Screening and Use of Sex Attractants in Monitoring of Geometrid Moths in Bulgaria*

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Z. Naturforsch. 41c, 1082—1086 (1986); received May 7, 1986

Pheromones, Sex Attractants, Geometridae, Polyene Hydrocarbons, Inhibitor

Four candidate sex attractants for geometrid moths have been screened individually and in mixtures. As a result, in addition to the confirmation of the known sex attractants of Operophtera brumata L. and Alsophila aceraria Denis & Schiff (= A. quadripunctata Esper), possible sex attractants for five other geometrid species have also been established. For O. brumata and A. aceraria an inhibitor has been found. For the same species the possibility for seasonal monitoring by means of sex pheromone traps was demonstrated.

During the last four years considerable progress has been made in the identification of female sex pheromones of a number of geometrid moth species (Lepidoptera: Geometridae). In all cases the pheromones or pheromone components were polyene hydrocarbons with 19 carbon atoms and two to four double bonds [2—8]. By field screening of these compounds, individually and in various combinations, sex attractants for some other geometrid species have also been established [2, 9, 10].

In this paper the results of two years of screening (6Z, 9Z)-6,9-nonadecadiene [Z6Z9-19Hy], a pheromone component of Bupalus piniarius [5], (3Z, 6Z, 9Z)-3,6,9-nonadecatriene [Z3Z6Z9-19Hy], a component of the pheromone complex of Boarmia selenaria [4], Alsophila pometaria [6] and Peribatodes (= Boarmia) rhomboidaria [8], (3Z, 6Z, 9Z)-1,3,6,9-nonadecatetraene [1Z3Z6Z9-19Hy], the sex pheromone of Operophtera brumata [2, 3], (Z)-6-nonadecen-9-yn [Z6Y9-19Hy], a synthesis inter-


* Pheromones, 55 [1].

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Verlag der Zeitschrift für Naturforschung, D-7400 Tübingen 0341—0382/86/1100—1082 \$ 01.30/0

Materials and Methods

Four C19-polyene hydrocarbons, (6Z, 9Z)-6,9-nonadecadiene [Z6Z9-19Hy], (3Z, 6Z, 9Z)-3,6,9-nonadecatriene [Z3Z6Z9-19Hy], (3Z, 6Z, 9Z)-1,3,6,9-nonadecatetraene [1Z3Z6Z9-19Hy] and (Z)-6-nonadecen-9-yn [Z6Y9-19Hy], were selected for the screening experiments. The nonadecadiene, Z6Z9-19Hy, was obtained by transformation of linoleic acid into the corresponding aldehyde, followed by Wittig methylation, hydroboration of the terminal double bond with 9-BBN and subsequent hydrolysis (unpublished). The triene, Z3Z6Z9-19Hy, was formed by carbonyl olefination of propanal with hexadecadienylidene phosphorane [4]. The same reaction of the phosphorane with acrolein yielded the nonadecatetraene 1Z3Z6Z9-19Hy [3]. Nonadecynyne, Z6Y9-19Hy, was a synthetic intermediate of another nonadecadiene synthesis attempt (unpublished).

Pherocon 1C traps were used with rubber penicil-line vial caps to take up the bait substances. In all
cases, except the inhibitor experiments of Tables III
and IV, 1 mg of each substance was used as the bait.
Thus, a one-component bait contained 1 mg, a two-
component bait 2 mg, etc. After depositing the neat
attractant substance/substances in the cavity of the
vial caps, 1 ml of dichloromethane or hexane was
added for better penetration and impregnation. In
the tests with *A. aceraria* and *O. brumata*, when
different ratios of two-component mixtures were used
in the baits, disposable micropipettes were employed
for loading the vials.

The screening of all possible 15 combinations was
performed from August till the end of December
1984, and from March till midth of June 1985, in
Pancharevo, a countryside near Sofia. After that
point of time, only seven attractant blends consisting
of the possible diene, triene and tetraene combina-
tions and a single nonadecenyne bait was used till the
end of December 1985. The distances between the
traps were 10—15 m. The small-scale tests for *A. aceraria*
with different ratios of Z3Z6Z9-19Hy and Z6Z9-19Hy, and for *O. brumata* with
1Z3Z6Z9-19Hy and Z6Z9-19Hy, respectively,
were performed in Pancharevo and Gorna banja. A
third test area for *brumata* was chosen in Bojana,
both the latter locations being near Sofia also. In all
cases the baits were refurnished at least monthly and
checked weekly.

For the seasonal monitoring of *A. aceraria* and
*O. brumata*, two traps loaded with 1Z3Z6Z9-19Hy
and Z3Z6Z9-19Hy, respectively, were used in Pan-
charevo. Checks and replacing the sticky bottom of
the traps being done weekly.

### Results

In addition to the great numbers of males of
*A. aceraria* and *O. brumata* captured, which will be
discussed separately, male insects of five other
gemotrid species were also trapped (Table I). In
total, 20 males of *Alcis repandata* were attracted by
two two-component baits, both containing the nona-
decadiene Z6Z9-19Hy as one component, but none
were trapped with the diene alone. *Brephos notha*
was attracted more unspecifically with three different
blends (Table I). *Ecliptoperia silaceata* was attracted
by two attractant mixtures both having the nona-
decatetraene, 1Z3Z6Z9-19Hy, in common but not
to the substance alone. Three male *Eupithecia sub-
notata* moths were captured in a trap containing the
nonadecatriene Z3Z6Z9-19Hy bait. In total, eight
insects of *Ourapteryx sambucaria* were attracted by
the two single compounds Z3Z6Z9-19Hy and
1Z3Z6Z9-19Hy. Beside the number of males
captured, Table I also gives the time of flight observed
of the respective moth species.

During the experiments, two rare species, not
included in the tables, were also caught in low
numbers. *Apeira syringaria* L.: 1 δ attracted to

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**Table I. Geometrid males attracted to C_{19}-polyene hydrocarbons and mixtures of them, and flight
period. Test time August—December 1984, and March—December 1985, test area Pancharevo near
Sofia.**

<table>
<thead>
<tr>
<th>Species attracted</th>
<th>Attractant/mixture polyene hydrocarbon</th>
<th>Number of males caught</th>
<th>Flight period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C_{19}Hy [1 mg each]</td>
<td>1984  1985 [month]</td>
<td></td>
</tr>
<tr>
<td><strong>Alcis repandata L.</strong></td>
<td>Z6Z9 + Z3Z6Z9</td>
<td>0          5</td>
<td>VI—VIII</td>
</tr>
<tr>
<td></td>
<td>Z6Z9 + 1Z3Z6Z9</td>
<td>3          12</td>
<td></td>
</tr>
<tr>
<td><strong>Brephos notha Hübner</strong></td>
<td>Z3Z6Z9 + Z6Y9</td>
<td>0          1</td>
<td>IV</td>
</tr>
<tr>
<td></td>
<td>Z3Z6Z9 + 1Z3Z6Z9</td>
<td>0          1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Z3Z6Z9 + 1Z3Z6Z9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ Z6Z9 + Z6Y9</td>
<td>0          1</td>
<td></td>
</tr>
<tr>
<td><strong>Ecliptoperia silaceata</strong></td>
<td>1Z3Z6Z9 + Z6Z9</td>
<td>2          0</td>
<td>VIII</td>
</tr>
<tr>
<td>Denis &amp; Schiff.</td>
<td>1Z3Z6Z9 + Z3Z6Z9 + Z6Y9</td>
<td>1          0</td>
<td></td>
</tr>
<tr>
<td><strong>Eupithecia subnotata</strong> Hübner (= <em>E. simpliciata</em> Haworth)</td>
<td>Z3Z6Z9</td>
<td>3          0</td>
<td>VIII</td>
</tr>
<tr>
<td><strong>Ourapteryx sambucaria L.</strong></td>
<td>Z3Z6Z9</td>
<td>0          7</td>
<td>VI—VIII</td>
</tr>
<tr>
<td></td>
<td>[1Z3Z6Z9]</td>
<td>0          1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attractant C19-Hy [1 mg each]</th>
<th>Total number of males caught</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Z3Z6Z9]</td>
<td>25 86 - -</td>
</tr>
<tr>
<td>[Z3Z6Z9 + Z6Y9]</td>
<td>9 nt - -</td>
</tr>
<tr>
<td>[Z3Z6Z9 + Z6Z9]</td>
<td>11 6 - -</td>
</tr>
<tr>
<td>[Z3Z6Z9 + 1Z3Z6Z9]</td>
<td>12 15 68 257</td>
</tr>
<tr>
<td>[1Z3Z6Z9]</td>
<td>- - 101 253</td>
</tr>
<tr>
<td>[1Z3Z6Z9 + Z6Y9]</td>
<td>- - 118 nt</td>
</tr>
<tr>
<td>[1Z3Z6Z9 + Z6Z9]</td>
<td>- - 26 155</td>
</tr>
</tbody>
</table>

nt = not tested.

The flight period of O. brumata, as it was registered by means of pheromone traps, began in both years at the beginning of November and lasted almost till the end of December. The males of A. aceraria appeared somewhat later, but the end of their flight period coincided with that of O. brumata (Fig. 1).

Table III. Effect of Z6Z9-19Hy on the attractiveness of Z3Z6Z9-19Hy to A. aceraria males (test period November 26—December 9, 1985, two weeks; test area Pancharevo and Gorna banja).

<table>
<thead>
<tr>
<th>Amount of Z6Z9-19Hy [jg] added to 1000 jg of Z3Z6Z9-19Hy</th>
<th>Total number of males caught</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pancharevo week I II Gorna banja week I II</td>
</tr>
<tr>
<td>0</td>
<td>27 32 17 0</td>
</tr>
<tr>
<td>100</td>
<td>32 17 6 0</td>
</tr>
<tr>
<td>500</td>
<td>24 5 7 0</td>
</tr>
<tr>
<td>1000</td>
<td>7 2 2 0</td>
</tr>
</tbody>
</table>

* Trap found fallen.
Discussion

Our results confirm the finding of Bogenschütz et al. [9], that *A. repandata* males are well attracted by both mixtures, Z6Z9-19Hy + Z3Z6Z9-19Hy and Z6Z9-19Hy + 1Z3Z6Z9-19Hy. *Brephos notha* is a rare species in Bulgaria and the presence of Z3Z6Z9-19Hy in all attractive baits could show that this compound has some attractancy towards conspecific males. In the case of *E. silaceata* (not a very common species), 1Z3Z6Z9-19Hy could be accepted as a similar attractant. This compound was also the common constituent of three different lures that attracted the males of this species ( = *Diactrinia siliceata*) in Germany [9], the catch rate (total of 9 ♂♂) was slightly greater.

The attractancy of Z3Z6Z9-19Hy to the males of *O. sambucaria*, a common species in Bulgaria, and to the males of the rare species, *E. subnotata* (= *E. simplicata*) was significantly more. Bogenschütz et al. [9] reported the trapping of one male moth of *O. sambucaria* in traps baited with two parts of Z3Z6Z9-19Hy and one part of 1Z3Z6Z9-19Hy. The German authors also reported the capture of *E. alternata*, 4 males, one each attracted by four differently baited traps, each containing 1Z3Z6Z9-19Hy. However, taking into account, that this species is quite common in Bulgaria, we are inclined to regard these captures as rather occasional and not specific.

Szöcs et al. reported a two-component sex attractant for *A. quadripunctata* (= *A. aceraria*) found in Hungary [10] in which Z6Z9-19Hy has shown to possess a well defined synergistic effect to the main attractant of this species, Z3Z6Z9-19Hy. Our results, however, failed to confirm any synergistic activity of Z6Z9-19Hy (cf. Table III). On the contrary, the compound, at least when admixed in a ratio of 1:1 to Z3Z6Z9-19Hy, clearly inhibited its attractancy to this species. When a smaller amount of Z6Z9-19Hy was admixed to Z3Z6Z9-19Hy, this effect was not evident anymore. This contradiction could be explained by the existence of a geographical variation in the pheromone systems between the populations of the species in the two countries, and further experiments are needed to support this speculation.

Knauf et al. have proved the high potency of 1Z3Z6Z9-19Hy as a sex attractant for *O. brumata* in field trials in Western Germany [11]. In addition, they have concluded, that none of the structural analogs (including Z6Z9-19Hy) tested by them, has significant inhibitory effect on the *brumata* attractant. However, in our experiments a somewhat smaller number of *O. brumata* males was caught with the mixture of 1Z3Z6Z9-19Hy and Z6Z9-19Hy. But again, this inhibition could be observed significantly only, when 50–100 percent of the diene had been added to the tetraene sex attractant.
At least for Bulgaria, a seasonal monitoring of the geometrids, *O. brumata* and *A. aceraria* by means of pheromone traps has been carried out for the first time. Although we have not done any comparison with other methods of monitoring, the good captures in both cases show that pheromone traps are a promising tool for seasonal monitoring of these species.