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CHEMICAL ATTRACTION OF MALE CRAB SPIDERS (ARANEAE, THOMISIDAE) AND KLEPTOPARASITIC FLIES (DIPTERA, MILICHIIDAE AND CHLOROPIDAE)

After the first day of a study testing the attraction of scavenging flies (Diptera, Milichiidae and Chloropidae) to defensive chemicals of true bugs (Heteroptera), it was apparent that males of one type of crab spider (Thomisidae) were also attracted to the chemical treatments. Therefore, the original goal of the study was abandoned in 1993 in favor of a full-time investigation of spider attraction.

Traps were constructed of transparent cylindrical containers (20.2 × 19.7 cm; Tri-State Molded Plastic, Dixson, Kentucky) by cutting two 9-cm diameter holes in opposite sides, and covering each hole with an inwardly projecting screen funnel (Aldrich et al. 1984). On 8 June 1993, nine traps were hung from stakes in a 0.9 ha fallow field 10 m apart in contact with foliage (mixed grasses, goldenrod, and bush-clover), alternating the following three treatments: *(E)*-2-octenal, *(E)*-2-decenal, and unbaited controls. Chemicals were dispensed from cotton swabs (Q-Tips®, Chesebrough Pond's Co., Greenwich, Connecticut) dipped in neat standards (*ca.* 200 μl; Bedoukian Research, Inc., Danbury, Connecticut). Traps were inspected every 1–2 days, and rebaited every 2–3 days.

From 9–18 June, 200 males of *Xysticus ferox* (Hentz) (Thomisidae) were caught in traps baited with alkenals; none were captured in controls (Table 1, Field 1). Capture of *X. ferox* males was variable for both *(E)*-2-octenal-baited traps (totals of 28, 33, 59 males/trap) and *(E)*-2-decenal-baited traps (7, 28, and 45 males/trap) such that attraction to *(E)*-2-octenal was not significantly greater than to *(E)*-2-decenal ($P = 0.33$).

From 18–20 June 1993, captures of *Xysticus* males dropped to almost zero in Field 1; therefore, on 21 June the traps were redeployed in another field (0.5 ha) that had been lightly sown with a mixed ground cover including red clover and vetch (Table 1, Field 2). Vegetation in Field 2 was sparse, so traps were placed directly on the ground. From 22 June–15 July, a total of 74 males of four *Xysticus* spp. was caught in traps baited with *(E)*-2-octenal or *(E)*-2-decenal: *X. ferox, X. discursans* Keyserling, *X. triguttatus* Keyserling, and *X. auctificus* Keyserling. No *Xysticus* females were caught, and one *Xysticus* individual was caught in a control trap. *Xysticus* spp. from Field 2 were grouped because we could not reliably separate the species; however, 15 out of the 25 specimens determined were *X. auctificus*. Again, the attraction to *(E)*-2-octenal was greater, but not significantly so, than to *(E)*-2-decenal (Table 1, $P = 0.35$).

In order to determine if other compounds were involved in spider attraction or if the known attractants acted synergistically, additional sets of traps were deployed in Field 2 baited in a similar manner with *(E)*-2-octenoic acid, octanoic acid, 1-octanol, *(E)*-2-octenal/*(E)*-2-decenal (1:1 blend), *(E)*-2-nonenal, *(E)*-2-decenal acetate, and *(E)*-2-hexenal butyrate (Aldrich Chemical Co., Milwaukee, Wisconsin; or Bedoukian Research, Inc.). Standards of octenal and decenal contained impurities of the corresponding acids (1.48% *(E)*-2-octenoic acid; 1.58% *(E)*-2-decenoic acid; analyzed by standard methods, e. g., Aldrich et al. 1984), and the acids predominated in extracts of Q-Tips after 24 h field exposure in hot, sunny weather (88% and 65% *(E)*-2-octenoic acid and *(E)*-2-decenoic acid, respectively). Nevertheless, there was no indication that *(E)*-2-octenoic acid or octanoic acid are attractive to *Xysticus* species. Octanol was a common minor impurity (< 1%) in both octenal and decenal standards, but it seemed inactive. Similarly, there was no indication of synergism between octenal and decenal, no evidence that *(E)*-2-nonenal is attractive, and common esters of stink bugs, *(E)*-2-decenyl acetate, and plant bugs (Miridae), *(E)*-2-hexenyl butyrate, appeared inactive.

In 1994, traps were deployed earlier in Field 1 (14 May–30 June), and an additional set of traps was baited with another alkenal commonly produced by heteropterans, *(E)*-2-hexenal (Bedoukian Research, Inc.) (Aldrich 1988). *Xysticus* individuals were caught from the first day of the experiment in numbers greater than the previous year (Table 1). The results for *Xysticus* (identified to genus only) corroborated previous results for male-specific attraction to *(E)*-2-octenal and *(E)*-2-decenal, but *(E)*-2-hexenal was not attractive.

In 1994 we also decided to collect the trapped

Table 1.—Total numbers of *Xysticus* species males and females caught in traps in 1993 and 1994. Within a column, sums followed by the same letter are not significantly different at the 5% level (three traps/treatment; one-way ANOVA of rank transformed sums/trap/trapping period, fit separately for each field).

	1993				1994	
	Field 1		Field 2		Field 1	
Treatment	Male	Female	Male	Female	Male	Female
(*E*)-2-Hexenal	—	—	—	—	1a	3a
(*E*)-2-Octenal	120a	0a	52a	0a	224b	0a
(*E*)-2-Decenal	80a	0a	22a	0a	115b	1a
Control	0b	0a	1b	0a	0a	0a

milichiid and chloropid flies, several of which are kleptoparasitic on true bugs caught in spider webs (Eisner et al. 1991; Landau & Gaylor 1987). Exclusively females of one milichiid, *Milichiella arcuata* (Loew), were significantly attracted to *(E)*-2-hexenal-baited traps, but not to the other alkenal-baited or control traps (Table 2). Fifteen chloropid species were caught, totalling 2269 individuals (predominantly females), but *Ocella trigramma* (Loew) accounted for over 95% of the total, with *O. cinerea* (Loew) and *O. parva* (Adams) comprising about 1%. Chloropids were attracted to all three alkenals compared to control traps; however, *(E)*-2-octenal was most attractive, followed by *(E)*-2-decenal, and *(E)*-2-hexenal was the least attractive (Table 2). These data suggest that scavenging milichiid and chloropid flies use allomones from dying bugs in spider webs (and probably elsewhere), not just to find food, but also to discriminate between heteropteran species (see also Sugawara & Muto 1974).

The surprising discovery that male *Xysticus* species are attracted to *(E)*-2-octenal and *(E)*-2-decenal is difficult to explain. *Xysticus* species chemically attracted to alkenals are brown, ground-dwelling spiders that probably seize most of their prey after laying-in-wait in the litter zone (Morse 1983). A variety of heteropterans are among the natural prey of litter-inhabiting crab spiders (Nyffeler & Breene 1990; Nentwig 1986; Araya & Haws 1988); therefore, it is possible that *Xysticus* use alkenals as host-finding kairomones as do scavenging flies. This seems unlikely, though, because Heteroptera constitute only a small portion of the prey taken by ground-dwelling *Xysticus* species (Nyffeler & Breene 1990; Nentwig 1986), and esters of Heteroptera were unattractive. Most importantly, only four females and no immatures were caught in chemically baited traps, compared to 615 adult *Xysticus* males.

Behavioral studies have shown that both web-building and hunting spiders communicate with pheromones (Barth 1993; Pollard et al. 1987; Rovner 1991; Suter & Hirscheimer 1986; Tietjen 1979). To date, there has been only one spider sex pheromone chemically identified: unmated females of the sheet-web weaving spider, *Linyphia triangularis* (Clerck) (Linyphiidae), deposit the dimer of *(R)*-3-hydroxybutyric acid on their webs which, after breaking down to the more volatile monomer, elicits the web reduction behavior of males leading to copulation (Schulz & Toft 1993). Discovery of an acidic pheromone for a spider suggested that acidic impurities in alkenal standards might be responsible for attraction of *Xysticus* males. Nonetheless, traps baited with high and low (10 μl) doses of *(E)*-2-octenoic acid were unattractive in the field.

In summary, the exact role of (*E*)-2-decenal and (*E*)-2-octenal in attraction of *Xysticus* males is not yet clear, but our results suggest that the alkenals, or impurities in the synthetic standards, are related or identical to sex pheromone components of these spiders. This is apparently the

Table 2.—Milichiid and chloropid flies caught in traps in 1994. Within a column, sums followed by the same letter are not significantly different at the 5% level (three traps/treatment; one-way ANOVA of rank transformed sums/trap/trapping period).

Treatment	Milichiidae	Chloropidae
(*E*)-2-Hexenal	136a	33a
(*E*)-2-Octenal	1b	2069b
(*E*)-2-Decenal	7b	167c
Control	0b	0d

first report of spiders being attracted into traps baited with synthetic chemicals.

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