EFFECTS OF PHEROMONE, PHEROMONE COMPONENTS, AND PHEROMONE ANALOGUES ON MATING OF THE SPRUCE BUDWORM (LEPIDOPTERA: TORTRICIDAE)

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Abstract

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Either (*E*)- or (*Z*)-11-tetradecenal, the two pheromone components, or one analogue, 9-(cyclopent-2-en-1-yl)-nonanal, effectively reduced mating of spruce budworm moths, *Choristoneura fumiferana* (Clem.), in the laboratory. The results suggest that different behavioural and physiological processes may be occurring in pheromonal attraction and close range mating prevention in the spruce budworm.

Résumé

Les 2 composantes de la phéromone, soit le (*E*)- et le (*Z*)-11-tétradécénal, de même qu'un analogue, le 9-(cyclopent-2-en-1-yle)-nonanal, ont effectivement réduit l'accouplement des papillons de la tordeuse des bourgeons de l'épinette, *Choristoneura fumiferana* (Clem.), en laboratoire. Ces résultats indiquent que les processus comportementaux et physiologiques impliqués diffèreraient entre la réponse d'attraction à distance et la perturbation de l'accouplement à proximité.

Introduction

Goals in studying lepidopterous pheromones include understanding the mechanism by which disruption occurs and being able to suppress mating in very high density populations. The brevity of the flight season of the spruce budworm, *Choristoneura fumiferana* (Clem.), essentially necessitates that potential compounds which might prevent mating be quickly screened in the laboratory before field testing. The results of tests using pheromone and various analogues of pheromone to reduce mating in the laboratory are the subject of this report.

Materials and Methods

Synthetic sex pheromone and analogues shown in Fig. 1 were used in this study. The synthetic sex pheromone of the natural ratio, a blend of 97% (*E*)-11-tetradecenal (I) with 3% (*Z*)-11-tetradecenal (II) (Sanders and Weatherston 1976), was obtained from ChemSampCo, Columbus, Ohio. Highly purified individual pheromone components were synthesized in the laboratory. Final purities of 99.5% for I and 99.8% for II were obtained as indicated by gas–liquid chromatographic (GLC) analysis using 6.1 m × 2 mm i.d. column containing 10% Silar 10C liquid phase and operated at 160°. The following analogues were synthesized: tetradecanal (III), 11-dodecenal (IV) and in a 94:6 *E*:*Z* ratio: 11-tetradecen-1-ol acetate (V); 11-tetradecen-1-ol (VI), 9-dodecen-1-ol formate (VII); 11-tetradecenonitrile (VIII); 11,12-epoxy-tetradecanal (IX), and 12-pentadecen-2-one (X). Two ring analogues, 3-(8-undecenyl)-cyclohexanone (XI) and 11-tetradecen-1,3-diol cyclic carbonate (XII), plus both the racemate and an 85% (*S*) : 15% (*R*) enantiomeric mixture of 10-(cyclopent-1-en-1-yl)-decanal (XIII) completed the laboratory syntheses. The analogues were of 97% purity. Optical purity of partially resolved XIII was determined by a comparison with (*S*)-(-)-9-(cyclopent-2-en-1-yl)-nonyl acetate reported by Chapman *et al.* (1978). Conrel hollow fibres filled in 1976 with ChemSampCo-produced

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pheromone were tested as a slow release formulation. These fibres released pheromone at a rate of ca. 25 ng/fibre/h (C. J. Wiesner, pers. comm.).

Laboratory moths reared by the method of McMorran (1965) as modified by Harvey (1974) were used in all tests. In the testing procedure groups of 10 one-day-old male spruce budworm moths plus a sprig of balsam fir were placed in 500 ml Erlenmeyer flasks which had been washed, cleaned with chromerge, rinsed with water, acetone and petroleum ether, and dried. Test chemicals dissolved in hexane were placed on squares of glass filter paper, aired to evaporate the hexane, and pinned to the bottoms of aluminium foil-covered rubber stoppers which were used to seal the flasks. Ten newly emerged female moths were likewise treated in separate flasks. The moths plus flasks were maintained at 20°–24° for approximately 2 h or until just before the beginning of scotophase (17:7 LD). At this time the males in one flask were added to the females in another. Eighteen hours later the moths were frozen and the females dissected to determine whether or not they had been mated (i.e. contained a spermatophore in the bursa copulatrix). The aluminium foil and pin with chemical source were discarded at the end of each test. Controls consisted of hexane-impregnated filter squares which were aired like the test chemicals.

Tests utilizing the hollow fibres filled with pheromone were performed in systems both with and without air flow. The systems without air flow were identical with those just described except fibres were attached to microscope cover slips pinned to the undersides of the stoppers. The tests involving an air flow were performed in cylindrical glass tubes 30×5.5 cm. Air was passed at a rate of 500 ml/min in one end, across the fibres, through the tube containing moths and out the other end to be evacuated through a fume hood.

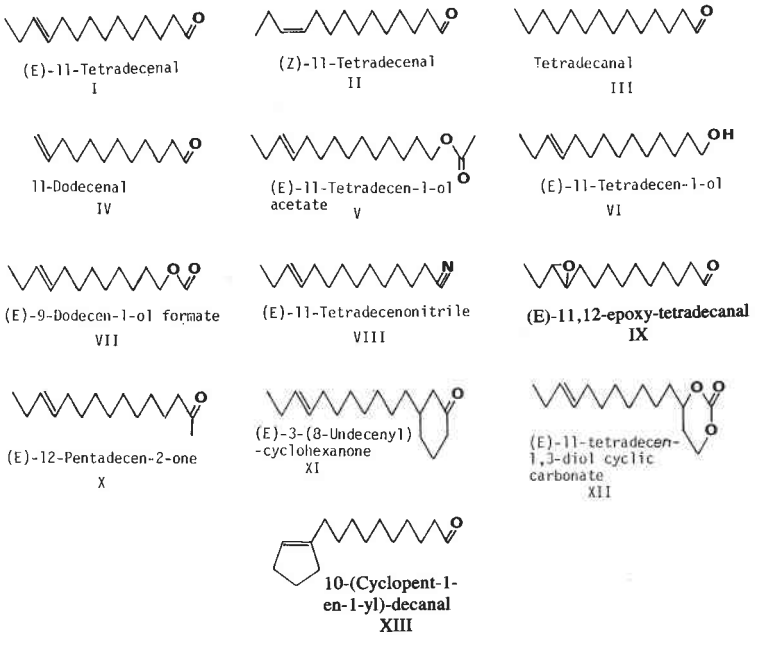

FIG. 1. Chemical structures of compounds tested in laboratory bioassays for effects on mating of spruce budworm moths.

Results and Discussion

The results (Table I) indicate that either pheromone component alone or the 97:3 mixture very significantly reduces mating when 1 mg of material is used. It should also be noted that both pheromone components when individually tested were as effective as the natural blend in reducing mating. This finding is strikingly different from the results obtained when pheromone is used for attraction of males to traps: neither component alone exhibits any attractancy (Sanders and Weatherston 1976).

The fact that only one analogue significantly reduced mating indicates that most of the analogues probably possess little field potential in the management of the spruce budworm. The exception, compound XIII, reduced mating almost as effectively as the pheromone. This encouraging finding is most interesting because XIII, unlike the pheromone, possesses a ring structure. The only other example of a biologically active ring analogue of a straight chained pheromone is reported by Chapman *et al.* (1978) who synthesized an analogue which induces precopulatory behaviour in European corn borer and redbanded leafroller moths. The ring compound XI might cause an increase in mating though it would be premature based on the

Table I. Mating of *C. fumiferana* in atmospheres containing pheromone, pheromone components, or pheromone analogues

Treatment	Replicates (n = 10)	% mated	% mated in control	% mating reduction (increase)[3]	χ^2[4]
Pheromone and components[1]					
100 μg 97:3 I:II[2]	7	32	54	41	6.68**
100 μg pure I	3	21	40	47	1.54
100 μg pure II	7	38	48	21	.98
1 mg 97:3 I:II[2]	9	23	52	56	14.7***
1 mg pure I	6	24	66	64	19.0***
1 mg pure II	5	13	57	77	21.5***
5 hollow fibres (~125 ng/h)	5	32	38	16	.18
40 hollow fibres (~1 μg/h)	5	10	38	74	13.1***
5 hollow fibres with 500 ml/min air flow	6	12	33	64	8.89**
40 hollow fibres with 500 ml/min air flow	4	0	63	100	33.5***
Pheromone analogues					
1 mg V	3	57	57	0	.000
1 mg VIII	3	47	50	6	.001
1 mg VI	3	53	57	7	.001
1 mg III	2	45	50	10	.001
1 mg VII	3	45	51	12	.80
1 mg X	2	45	55	18	.10
1 mg IV	3	38	60	37	2.06
1 mg IX	4	32	53	40	3.06
1 mg XI	3	70	43	(63)	3.32
1 mg XII	3	50	43	(16)	.07
1 mg 85% (S) : 15% (R) XIII	4	28	56	50	5.69*
2 mg (R,S) XIII	3	27	62	56	6.13*

[1]See Fig. 1 for chemical structures.
[2]Natural pheromone blend.
[3]% reduction = [(% mated in control − % mated in treatment/% mated in control)] × 100%.
[4]χ^2 calculated from original data; *$P < .05$, **$P < .01$, ***$P < .001$.

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lack of a statistical difference between this treatment and the control to speculate further concerning the potential increase in mating.

It is of interest that in spite of the unrealistically high population densities used in these experiments good mating suppression was obtained. Moreover, the good reduction in mating with the hollow fibres indicates that, at least under laboratory conditions, the 1976 Conrel hollow fibre formulation, used without sticker, very effectively reduced mating. Nevertheless any extrapolation of laboratory results to actual field results must be guarded against.

This study indicates that the natural blend of pheromone of the spruce budworm is not necessary for effective interference with mating behaviour under laboratory conditions: either pheromone component alone is equally effective. This is contrary to the situation for male attraction in which only a narrow range of pheromone components is effective (Sanders and Weatherston 1976). This difference suggests that pheromonal attraction and mating suppression are governed by different behavioural or physiological processes.

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