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R. E. Sheads,<sup>1</sup> Morton Beroza,\*<sup>2</sup> and E. C. Paszek<sup>3</sup>

tors of the attraction of disparlure. Structural modifications of disparlure were mainly of its epoxy group. Many of the chemicals were attractive to the male moths, but none were as effective as disparlure. None of the compounds had any significant synergistic effect.

Most of the syntheses involved reactions of disparlure and (Z)-2-methyl-7-octadecene with various reagents, in which the epoxy group was replaced by another group or groups. For example, the oxygen atom in disparlure was replaced by methylene and imino groups and sulfur. In this respect, the chemicals differed from the disparlure-related compounds synthesized and tested previously (Sarmiento *et al.*, 1972), since they were mostly positional isomers or homologs of disparlure. The flow sheet (Chart I) summarizes the syntheses of the 7 compounds and 11 isomeric mixtures that were prepared.

## MATERIALS AND METHODS

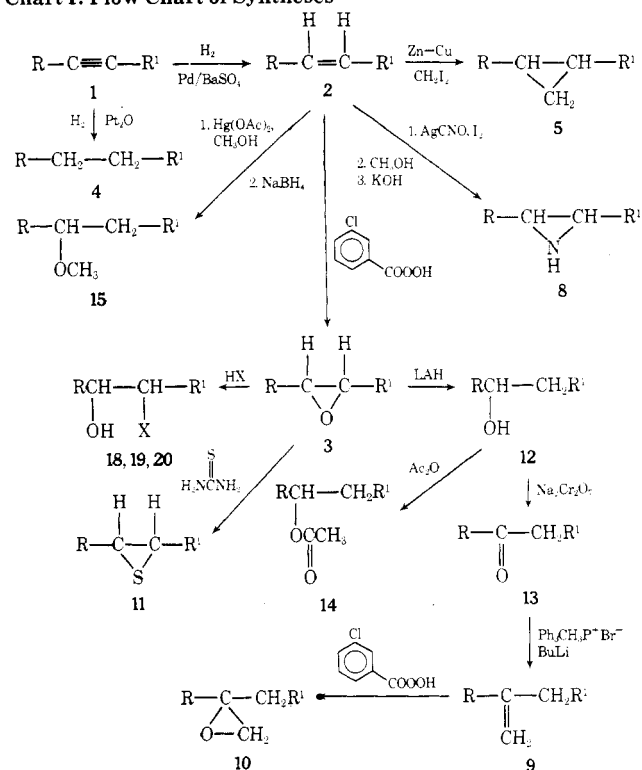
U.S. Department of Agriculture, Agricultural Research  
Service, Beltsville, Maryland 20705.

<sup>1</sup> Present address: Andrulis Research Corporation, Bethesda, Maryland 20014.

<sup>2</sup> Agricultural Environmental Quality Institute, Agricultural Research Service, Beltsville, Maryland 20705.

<sup>3</sup> Animal Plant Health Inspection Service, Otis Air Force Base, Massachusetts 02542.

**Chart I. Flow Chart of Syntheses<sup>a</sup>**



<sup>a</sup> R and R<sup>1</sup> are 5-methylhexyl and decyl or *vice versa*; X is Cl, Br, or I.

overnight at 110° before use), and Adsorbosil-CABN (100-140 mesh, 25% silver nitrate on silica gel).

For thin-layer chromatography (tlc), Brinkmann plates (5 × 20 cm, precoated 0.25-mm thick silica gel F254) were

used. For  $\text{AgNO}_3$  tlc, the plates were dipped in a solution of 10%  $\text{AgNO}_3$  in 75% aqueous ethanol and dried. Spots were made visible by charring; the plates were sprayed with a solution of 2% cupric acetate in 8% phosphoric acid and heated at  $110^\circ$  for 0.5 hr.

For gas chromatography (glc), a Varian Model 2740 instrument, equipped with a flame ionization detector and a  $1.8 \text{ m} \times 0.32 \text{ cm}$  stainless-steel column containing 3% HI-EFF-8BP on Gas-Chrom Q (100–120 mesh), at  $150\text{--}180^\circ$  as indicated, was used with a nitrogen carrier gas flow rate of 20 ml/min.

Nmr data were obtained with a Varian T-60 instrument and infrared data with a Perkin-Elmer 457A unit.

Disparlure (3) and its precursor [(Z)-2-methyl-7-octadecene (2)] were obtained from Chemical Samples Co., Columbus, Ohio. 2-Methyl-7-octadecyne (1) was prepared as described by Sheads and Beroza (1973).

**Synthesis of 2-Methyloctadecane (4).** 2-Methyl-7-octadecyne (1.0 g, 3.78 mmol) dissolved in 25 ml of hexane was magnetically stirred at room temperature in the presence of 100 mg of  $\text{PtO}_2$  and hydrogen at atmospheric pressure. After 1 hr, when the uptake of hydrogen had stopped (160 ml), the solution was decanted from the catalyst and dried over  $\text{MgSO}_4$ . The hexane was removed by evaporation, and the residue was distilled to give 0.9 g of 2-methyloctadecane (91% yield, bp  $106^\circ$  (0.02 mm);  $n_D^{25}$  1.4377; one peak in glc at  $170^\circ$ ). The ir spectrum showed peaks at 2955, 2922, 2854, 1467, 1382, 1366, and  $721 \text{ cm}^{-1}$ .

*Anal.* Calcd for  $\text{C}_{19}\text{H}_{40}$ : C, 84.98; H, 15.02. Found: C, 84.90; H, 14.98.

**Synthesis of 1-Decyl-2-(5-methylhexyl)cyclopropane (5).** A modification (Rawson and Harrison, 1970) of the method of Simmons and Smith of olefin methylenation (1958) was used to form the cyclopropane ring. A mixture of zinc dust (1.7 g, 26 mmol) and cuprous chloride (0.3 g, 2.6 mmol) in 50 ml of ether was magnetically stirred under reflux in a nitrogen atmosphere for 30 min. Methylene iodide (11 ml, 13 mmol) was added, and the reaction mixture was refluxed an additional 30 min. (Z)-2-Methyl-7-octadecene (2.7 g, 10 mmol) was then added, and the mixture was maintained at reflux for 48 hr. The ether solution was decanted from the liberated copper and unreacted zinc-cuprous chloride couple, and the residue was washed twice with 50-ml portions of ether. The decanted solution and washes were combined and washed successively with 50-ml portions of saturated ammonium chloride (twice), saturated sodium bicarbonate, and water. The ether layer was then dried over  $\text{MgSO}_4$  and filtered, and the solvent was removed by evaporation. Glc showed that about 60% of the olefin had been converted. The cyclopropane compound was separated by column chromatography on 20 g of Adsorbosil CABN with hexane as the eluent. A total of 1.0 g (36%) of pure compound was obtained ( $n_D^{25}$  1.4442, one peak by glc at  $170^\circ$ ). The ir spectrum showed characteristic absorption for cyclopropanes at 3032 and  $1023 \text{ cm}^{-1}$ , and the nmr spectrum had a peak at  $\delta$  0.60 for the  $\text{CH}_2$  of the cyclopropane ring.

*Anal.* Calcd for  $\text{C}_{20}\text{H}_{40}$ : C, 85.63; H, 14.37. Found: C, 85.70; H, 14.32.

**Iodoisocyanation of (Z)-2-Methyl-7-octadecene.** The mixture of iodoisocyanates (6) was prepared as described by Hassner and Heathcock (1965). (Z)-2-Methyl-7-octadecene (2.1 g, 7.8 mmol) was dissolved in 20 ml of anhydrous ether, and 3.65 g (24.4 mmol) of freshly prepared silver cyanate was added. The suspension was cooled to  $-10^\circ$  in an ice-salt bath with magnetic stirring, and 2.06 g (8 mmol) of solid iodine was added in a single portion; stirring was continued for 1 hr in the cold and then for 2 hr at room temperature. The ether solution was filtered through Celite 545 to remove the yellow inorganic salts and evaporated in the cold to give 2.0 g (59%) of an orange oil. The material was not further purified. The ir

spectrum showed bands at 2920, 2835, 2260 ( $\text{N}=\text{C}=\text{O}$ ), 1460, 1360, and  $720 \text{ cm}^{-1}$ .

**Synthesis of Methyl [1-(1-Iodo-6-methylheptyl)undecyl]carbamate and Methyl [2-Iodo-1-(5-methylhexyl)dodecyl]carbamate (7).** A solution containing 1.0 g (2.3 mmol) of the mixed iodoisocyanates prepared as described above) in 100 ml of 1:1 ether-methanol was refluxed for 6 hr and poured into 100 ml of water. The suspension that formed was extracted with ether; the ether extract was then washed with water and dried over  $\text{MgSO}_4$ . The solution was filtered, and the ether was evaporated off to give 0.8 g (74%) of a yellow liquid. The ir spectrum showed adsorption bands at 3420 (NH), 3310 (NH), 2940, 2835, 1710 ( $\text{COOCH}_3$ ), 1510, 1465, 1235, 1120, 780, and  $720 \text{ cm}^{-1}$ .

**Synthesis of 2-Decyl-3-(5-methylhexyl)aziridine (8).** The method of Hassner and Heathcock (1964) was used. A solution containing 0.5 g (1 mmol) of the methyl carbamate mixture (prepared above) in 100 ml of ethanol, 10 ml of water, and 10 g of KOH was refluxed for 4 hr. The solution was poured into 200 ml of water, and the suspension formed was extracted with ether. The ether extract was washed with water and dried over  $\text{MgSO}_4$ . The ether solution was filtered and the solvent evaporated to give 0.25 g (89%) of a yellow liquid. The ir spectrum showed absorption at 3240 (NH), 2940, 2860, 1460, 1382, 1370, 1260, 1100, 810, and  $720 \text{ cm}^{-1}$ .

*Anal.* Calcd for  $\text{C}_{19}\text{H}_{39}\text{N}$ : C, 81.06; H, 13.96; N, 4.98. Found: C, 81.23; H, 13.96; N, 4.85.

**Synthesis of 2-(5-Methylhexyl)-1-tridecene and 2-(6-Methylheptyl)-1-dodecene (9).** A 250-ml three-necked flask equipped with a magnetic stirring bar, a 50-ml addition funnel topped with a rubber septum through which all additions were made by syringe, and a nitrogen inlet was successively evacuated and flushed with nitrogen. A solution of 50 ml of anhydrous tetrahydrofuran (THF) and 1.8 g (5 mmol) of methyltriphenylphosphonium bromide was added to the flask and cooled to  $0\text{--}10^\circ$ . *n*-Butyllithium (3.5 ml of 1.6 M; 5.5 mmol) in hexane was then injected into the addition funnel and added dropwise to the stirred solution over a period of 15 min. After 1 hr, 1.4 g (5 mmol) of a mixture of 2-methyl-7-octadecanone and 2-methyl-8-octadecanone (13, synthesis described later) in 30 ml of THF was added slowly over a 15-min period; then the reaction mixture was allowed to warm to room temperature overnight. The resulting mixture of olefins was poured into 200 ml of hexane, and the solution was filtered through silica gel. The hexane was evaporated to give 1.3 g (4 mmol) of a liquid. The olefins were purified by column chromatography on 50 g of silica gel with hexane as the eluent. The liquid product showed one spot in tlc:  $R_f$  0.70 ( $\text{C}_6\text{H}_6$ );  $n_D^{25}$  1.4496. Glc ( $180^\circ$ ) showed one peak. The ir spectrum showed absorption at 3040, 1718, and  $892 \text{ cm}^{-1}$  characteristic of the vinylidene group.

*Anal.* Calcd for  $\text{C}_{20}\text{H}_{40}$ : C, 85.63; H, 14.37. Found: C, 85.74; H, 14.22.

**Synthesis of 1,2-Epoxy-2-(5-methylhexyl)tridecene and 1,2-Epoxy-2-(6-methylheptyl)dodecene (10).** To the magnetically stirred solution of 0.7 g (2.48 mmol) of the olefin mixture (9) of 2-(5-methylhexyl)-1-tridecene and 2-(6-methylheptyl)-1-dodecene in 10 ml of methylene chloride, 0.6 g of *m*-chloroperbenzoic acid was added, and the solution was stirred for 2 hr at room temperature. Tlc ( $\text{C}_6\text{H}_6$ ) showed a spot at  $R_f$  0.40 and no spot for the olefin at  $R_f$  0.70. The solvent was removed by evaporation, and the residue was purified by column chromatography on 2 g of silica gel with 5% ether-hexane as the eluent. The solvent was removed by evaporation to give 0.7 g (95%) of a clear liquid ( $n_D^{25}$  1.4464). The ir spectrum showed absorption at 2963, 2860, 1462, 1385, 1170, 722, and  $680 \text{ cm}^{-1}$ .

*Anal.* Calcd for  $\text{C}_{20}\text{H}_{40}\text{O}$ : C, 81.01; H, 13.60. Found: C, 80.96; H, 13.45.

**Synthesis of 7,8-Epithio-2-methyloctadecane (11).** The episulfide was prepared (Bordwell and Andersen, 1953) as follows: 2.8 g (10 mmol) of disphalure was added at 0–10° to a solution of 1 g of thiourea, 4 ml of concentrated sulfuric acid, and 35 ml of water. The mixture was stirred 1 hr and then allowed to warm to room temperature. The white solid that formed was neutralized with aqueous sodium carbonate, and the reaction mixture was extracted with ether. The ether extract was washed twice with saturated NaCl and dried over  $\text{MgSO}_4$ . The ether was removed by evaporation to give a liquid shown by tlc to be a mixture of the episulfide and disphalure. Repeated column chromatography on Florisil with hexane as the eluent yielded 100 mg of a clear liquid (tlc:  $R_f$  0.60 ( $\text{C}_6\text{H}_6$ );  $n_D^{25}$  1.4618). The glc (170°) showed one peak. The ir spectrum showed absorption at 2928, 2840, 1460, 1385, 1368, 1170, 968, 725 and 670 ( $\text{C-S-C}$ )  $\text{cm}^{-1}$ .

*Anal.* Calcd for  $\text{C}_{19}\text{H}_{38}\text{S}$ : C, 76.43; H, 12.83; S, 10.74. Found: C, 76.35; H, 12.86; S, 10.92.

**Synthesis of 2-Methyl-7-octadecanol and 2-Methyl-8-octadecanol (12).** The mixture of alcohols was prepared as follows: 3.5 g of disphalure (12.5 mmol) was dissolved in 100 ml of anhydrous ether, and 50 mmol of lithium aluminum hydride was added in small portions with stirring. The solution was refluxed 3 hr, and excess hydride was destroyed with dilute hydrochloric acid. The ether layer was separated, washed with saturated  $\text{NaHCO}_3$  and saturated NaCl, and dried over  $\text{MgSO}_4$ . The solution was filtered, and the solvent was removed by evaporation to give a heavy liquid. Column chromatography of this residue on 50 g of silica gel with 10% ether-hexane as eluent yielded a total of 3.1 g (88%) of a waxy solid, mp 36–37°. The ir spectrum showed OH absorption at 3340  $\text{cm}^{-1}$ .

*Anal.* Calcd for  $\text{C}_{19}\text{H}_{40}\text{O}$ : C, 80.20; H, 14.17. Found: C, 80.23; H, 14.35.

**Synthesis of 2-Methyl-7-octadecanone and 2-Methyl-8-octadecanone (13).** In accordance with the procedure of Brown and Garg (1961), 20 ml of ether and 2.8 g (1.0 mmol) of a mixture of 2-methyl-7-octadecanol and 2-methyl-8-octadecanol were placed in a 100-ml flask fitted with a condenser, addition funnel, and magnetic bar for stirring. A chromic acid solution, prepared from 1.0 g (3.36 mmol) of sodium dichromate dihydrate and 0.8 ml (13.4 mmol) of 96% sulfuric acid diluted with water to 25 ml, was added to the stirred solution over 15 min while the temperature was maintained at 25°. After 4 hr, the ether layer was separated, and the aqueous phase was extracted with two 10-ml portions of ether. The combined extracts were washed with saturated  $\text{NaHCO}_3$  and saturated NaCl and dried over  $\text{MgSO}_4$ . The ethereal solution was filtered and concentrated to give a liquid residue that was purified by column chromatography on 40 g of silica gel with hexane as the eluent. A total of 1.7 g (61%) of product was obtained ( $n_D^{25}$  1.4428). Glc (170°) showed a single peak. The ir spectrum showed absorption at 1712  $\text{cm}^{-1}$  ( $\text{CO}$ ).

*Anal.* Calcd for  $\text{C}_{19}\text{H}_{38}\text{O}$ : C, 80.78; H, 13.56. Found: C, 80.92; H, 13.49.

**Synthesis of 2-Methyl-7-octadecanol Acetate and 2-Methyl-8-octadecanol Acetate (14).** The acetates were prepared by adding 1.0 g (3.5 mmol) of a mixture of 2-methyl-7-octadecanol and 2-methyl-8-octadecanol to a mixture of 10 ml of acetic anhydride and 1 ml of pyridine. The solution was magnetically stirred overnight at room temperature and then neutralized with solid sodium bicarbonate. After extraction with ether, the ether was washed sequentially with 5% HCl, water, 5%  $\text{NaHCO}_3$ , and saturated NaCl. The ethereal solution was dried over  $\text{MgSO}_4$  and filtered. Removal of solvent left 1 g (88%) of a liquid ( $n_D^{25}$  1.4386). Glc (170°) showed one peak. The ir spectrum showed absorption at 1738 ( $\text{CO}$ ) and 1245 ( $\text{C-O}$ )  $\text{cm}^{-1}$ .

*Anal.* Calcd for  $\text{C}_{21}\text{H}_{42}\text{O}_2$ : C, 77.00; H, 13.23. Found: C, 76.91; H, 13.09.

**Synthesis of 7-Methoxy-2-methyloctadecane and 8-Methoxy-2-methyloctadecane (15).** The methyl ethers were prepared by the method of Brown and Rei (1969). To a solution of 0.7 g (2.5 mmol) of (Z)-2-methyl-7-octadecene dissolved in 20 ml of methanol and cooled in an ice bath, 0.8 g (2.5 mmol) of mercuric acetate dissolved in 20 ml of methanol was added over a period of 10 min. The solution was stirred for 30 min, then 0.5 g of KOH in 10 ml of methanol was added, followed by 0.1 g of sodium borohydride. The solution was stirred 30 min, decanted from the mercury, and taken up in ether. The ethereal solution was washed with water and saturated NaCl and dried over  $\text{MgSO}_4$ . After the solution was filtered, the ether was evaporated off to give 0.7 g (94%) of the liquid product ( $n_D^{25}$  1.4385). Glc (170°) showed one peak. The ir spectrum showed absorption at 1100 ( $\text{C-O-C}$ )  $\text{cm}^{-1}$ .

*Anal.* Calcd for  $\text{C}_{20}\text{H}_{42}\text{O}$ : C, 80.46; H, 14.18. Found: C, 80.67; H, 14.18.

**Synthesis of 2,8-Dimethyl-7-octadecene (16).** The olefin was prepared by a Wittig reaction. The triphenylphosphonium salt of 1-bromo-6-methylheptane (4.6 g, 0.01 mol) in 100 ml of dry tetrahydrofuran was treated with 7 ml of *n*-butyllithium in hexane (1.6 M, 0.01 mol) at 0–10°. After 1 hr, 1.9 g (0.01 mol) of 2-dodecanone was added slowly over 15 min, and the reaction mixture was allowed to warm to room temperature overnight. The product was poured into 200 ml of hexane, and the solution was filtered through silica gel. The solvent was evaporated and the residue purified by column chromatography on 50 g of silica gel with hexane as the eluent. A total of 1.2 g (43%) of a liquid ( $n_D^{25}$  1.4470) was obtained. Glc (150°) showed two peaks (geometric isomers). The ir spectrum showed absorption at 2960, 2930, 2860, 1465, 1380, 1368, and 732  $\text{cm}^{-1}$ .

*Anal.* Calcd for  $\text{C}_{20}\text{H}_{40}$ : C, 85.63; H, 14.37. Found: C, 85.80; H, 14.38.

**Synthesis of 7,8-Epoxy-2,8-dimethyloctadecane (17).** To the magnetically stirred solution of 0.6 g (2.14 mmol) of olefin (16) in 10 ml of methylene chloride, 0.4 g of *m*-chloroperbenzoic acid was added, and the solution was stirred for 2 hr at room temperature. Tlc ( $\text{C}_6\text{H}_6$ ) showed a spot at  $R_f$  0.70. The epoxide was purified by column chromatography on 10 g of silica gel with 5% ether-hexane as the eluent. The solvent was evaporated to give 0.59 g (93%) of a liquid ( $n_D^{25}$  1.4440). Glc (150°) showed two peaks (isomers). The ir spectrum showed absorption at 2962, 2935, 2862, 1468, 1382, 1370, 1255, 900, 870, and 728  $\text{cm}^{-1}$ .

*Anal.* Calcd for  $\text{C}_{20}\text{H}_{40}\text{O}$ : C, 81.01; H, 13.60. Found: C, 80.88; H, 13.44.

**Synthesis of 7-Chloro-2-methyl-8-octadecanol and 8-Chloro-2-methyl-7-octadecanol (18).** A mixture of 1.4 g (5 mmol) of disphalure and 10 ml of concentrated HCl was stirred for 1 hr, and excess acid was removed by the addition of solid sodium carbonate. The ether extract of the reaction mixture was washed with water and saturated NaCl and dried over  $\text{MgSO}_4$ . Removal of the ether gave a liquid residue that was purified by column chromatography on 50 g of Florisil with 10% ether-hexane as the eluent. A total of 1.3 g (82%) of a light yellow liquid ( $n_D^{25}$  1.4556) was obtained: tlc (10% ether-hexane)  $R_f$  0.40. The ir spectrum showed OH absorption at 3440  $\text{cm}^{-1}$ .

*Anal.* Calcd for  $\text{C}_{19}\text{H}_{39}\text{OCl}$ : C, 71.54; H, 12.32. Found: C, 73.55; H, 12.37.

**Synthesis of 7-Bromo-2-methyl-8-octadecanol and 8-Bromo-2-methyl-7-octadecanol (19).** The bromohydrin of disphalure was prepared similarly to compound 18 by using 1.4 g (5 mmol) of disphalure and 10 ml of 85% hydrobromic acid. A total of 1.7 g (94%) of a light yellow liquid was obtained ( $n_D^{25}$  1.4569). Tlc showed one spot,  $R_f$

**Table I. Captures of Male Gypsy Moths by Disparlure and Related Compounds in a Light Infestation (Falmouth, Mass.; July 19-Aug 10, 1973)**

No.	Chemical	Captures/ trap with	
		20 $\mu$ g of compd + 20 $\mu$ g of 200 $\mu$ g of dispar- lure <sup>a</sup>	200 $\mu$ g of dispar- lure <sup>a</sup>
1	2-Methyl-7-octadecyne	7.5	10.3
2	(Z)-2-Methyl-7-octadecene	1.0	8.3
3	cis-7,8-Epoxy-2-methyloctadecane (standard) <sup>a</sup>	10.8	10.8
4	2-Methyloctadecane	6.3	8.8
5	1-Decyl-2-(5-methylhexyl)- cyclopropane	5.0	12.3
6 <sup>b</sup>	1-(1-Iodo-6-methylheptyl)undecyl isocyanate		
	2-Iodo-1-(5-methylhexyl)dodecyl isocyanate	3.8	10.8
7 <sup>b</sup>	Methyl [1-(1-iodo-6-methylheptyl)- undecyl]carbamate		
	Methyl [2-iodo-1-(5-methylhexyl)- dodecyl]carbamate	6.0	9.8
8	2-Decyl-3-(5-methylhexyl)- aziridine	5.8	9.8
9 <sup>b</sup>	2-(5-Methylhexyl)-1-tridecene		
	2-(6-Methylheptyl)-1-dodecene	8.8	11.0
10 <sup>b</sup>	1,2-Epoxy-2-(5-methylhexyl)- tridecene		
	1,2-Epoxy-2-(6-methylheptyl)- dodecene	9.3	10.5
11	7,8-Epithio-2-methyloctadecane	0.3	9.3
12 <sup>b</sup>	2-Methyl-7-octadecanol		
	2-Methyl-8-octadecanol	7.0	10.8
13 <sup>b</sup>	2-Methyl-7-octadecanone		
	2-Methyl-8-octadecanone	7.0	9.3
14 <sup>b</sup>	2-Methyl-7-octadecanol acetate		
	2-Methyl-8-octadecanol acetate	5.3	8.5
15 <sup>b</sup>	7-Methoxy-2-methyloctadecane		
	8-Methoxy-2-methyloctadecane	6.3	11.3
16	2,8-Dimethyl-7-octadecene	4.3	12.5
17	7,8-Epoxy-2,8-dimethyloctadecane	4.8	10.5
18 <sup>b</sup>	7-Chloro-2-methyl-8-octadecanol		
	8-Chloro-2-methyl-7-octadecanol	5.5	9.5
19 <sup>b</sup>	7-Bromo-2-methyl-8-octadecanol		
	8-Bromo-2-methyl-7-octadecanol	10.0	8.5
20 <sup>b</sup>	7-Iodo-2-methyl-8-octadecanol		
	8-Iodo-2-methyl-7-octadecanol	10.0	11.0

<sup>a</sup> With disparlure (3), the standard, the rate was 20  $\mu$ g/trap.<sup>b</sup> Mixture of the two regioisomers listed.

0.40 (10% ether-hexane); the ir spectrum showed OH absorption at 3440  $\text{cm}^{-1}$ .

Anal. Calcd for  $\text{C}_{19}\text{H}_{39}\text{OBr}$ : C, 62.78; H, 10.96. Found: C, 66.29; H, 10.82.

**Synthesis of 7-Iodo-2-methyl-8-octadecanol and 8-Iodo-2-methyl-7-octadecanol (20).** The iodohydrin of disparlure was prepared similarly to compound 18 with 1.0 g (3.5 mmol) of disparlure and 10 ml of 57% hydriodic acid. A total of 1.1 g (77%) of a slightly pink liquid was ob-

tained ( $n_D^{25}$  1.4794). The ir spectrum showed OH absorption at 3400  $\text{cm}^{-1}$ .

Anal. Calcd for  $\text{C}_{19}\text{H}_{39}\text{OI}$ : C, 55.60; H, 9.58. Found: C, 57.21; H, 9.80.

**Bioassay.** The chemicals were applied to a cotton wick (1.27 diameter  $\times$  1.0 cm) at a rate of 200  $\mu$ g/wick and exposed on a 10 cm long  $\times$  5 cm diameter tubular survey trap (Beroza *et al.*, 1971) with the wick suspended centrally. The bioassay was conducted from July 19 to Aug 10, 1973 at Falmouth, Mass., in an area with a very light infestation of the gypsy moth. Traps were set 8 m apart, and there were four replicates of each treatment. Included in the test were "standard" traps, each of which was baited with a cotton wick containing 20  $\mu$ g of disparlure. The fact that captures by the ten standard traps were very similar (14, 9, 10, 12, 12, 11, 12, 11, 10, and 8) indicated that the infestation was a uniform one.

## RESULTS AND DISCUSSION

Table I presents a list of the chemicals tested and the captures in traps baited with these materials (at a rate of 200  $\mu$ g when the candidate was tested alone and at a rate of 20  $\mu$ g with 20  $\mu$ g of disparlure added). There were highly significant differences in the captures by compounds 9, 10, 19, and 20 from captures with the other 15 compounds in single degree of freedom comparisons. Although the four compounds exhibited good attraction, none was as attractive as the disparlure standard, which was tested at one-tenth the concentration of the experimental chemicals. Also, captures by compound 2, the so-called precursor of disparlure, were significantly lower than those by the other compounds (except compound 11). This result was not unexpected since Cardé *et al.* (1973) reported the precursor to be an inhibitor of the attraction of disparlure.

In contrast to the low captures obtained by Sarmiento *et al.* (1972) with homologs and positional isomers of disparlure, many of the chemicals of this study, in which the epoxy group was replaced by another group or groups, were fairly attractive. (Most caught more than half as many moths as the standard.) These results suggest that the response of the moth's receptors to the epoxy group of the disparlure molecule is highly, but not completely, specific. It would be interesting to determine whether the electroantennogram responses of the compounds would parallel captures of insects in the field.

The results obtained in testing the chemicals in combination with disparlure were disappointing since none of the compounds was significantly synergistic or inhibitory.

Several comments on the syntheses should be made. Some syntheses produced two isomers, either positional or geometric, and no effort was made to separate these compounds. Also, the higher-than-theoretical elemental carbon values of the halogenated compounds indicate that hydrohalogenation was probably not complete.

The data should be of considerable interest to those studying the mechanism of olfaction, which is still very poorly understood. More specifically, the results may shed some light on the requirements of the antennal receptors for insect response.

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## Insecticide Residues in Cigarette Smoke. Transfer and Fate in Rats

Yousef H. Atallah<sup>1</sup> and H. Wyman Dorough\*

A quantitative smoking system was devised for mainstream smoke collection or for delivery to the lungs of rats *via* the trachea. Percentage transfer of <sup>14</sup>C-labeled insecticide equivalents to the mainstream smoke of cigarettes impregnated with five different <sup>14</sup>C-labeled insecticides (carbaryl, carbofuran, leptophos, DDT, and mirex) was approximately the same per milliliter of smoke, 0.2–0.3% of the <sup>14</sup>C-labeled insecticide contained in the burned tobacco, with puff volumes of 35 and 5 ml. Thirty-five milliliter puffs represent the average puff volume of man while a

5-ml puff was the volume administered to rats. Total recovery (ash, butt, sidestream smoke, and mainstream smoke) ranged from 88 to 102% of the ring-<sup>14</sup>C-labeled insecticides added to that tobacco subsequently burned during the smoking process. Rats were administered eight 5-ml puffs at 15-sec intervals from cigarettes impregnated with the radioactive insecticides. Results are presented relative to levels of radiocarbon in the exhaled air, lungs, blood, and heart following the smoking process.

A degree of human exposure to insecticides and other types of pesticidal chemical residues is unavoidable because of their ubiquitous nature in the environment and particularly on food commodities. This source of contamination has long been recognized and stringent use limitations are established for each pesticide in an effort to assure that levels of exposure are kept well below those believed to be hazardous. Tobacco smoke is another possible source of human exposure to insecticides but their actual significance to the health of the smoker is largely unknown (Wynder and Hoffmann, 1967). However, it is known that various insecticide residues occur in commercial tobacco products (Dorough and Gibson, 1972) and that insecticides and their pyrolysis products may be transferred to the mainstream smoke of cigarettes (Chopra *et al.*, 1970; Chopra and Domanski, 1972; Chopra and Sherman, 1972; Guthrie, 1968; Hengy and Thirion, 1970, 1971; Hoffmann and Rathkamp, 1968; Hoffmann *et al.*, 1969; Iso, 1972).

Even so, tobacco smoke has not been generally considered as an important source of human exposure to insecticides and, not being a food crop, tobacco is not included among those crops requiring official pesticide tolerances. Nevertheless, regulatory officials do carefully consider the levels and nature of residues in tobacco and in smoke condensates as part of the evaluation of pesticides whose proposed use includes the control of tobacco pests. If hazardous conditions appear likely, the use may be denied or proper limitations imposed to circumvent the potential problems involved. This type of consideration is relatively new and there is a critical need for information which will assist in determining the significance of pesticide residues in tobacco and tobacco smoke. A most obvious void in this regard is information relating to the fate of insecticide residues, their metabolites, and/or pyrolysis products after being inhaled. Studies of this nature should be con-

ducted with animals and, as is the case with pesticide residues on food crops, the data extrapolated to humans.

In the current study, a simple but quantitative smoking device was constructed whereby smoke containing radioactive insecticide residues was transferred directly from the cigarette to the lungs of rats *via* the trachea. Rats were selected because they are commonly used in metabolic fate studies of pesticides, and the existing information would be useful in interpreting the significance of data obtained in the smoke experiments. While it is desirable to administer the smoke to the animal in a more natural manner, an effective quantitative system that would allow the "smoking" of animals similar to the process in humans has yet to be developed. Enclosing animals in cylinders or chambers (Moore and Bock, 1956; Holland *et al.*, 1958) may be sufficient for studying the pathological affects of chronic smoke exposure, but the quantitative aspects necessary for pesticide fate studies and for determining exposure potential of pesticides to the smoker are not provided by such methods. Forced smoking *via* the trachea (Wynder and Hoffmann, 1967; Armistage *et al.*, 1969) allows an excellent means of administering quantitative doses of smoke containing insecticide residues to the lungs of animals, and the subsequent determination of the fate of the inhaled residues.

### MATERIALS AND METHODS

**Treatment of Cigarettes.** Radioactive insecticides were used in all experiments. The identity of the compounds and the position of the <sup>14</sup>C label on the molecule are shown in Table I. These insecticides were selected to represent different chemical types and not as examples of compounds used for the control of tobacco pests. In fact, of those insecticides listed in Table I, only carbaryl and carbofuran are currently approved for this use. DDT was registered for use on tobacco until 1970 and residues do exist in commercial cigarettes (Dorough and Gibson, 1972).

Reference research cigarettes 1R1 were provided by the Tobacco and Health Research Institute (University of Kentucky, Lexington, Ky). The desired quantity of insecticide

Department of Entomology, University of Kentucky, Lexington, Kentucky 40506.

<sup>1</sup> Present address: Velsicol Chemical Corporation, Chicago, Illinois.