Lambert's law of cosines, the amount of radiation varies as the cosine of the angle between the detector and a line perpendicular to the plane of the source. Further, the inverse square law states that the total radiation received from the source is inversely proportional to the square of the distance away from it. From these laws, the following equation is obtained:

$$W = \frac{HA}{2\pi^2} \text{ Cos } \phi \quad (1)$$

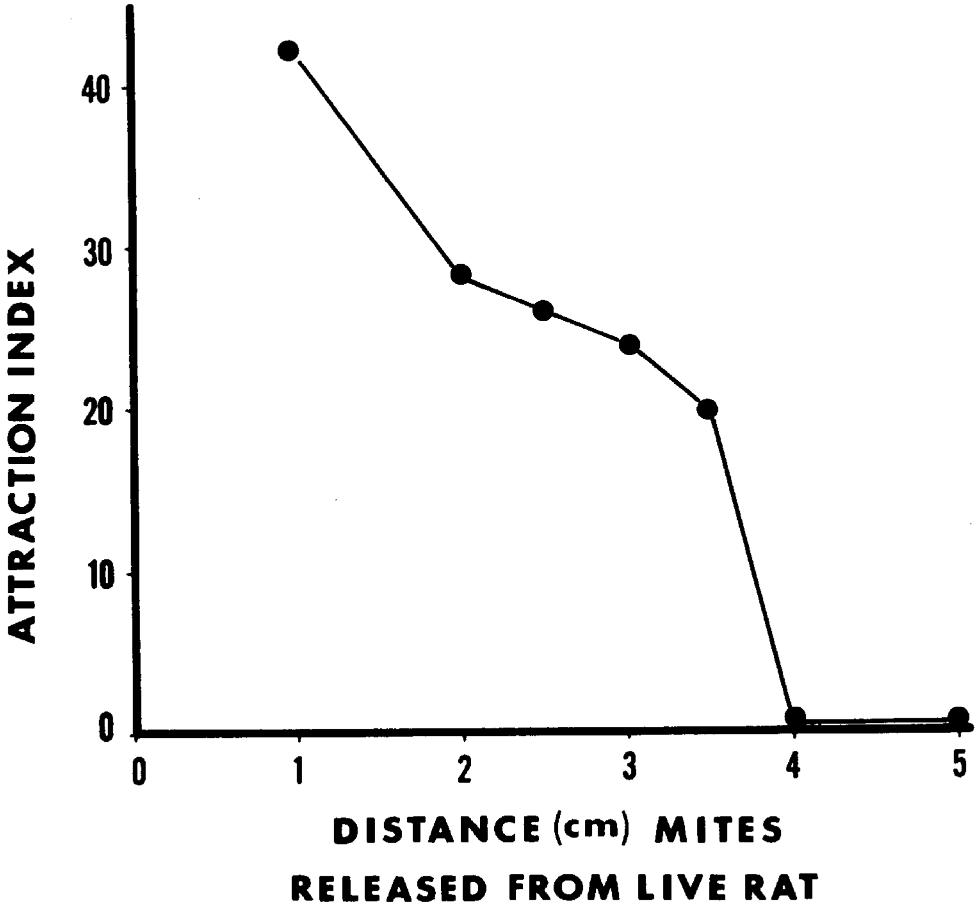


Fig. 1. Response of *L. echidnina* to host-emitted IR radiation at several distances. A total of 50 mites was released individually at each distance, and the position was noted after 15 sec. Movement from the release distance toward the stimulus was scored as a positive response; movement away was scored as a negative response; a lateral position at the release distance was scored as zero.

$$\text{Attraction index (AI)} = \frac{\text{positive - negative}}{\text{positive + negative + zero}} \text{ X 100.}$$

in which H equals the total radiant energy of the source (535×10^{-4} w/cm^2) transmitted and radiated into a hemisphere of radius d(cm); A equals the source area; W equals the irradiance (w/cm^2) at a distance d(cm) from the source; and ϕ equals the angle between the receptor and a line perpendicular to the source.

Since studies of the attraction of IR radiation for the spiny rat mite showed that the operation of the receptor is a function of irradiance, wavelength, and distance, the transducing mechanism for IR reception in *L. echidnina* could be thermal in mode of operation.

This paper provides an explanation of some of the host-finding behavior found in *L. echidnina* in terms of IR radiation transmission and detection.

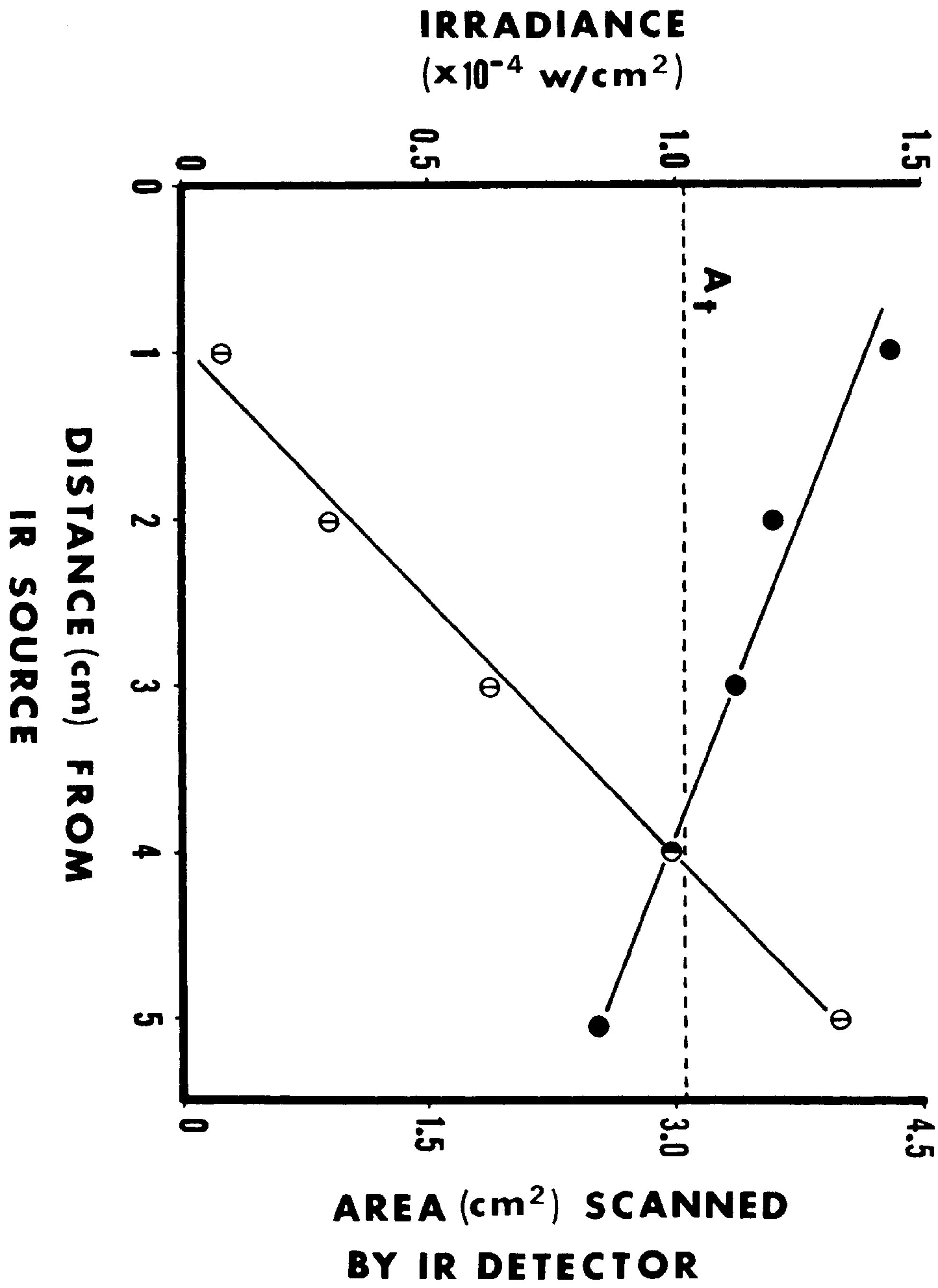
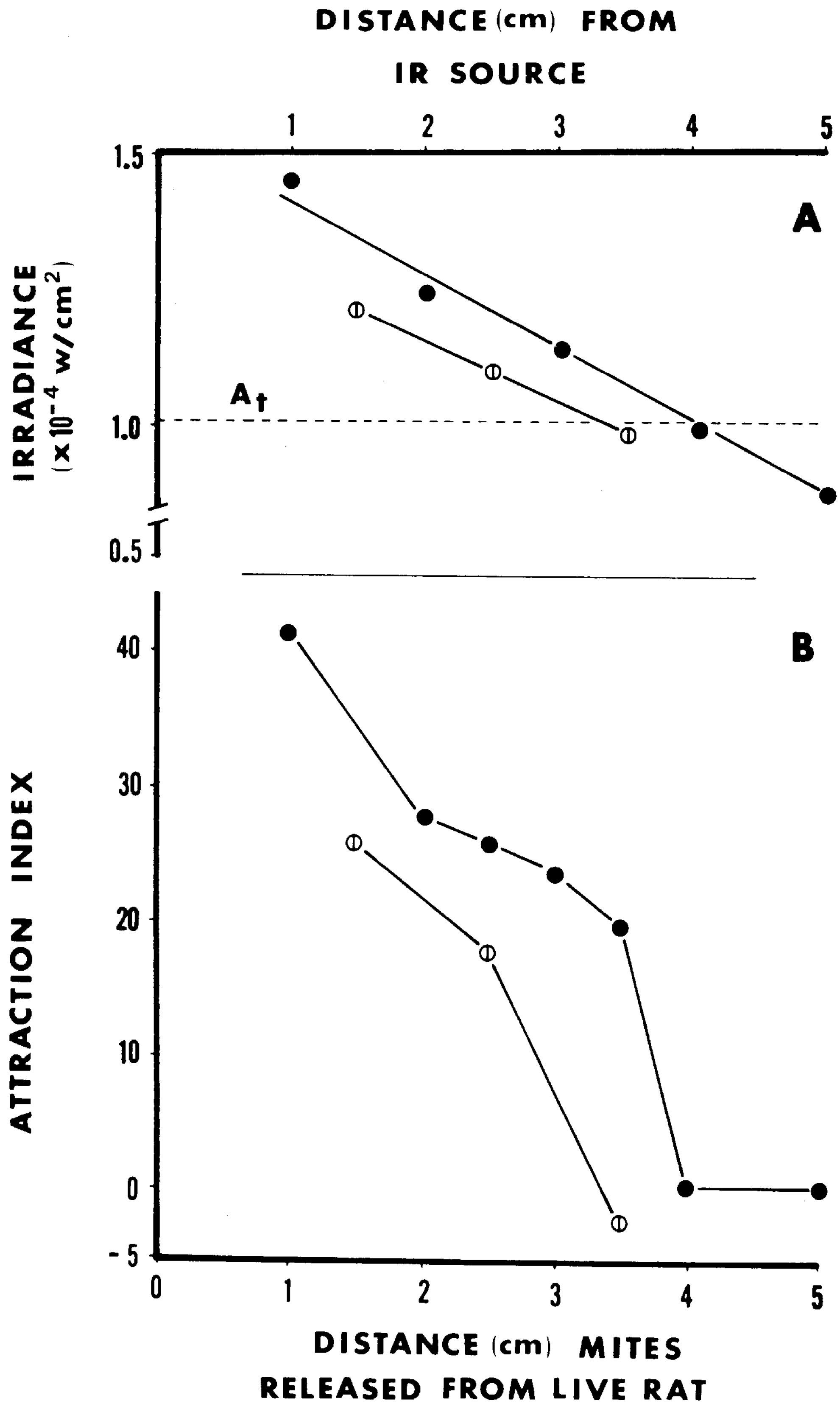


Fig. 2. Relationship between IR source area scanned (Θ) by *L. echidnina* and irradiance (•) at several distances from the IR source. At = attraction threshold.

The IR detection system of the spiny rat mite is wavelength limited and so would receive only a portion of the total radiation emitted. For example, IR


DISTANCE (cm) FROM
IR SOURCE
1
2
3
4
5
1.5
1.0
0.5
A
A_t
IRRADIANCE
(x 10^{-4} w/cm^2)
B
40
30
20
10
0
- 5
ATTRACTION INDEX
0
1
2
3
4
5
DISTANCE (cm) MITES
RELEASED FROM LIVE RAT

receptors, positioned on legs I (shown photographically to move vertically from 0 to approximately 40°-Bruce, unpublished) would scan only a small portion of the total area of the rat. Equation (1) should therefore be amended to the following:

$$W = \frac{H_{\lambda 1\text{-}\lambda 2} Ahv}{2\pi d^2} \int_{0^\circ}^{40^\circ} \cos\phi \, d\phi$$

or

$$W = \frac{H_{\lambda 2\text{-}\lambda 2} Ahv}{2\pi d^2} \sin 40^\circ \qquad (2)$$

where λ_1-λ_2 equals the radiant emittance from 3.6 to 7.0 μm; A_{hv} equals the area scanned; and ϕ may range from 0 to 40°.

The threshold irradiance for IR radiation attraction to the mite is estimated to be 1.02×10^{-4} w/cm^2 (Bruce, 1971). Theoretically, this value could be expected to occur at a distance of approximately 4 cm since this distance is the closest distance to the source of IR radiation at which no attraction occurred. Then if one solves for A_{hv} in equation (2), the area scanned by the mite at 4 cm is equal to an area of approximately 3 cm^2. A vertical scan of 40° at this distance would equal a vertical height at the source of 3.3 cm, and the horizontal component (A_h) would be equal to 0.9 cm; thus, the beamwidth would be approximately 12°.

If the model is correct, any movement within 4 cm toward the rat would result in an irradiance sufficient to produce attraction even though the area scanned would decrease. Conversely, the irradiance at a distance greater than 4 cm should be insufficient to elicit attraction despite the increase in the area scanned. Fig. 2 shows the relationship between areas scanned and irradiance that appears when one substitutes various distances into equation 2. If the detection system of the mite is indeed thermal in operation, a 10% reduction in irradiance should make it necessary for the mite to be closer to the source to receive the same irradiance received at optimum conditions. Fig. 3 shows the similarity in effect from irradiance, attraction index, and source distance.

Most animal IR detectors investigated (Evans 1966, Eldumiati 1971, Harris 1971) have been "passive" detectors, that is, the incoming IR signal apparently need not be modulated or chopped to ensure effective operation. It is entirely possible that scanning, in contrast to remaining in a fixed position

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Fig. 3. A. Irradiance (●) received by *L. echidnina* at several distances from the source; irradiance received when emission from the source was reduced by 10% (◐). At = attraction threshold. B. Attraction index of *L. echidnina* to host-emitted IR radiation at several distances (●); attraction index of *L. echidnina* when host-emitted IR radiation was reduced 10% (◐)

and absorbing enough energy per unit time so a response is elicited, could function, at least in part, to chop the rat IR signal. Indeed, scanning would decrease the intensity received as ϕ was increased and would reverse the process on the return scan. The receptor would, therefore, be modulating the IR signal by observing rapidly changing thermal transients. As less area was scanned and integrated (at close range), the more constant (or DC-like) the incoming signal would become. Thereby the mites might be provided with additional cues as to host distance and location.

Two hypotheses are possible regarding the scanning receptor system. The first is that a single scan from 0 to 40° is sufficient to elicit a response by the mite. The second is that multiple scans are required to elicit the same response. The second possibility would necessitate a receptor beamwidth of less than 12° or a slower detector rise time. Both hypotheses are currently being investigated.

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