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(Z,Z)-6,9-NONADECADIEN-3-ONE AND (Z,Z,Z)-3,6,9-NONADECATRIENE: IDENTIFICATION AND SYNTHESIS OF SEX PHEROMONE COMPONENTS OF PERIBATODES RHOMBOIDARIA.

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Summary: (Z,Z)-6,9-Nonadecadien-3-one and (Z,Z,Z)-3,6,9-nonadecatriene were identified by GC-EAD and GC-MS in ovipositor extracts of P. rhomboidaria; the synthetic mixture is attractive to males of the species in the field.

Peribatodes [=Boarmia] rhomboidaria (Schiff.) [Lepidoptera: Geometridae] is a polyphagous insect which has been reported as an occasional pest in vineyards causing damage by feeding on the buds and shootlets[1)]. As in other pests, monitoring with synthetic pheromone could assist control decisions. Here we report our first results on the chemical and biological characterization of the female sex pheromone of this species.

Most insects were collected in vineyards and reared on cherry leaves or an artificial diet in Hungary[2)]; additional insects were collected in Switzerland. Biologically active extracts were obtained by placing excised female ovipositors in a few microliters of n-hexane.

Gas chromatographic analyses with electroantennographic detection (GC-EAD) using the male P. rhomboidaria antenna[3)] were made on ca. 1-2 female equivalents (FE) on high-resolution GC columns (50 m, SE-30 and Silar 10c), indicating the presence of two biologically active products in the extracts:
- an early eluting component I of low EAD activity and with retention indices of 1870 on SE-30 and 1940 on Silar 10c,
- a later eluting component II of high EAD activity and with retention indices of 2030 on SE-30 and 2490 on Silar 10c.

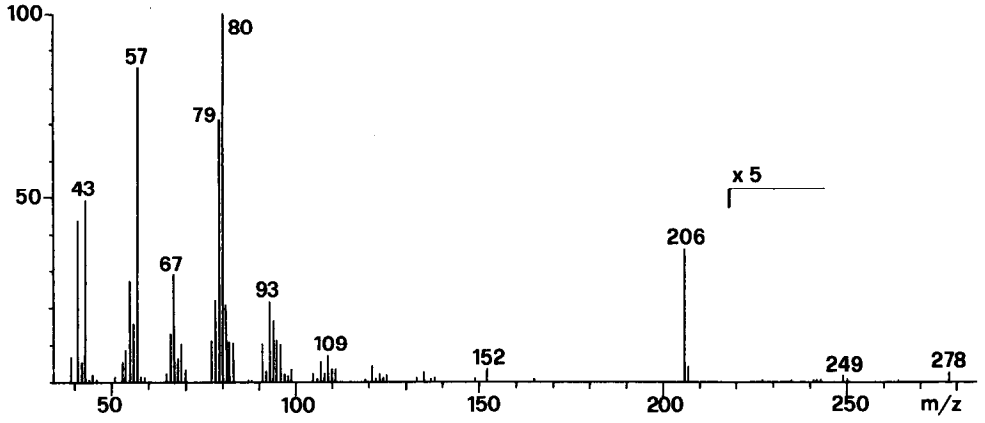
The retention indices suggested component I to be a hydrocarbon ($\Delta I = I_{Silar} - I_{SE-30} = 70$), whereas component II was considerably more polar ($\Delta I = 460$).

For GC-MS analysis (Finnigan 4015 instrument), 5-10 FE were injected on the Silar 10c column. Spectra were recorded using electron-impact (EI, 70 eV) and chemical ionisation (CI, 0.4 torr CH_4, 180°C). The column was kept at 50°C for 2 min, then programmed to 80°C at 20°/min and to 260°C at 5°/min.

Upon comparison with a known mass spectrum[4], component I, showing key ions (EI) at m/z 206 and m/z 108, could be identified as (Z,Z,Z)-3,6,9-nonadecatriene in amounts of ca. 1 ng per individual. This compound was synthesized according to known methods[5].

To identify component II we proceeded as follows. On Silar 10c it eluted under the front edge of a large pentacosane peak at a level some 5 times less than component I. The EI-MS data indicated some relationship to (Z,Z,Z)-3,6,9-nonadecatriene. Its molecular weight was determined by CI-MS to be M=278, pointing to an oxygenated derivative of component I (M=262). The presence of oxygen was further indicated by loss of H_2O of the quasimolecular ions in the CI mass spectrum (m/z 261, 259).

Assuming a biogenetic relationship between components I and II, the presence of the key ion m/z 206 and the near absence of m/z 108 in the spectrum of component II suggested a 6,9-nonadecadiene chain containing an oxygen function at one of the first four carbon atoms[5]; the compound would then be either an epoxide, a vinyl carbinol or a carbonyl compound. A plotted spectrum of component II is given below.



EI mass spectrum of P. rhomboidaria female sex pheromone component II.

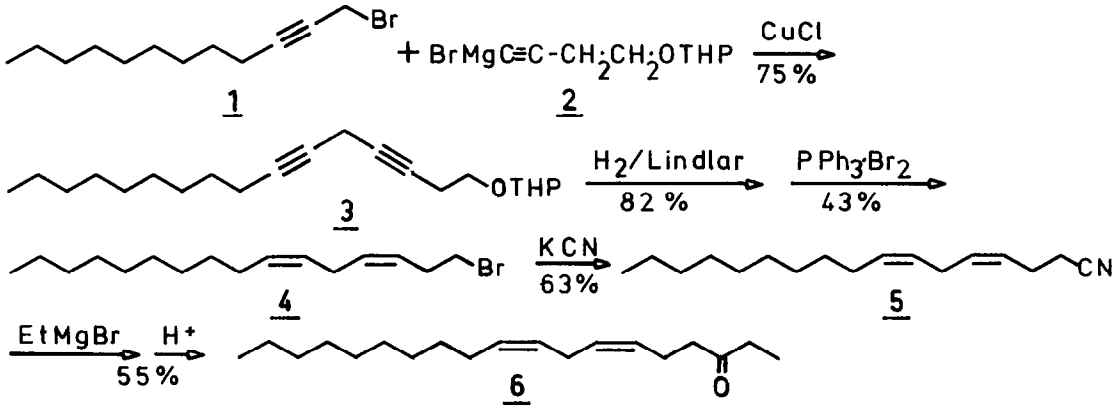
An alcohol function was ruled out since treating the extract with trifluoroacetic anhydride did not alter the retention time nor EAD activity of component II. The three epoxides produced as a mixture by reaction of (Z,Z,Z)-3,6,9-nonadecatriene with mCPB showed shorter retention times than the natural component. However, $NaBH_4$-reduction of the epoxides and PCC-oxidation to the corresponding ketones led to a mixture containing a biologically active component showing the same mass spectrum and retention indices as the natural product. This information and the presence of an intensive ion at m/z 57 in the mass spectrum of component II suggested a 6,9-nonadecadien-3-one. The (Z,Z)-isomer was stereoselectively synthesized as follows and proved to be identical to the natural product in all respects.

Coupling of 1-bromododecyne-2 (1)[6] with the Grignard derivative of

1-(2-tetrahydropyranyloxy)-3-butyne (2)[7] yielded 75% of 1-(2-tetrahydropyranyloxy)-3,6-hexadecadiyne (3). This base-sensitive skipped-conjugated acetal was hydrogenated with Lindlar catalyst to give the corresponding THP-protected dienol which, after treatment with triphenylphosphonium dibromide[8], gave (Z,Z)-3,6-hexadecadienyl bromide (4)[4] [bp: 90-95 °C / 0.01 mm; ^{1}H NMR ($CDCl_3$): δ = 0.89 (t,3H); 1.27 (mc,14H); 1.95-2.15 (m,2H); 2.66 (q,2H); 2.81 (t,2H); 3.36 (t,2H); 5.26-5.61 (m,4H)].

Similar to a synthesis of the Carposina pheromones[9], 4 was converted to 1-cyano-(Z,Z)-3,6-hexadecadiene (5) [IR (film): ν = 2245, -CN; ^{1}H NMR ($CDCl_3$): δ = 0.88 (t,3H); 1.29 (mc,14H); 1.96-2.13 (m,2H); 2.27-2.51 (m,4H); 2.80 (t,2H); 5.26-5.61 (m,4H)]. Reaction of the nitrile 5 with ethyl magnesium bromide gave the desired (Z,Z)-6,9-nonadecadien-3-one (6) which was purified by HPLC [^{1}H NMR ($CDCl_3$): δ = 0.88 (t,3H); 1.06 (t,3H); 1.26 (mc, 14H); 1.96-2.12 (m,2H);2.26-2.51 (m,6H); 2.80 (t,2H); 5.26-5.48 (m,4H)].

Reaction scheme:



EAD activity of the synthetic product 6 was compared with that of the natural component II. A dose-response curve was established with split injections of (Z,Z)-6,9-nonadecadien-3-one on Silar 10c at 160°C; 2-3% of the amount injected was estimated to reach the EAD. Female extracts were likewise analysed using the same three antennae providing the following results:

amount of (Z,Z)-6,9-nonadecadien-3-one injected	antennal response (mV) male no. 1	2	3
70 ng	3.0	-	-
7 ng	2.0	4.9	4.4
700 pg	1.0	4.2	3.4
70 pg	0.4	2.8	2.0
7 pg	0.1	1.0	0.9
700 fg	0.02	0.3	0.3
70 fg	0	0	0.1
blank	0	0	0
female extract tested (FE)	2	2.5	2.5
response to female extract (mV)	1.0	4.0	3.0
estimated amount per female (ng)	0.35	0.23	0.16

From these results, the mean amount of (Z,Z)-6,9-nonadecadien-3-one present in the female extract is about 0.25 ng/FE. This is in close accord with the quantity determined by GC-MS (using the m/z 206 ion) of 0.2 ng/FE and indicates that the synthetic compound is biologically as active as the natural component II. Other GC-EAD analyses indicate that the male antenna is ca. 1000 times more sensitive to (Z,Z)-6,9-nonadecadien-3-one than to the triene.

In preliminary field trials, (Z,Z)-6,9-nonadecadien-3-one, alone and in combination with the triene, proved highly attractive to P. rhomboidaria males in vineyards near Lake Balaton, Hungary, and Sion, Switzerland.

The novel (Z,Z)-6,9-nonadecadien-3-one could be biosynthetically derived from (Z,Z,Z)-3,6,9-nonadecatriene or a common precursor; the trienic hydrocarbon contains the skipped double bond system known from linolenic acid. Methylene-interrupted polyenes are widespread in nature and include sex pheromones of female moths of the genera Arctiidae, Geometridae and Noctuidae. While most of these compounds are hydrocarbons, oxygenated polyenes include linolealdehyde, linolenaldehyde[10], and epoxides such as (Z,Z)-3,6-cis-9,10-epoxyheneicosadiene[10], (Z)-6-cis-9,10-epoxyheneicosene[11] and (Z,Z)-3,6-cis-9,10-epoxynonadecadiene[11].

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1) A. Schmid, G. Raboud, Ph. Antonin, M. Baillod, Rev. suisse Vitic. Arboric. Hortic. 15, 63 (1983).
2) B. Nagy, Acta Phytopath. Acad. Sci. Hung. 5, 73 (1970).
3) a) H. Arn, E. Städler, S. Rauscher, Z. Naturforsch. 30c, 722 (1975); b) P. Guerin, H. Arn, H.R. Buser in: Semiochemistry: Flavors and Pheromones, T.E. Acree and D.M Soderlund, eds, Walter de Gruyter, in press.
4) D. Becker, T. Kimmel, R. Cyjon, I. Moore, M. Wysoki, H.J. Bestmann, H. Platz, K. Roth, O. Vostrowsky, Tetrahedron Lett. 24, 5505 (1983).
5) W.E. Conner, T. Eisner, R.K. Van der Meer, A. Guerrero, D. Ghiringelli, J. Meinwald, Behav. Ecol. Sociobiol. 7, 55 (1980).
6) S.C. Jain, W.L Roelofs, J. Meinwald, J. Org. Chem. 48, 2274 (1983)
7) S.C. Jain, D.E. Dussourd, W.E. Conner, T. Eisner, A. Guerrero, J. Meinwald, J. Org. Chem. 48, 2266 (1983).
8) G.A. Wiley, R.L. Hershkowitz, B.M. Rein, B.G. Chung, J. Am. Chem. Soc. 86, 964 (1964)
9) S. Tamada, K. Mori, M. Matsui, Agric. Biol. Chem. 42, 191 (1978).
10) a) A.S. Hill, W.L. Roelofs, J. Chem. Ecol. 7, 655 (1981); b) A.S. Hill, B.G. Kovalev, L.N. Nikolaeva, W.L. Roelofs, J. Chem. Ecol. 8, 383 (1983); c) J. Einhorn, J.-Y. Lallemand, P. Zagatti, M. Gallois, H. Virezelier, J. Riom, P. Menassieu, C.R. Acad. Sc. Paris 294 (II), 41 (1983).
11) Ch. Descoins, presented at the XVII Intern. Congress of Entomology, Hamburg, 20-26 Aug. 1984.

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