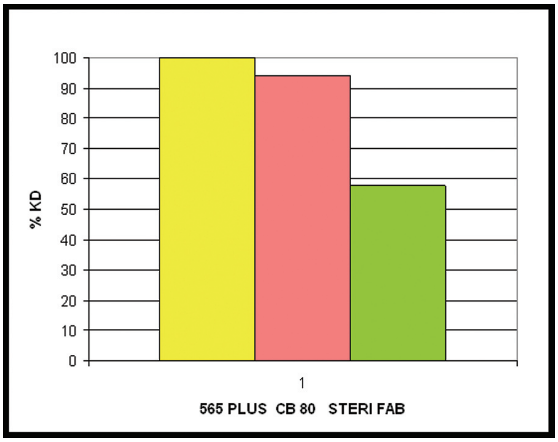

Fig. 15. Mean knockdown rates for pyrethroid-based contact products (there was no knockdown among the controls).

progeny were produced, they did cause substantial adult mortality.

The pyrethroid-based contact products gave little if any flushing action, fair knockdown, and good kill. The NIC product was not effective. The CleanAir mattress protector prevented biting.

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I wish to acknowledge Jim Sargent of Copesan for the idea of testing a mattress protector and for

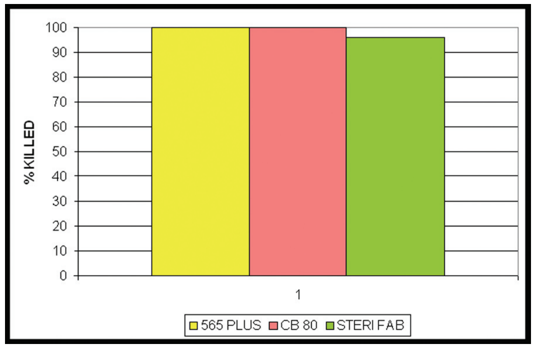

Fig. 16. Mean percentage of kill for pyrethroid-based contact products (there was no knockdown among the controls).

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Foraging and Communication Ecology of bed bugs, *Cimex lectularius* L. (Hemiptera: Cimicidae)

E. D. Siljander

How bed bugs find their hosts and each other is among the least understood aspects of bed bug biology. This has long been identified as a problem (Johnson 1942, Usinger 1966), but despite the efforts of many researchers, relatively little conclusive information has been produced. Much of this can be attributed to the fact that most research on bed bug foraging and communication ecology was done more than 40 years ago, when analytical methods were not as sophisticated as they are today. This contributed to many conflicting results between and within studies. Some studies concluded that bed bugs could not detect a human beyond 3–4 cm away (Kemper 1929, Rivnay 1932), whereas another concluded that they could orient to a human from a distance of 150 cm (Marx 1955). Moreover, some studies claim that bed bugs will aggregate under paper previously exposed to other bugs (Marx 1955, Levinson and Bar Ilan 1971), whereas others claim that they show no preference (Usinger 1966, Aboul-Nasr and Erakey 1968). Taking all the literature on bed bug foraging and communication ecology into account, there is little agreement on which stimuli affect their behavior.

Foraging Ecology

Haematophagous insects can use body temperature, moisture, host-derived volatiles, carbon dioxide, (CO_2) and visual cues to locate a host (Takken 1991). Studies of bed bug host location have tested for attraction to heat, humidity, blood, carbon dioxide, muscle and subcutaneous tissue, liver, bile, skin, hair, perspiration, sebum, and cerumen (Rivnay 1930, 1932; Marx 1955; Aboul-Nasr and Erakey 1967, 1968). From these studies, only one stimulus—heat—was found to be overwhelmingly attractive.

Heat above ambient temperature is undoubtedly attractive (Rivnay 1930, Marx 1955, Aboul-Nasr and Erakey 1967). The upper limit of heat attractiveness is 43° C (Rivnay 1930); higher temperatures are repellent (Rivnay 1930). The temperature difference bed bugs can detect is at least 1–2°C (Rivnay 1930), but the detection distance remains unclear. Rivnay (1930) gave a value of 3–4 cm, but Marx (1955) concluded that it was greater.

Carbon dioxide present in human breath has long been believed to be attractive because exhaled breath clearly excites bed bugs (Hase 1917; personal observation). Only one study, however, has tested their behavioral response to CO_2. Marx (1955) showed that bed bugs preferred the end of a glass tube from which CO_2 was introduced. The exact mode of action and whether CO_2 attracts or activates bed bugs are still unknown.

Sebaceous gland secretions, or sebum, were found to be slightly attractive in two studies (Rivnay 1932, Aboul-Nasr and Erakey 1968), but only at a very short range.

Communication Ecology

Insects are well known for using chemicals to communicate with each other. The gregarious behaviour, habitual shelter use, and well-developed scent glands of bed bugs clearly point to a complex communication system. Even so, only a few studies have been conducted or published.

The scent gland of the bed bug contains 73–92% (*E*)-2-hexenal and (*E*)-2-octenal, and 8–27% acetaldehyde, 2-butanone, and two unknowns (Collins 1968, Levinson et al. 1974a). Levinson and Bar Ilan (1971) bioassayed the two major components, (*E*)-2-hexenal and (*E*)-2-octenal, singly and in combination; and they found that bed bugs did not aggregate underneath treated papers. Also, when presented with these compounds in proportion to their occurrence in the scent gland, aggregated bed bugs quickly dispersed. Therefore, (*E*)-2-hexenal and (*E*)-2-octenal have been categorized as a bed bug alarm pheromone (Levinson and Bar Ilan 1971, Levinson et al. 1974a,b).

Marx (1955) tested the hypothesis that bed bugs were attracted to the odor of conspecfics by bioassaying paper discs previously exposed to bugs and unexposed paper discs. She found that the responders tended to aggregate under the previously exposed ("scented") paper discs more often than the control discs. However, other investigators found no orientation toward, or preference for, paper that had been exposed to conspecifics (Kemper 1936, Usinger 1966). Levinson and Bar Ilan (1971) repeated Marx's experiment and confirmed her results. Levinson and Bar Ilan (1971) showed that the increased aggregation under "scented" discs occurred several hours after bioassays began. The 30-min experiments by Usinger (1966) likely did not provide sufficient time for the insects to express their preference. There is good evidence for the existence of an "assembling scent" (Levinson and Bar Ilan 1971), but the source, mode of action, and chemicals remain unknown.

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