These results indicate that the ovipositional responses of the three Papilionid butterflies to rutaceous plants were host specific, and the oviposition-inducing contact chemicals in aqueous ethanol extracts from host plants were composed of water-soluble but ethyl acetate-insoluble substances. Isolation of the active principles is very difficult because general chromatographic separations such as an anion exchange chromatography, PPC and TLC for further purification of these fractions caused a considerable reduction of the activity. The further purification of active com-

ponents is now under investigation.

REFERENCES

- ICHINOSÉ, T. and H. HONDA (1978) *Appl. Ent. Zool.*, **13** : 103-114.
 INAIZUMI, M. (1979) *Kontyû* **47** : 412-415.
 NISHIDA, (1977) *Botyu-kagaku* **42** : 133-140.
 SAXENA, K. N. and S. GOYAL (1978) *Ent. exp. appl.* **24** : 1-10.
 WIKLUND, C. (1974) *Ent. exp. appl.* **17** : 189-198.

Sex Attractant Pheromone of the Turnip Moth, *Agrotis segetum* DENIS et SCHIFFERMÜLLER² (Lepidoptera: Noctuidae): Effects of the Geometrical Isomers on the Attractant Activity of the Synthetic Sex Pheromone¹

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The sex attractant pheromone of the turnip moth, *Agrotis segetum* DENIS et SCHIFFERMÜLLER, was isolated and identified to be a mixture of two components, (Z)-5-decenyl acetate and (Z)-7-decenyl acetate (WAKAMURA, 1978a). These components were synthesized and the mixture was proved to show a potent sex-attractant activity to the male moths (WAKAMURA, 1978a, 1980). A small proportion of the opposite geometrical isomers may have significantly synergistic or inhibitory effects on the activity of the synthetic sex pheromone in many lepidopterous insects, as reviewed by ROELOFS and CARDÉ (1977). These field tests were conducted to estimate the effects of the geometrical isomers on the attractant activity of the synthetic sex pheromone of *A. segetum*.

The synthetic sex pheromone components, (Z)-5-decenyl acetate and (Z)-7-decenyl acetate, were synthesized in this laboratory (WAKAMURA, 1980). Their geometrical isomers, (E)-5-decenyl acetate and (E)-7-decenyl acetate, were synthesized from their (Z)-isomers, using *cis-trans* isomerization reaction without double-bond migration (SGOUTAS and KUMMEROW, 1969). Each of the synthetic compounds was purified with column chromatography on silicic acid impregnated with silver nitrate (AgNO_3 : 16.7%). No spot corresponding to the opposite geometrical isomer was detected in either of these compounds on a thin layer plate of silicic acid impregnated with AgNO_3 . These synthetic compounds were impregnated into rubber septa (Takeda f, Takeda Chem. Ind., Ltd.) as a hexane solution and the solvent was evaporated at room temperature. Each of the septa was then placed in a trap as a lure. A rubber septa impregnated with 0.2 mg of a 10 : 90 mixture of (Z)-5-decenyl acetate and (Z)-7-decenyl acetate was used as a standard lure throughout the experiments. This formulation was the most attractive for the first 10 nights (WAKAMURA, 1980). Water-pan traps were used to evaluate the attractant activity. The trap consisted of a pan ($30 \times 24 \times 8$ cm) with a clear plastic plate as a roof (Takeda Chem. Ind., Ltd.), which was filled with a diluted detergent solution (about 3% Gramin®, Sankyo Ltd., Tokyo). A rubber septum impregnated with the compounds to be tested was suspended inside each trap about

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² This species was formerly called the common cutworm moth, *Agrotis fucosa* BUTLER.

5 cm above the water surface.

The field tests were conducted on the Nakatado Plain in Kagawa Prefecture. The traps were located at least 20 m apart each other and set 1 m above the ground level. Their positions were randomly rearranged daily to avoid any undesirable effects due to the trap position. Males obtained from the laboratory colony (WAKAMURA, 1977, 1978b) were released with marks when the wild population was at a low level. Mean trap catches of male moths ($\bar{X}$) were transformed to $\sqrt{\bar{X}+0.5}$, submitted to an analysis of variance, and ranked using Duncan's new multiple-range test. In Fig. 1 and 2, the numbers of males capped with the same letters are not significantly different at the 5% level of probability.

Attractant activities of 4 possible combinations of the geometrical isomers of 5-decenyl acetate and 7-decenyl acetate, that is (Z)-5/(Z)-7, (E)-5/(Z)-7, (Z)-5/(E)-7, and (E)-5/(E)-7, were tested at ratios of 0 : 100, 10 : 90, 33 : 67, 50 : 50, 67 : 33, 90 : 10 and 100 : 0. The total amount of

the mixture was 0.2 mg/septum.

Males of *A. segetum* were caught with a lure containing (Z)-5-decenyl acetate, and the maximum catches were obtained with the mixture of (Z)-5/(Z)-7 at the ratio of 10 : 90 (Fig. 1). No male was caught with the combinations of (E)-5/(Z)-7 or (E)-5/(E)-7. In the previous paper (WAKAMURA, 1978a), the (Z) configuration of the natural sex-pheromone components were assumed from the fact that the *cis*-fraction of the extracts of the virgin female secretions showed a potent attractant activity but the *trans*-fraction did not. Though these inferences had been supported by field-evaluation experiments (WAKAMURA, 1980), there remained a small amount of doubt about the configuration of 7-decenyl acetate, since (Z)-7-decenyl acetate had no attractant activity by itself and no test had been conducted concerning (E)-7-decenyl acetate. The results shown in Fig. 1 indicate that 7-decenyl acetate as a sex pheromone component of *A. segetum* should be in the (Z) configuration.

Fig. 1. The attractant activity of the combinations of the geometrical isomers of 5-decenyl acetate and 7-decenyl acetate. Values indicated are the means for 1 trap for 10 nights. Means capped with the same letters are not significantly different at the 5% level of probability as judged by Duncan's new multiple-range test. STD: a 10 : 90 mixture of (Z)-5/(Z)-7 at 0.2 mg/septum. Test periods: (E)-5/(Z)-7 and (Z)-5/(E)-7, April 24-May 4; (Z)-5/(Z)-7 and (E)-5/(E)-7, May 8-18, 1979.

Fig. 2. Effect of the (*E*)-5-decenyl acetate or (*E*)-7-decenyl acetate on the attractant activity of (*Z*)-5-decenyl acetate. Values indicated are the means for 1 trap for 10 nights. Means capped with the same letters are not significantly different at the 5% level as judged by Duncan's new multiple-range test. STD: a 10 : 90 mixture of (*Z*)-5/(*Z*)-7 at 0.2 mg/septum. Test period: May 19–29, 1979.

(*Z*)-7-Decenyl acetate had been shown to have a potent synergistic effect on the attractant activity of (*Z*)-5-decenyl acetate (WAKAMURA, 1980). The effect of (*E*)-5-decenyl and (*E*)-7-decenyl acetate were evaluated in the field test. (*E*)-5-Decenyl acetate or (*E*)-7-decenyl acetate at the amount of 0.5, 5, or 50 μg was added to a rubber septum which was impregnated with 5 μg of (*Z*)-5-decenyl acetate.

The number of males caught with (*Z*)-5-decenyl acetate was not significantly increased by the addition of (*E*)-5-decenyl acetate or (*E*)-7-decenyl acetate (Fig. 2). The number was much less than that obtained using the standard lure (a 10 : 90 mixture of (*Z*)-5/(*Z*)-7 at 0.2 mg/septum). Neither (*E*)-isomer is considered to have either significantly synergistic or inhibitory effects on the attractant activity of (*Z*)-5-decenyl acetate.

Then another field test was conducted to estimate the geometrical purity which might be demanded for effective attraction of *A. segetum* males. Both (*E*)-isomers were added to the 10 : 90 mixture of (*Z*)-5/(*Z*)-7 at 0.2 mg/septum (the standard lure) at the percentage of 1, 2, 5 and 10.

The number of males caught was neither increased nor decreased by the addition of the (*E*)-isomers (Fig. 3). The attractant activity of the

synthetic sex pheromone of *A. segetum* is not considered, therefore, to be affected by the presence of less than 10% of the (*E*)-isomers.

Alkenyl acetate with a (*Z*)-configuration has been synthesized from carbonyl compounds by the reduction of alkynes by the Wittig reactions and by other reactions. Rossi (1977) concluded

Fig. 3. Effect of the (*E*)-isomers on the attractant activity of the 10 : 90 mixture of (*Z*)-5-decenyl acetate and (*Z*)-7-decenyl acetate. Values indicated are the means for 1 trap for 10 nights. No significant difference was found by the analysis of variance. STD: a 10 : 90 mixture of (*Z*)-5/(*Z*)-7 at 0.2 mg/septum. Test period: May 19–29, 1979. Marked males were released during the test period (about 45 males/night).

in his review that the degree of stereo-selectivity was rarely higher than 95–96% by semihydrogenation of a triple bond, even in the presence of the Lindlar catalyst which appeared to be the most stereo-selective. HORIIKE et al. (1978) synthesized (Z)-alkenyl acetate with a stereo-selectivity higher than 90% by the Wittig reaction. The sex pheromone synthesized by these methods was considered to be useful for the effective field-trapping of *A. segetum* males without any geometrical purifications.

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REFERENCES

- HORIIKE, M., M. TANOUCI, C. HIRANO (1978) *Agr. Biol. Chem.* **42** : 1963–1965.
 ROELOFS, W. L. and R. T. CARDÉ (1977) *Ann. Rev. Entomol.* **22** : 377–405.
 ROSSI, R. (1977) *Synthesis* **1977** : 817–836.
 SGOUTAS, D. S. and F. A. KUMMEROW (1969) *Lipids* **4** : 283–287.
 WAKAMURA, S. (1977) *Jap. J. appl. Ent. Zool.* **21** : 146–149.
 WAKAMURA, S. (1978a) *Appl. Ent. Zool.* **13** : 290–295.
 WAKAMURA, S. (1978b) *Shokubutsu-Boeki* **32** : 390–394.
 WAKAMURA, S. (1980) *Appl. Ent. Zool.* **15** : 167–174.

Studies on Summer Diapause in Pupae
 of *Antheraea yamamai*
 (Lepidoptera : Saturniidae)¹
 III. Influence of Photoperiod in
 the Larval Stage

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Antheraea yamamai, a univoltine saturniid silkworm in Japan, overwinters at the embryonic stage, and enters summer diapause at the pupal stage. The moth emerges from the end of July to October with a peak in September. The termination of pupal summer diapause in this species is accelerated by short photoperiods such as 8L–16D to 12L–12D (KATO et al, 1979; SAKATE

et al., unpublished). However, the factors inducing the pupal summer diapause are not known.

In two other univoltine species of saturniid, *Antheraea polyphemus* and *Hyalophora cecropia* hibernating as diapause pupae, an 'obligatory' diapause is induced or averted by the photoperiod in the larval stage (MANSINGH and SMALLMAN, 1966, 1967). We examined such an effect on *A. yamamai* in 1979.

Eggs of *A. yamamai* used in this study were laid by the moths reared in the laboratory. After hatching, the larvae were kept in a short (12L–12D) or a long (16L–8D) photoperiod. Leaves of *Quercus actissima* were given as food. When they pupated, each group was divided into two sub-groups, which were exposed to photoperiods of 12L–12D and 16L–8D, respectively, till emergence. The temperature was 25°C throughout the experiments.

The duration from hatching to pupation was a little shorter in 12L–12D than in 16L–8D (Table 1). Fig. 1 shows the distribution of the pupal duration under various photoperiodic conditions. The pupal duration was shorter when the larvae were kept in 12L–12D than in 16L–8D. This effect was much larger when the pupae were exposed to 16L–8D. Obviously the larvae of *A. yamamai* responds to photoperiod: the photo-

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