Table 1. Mortality of *P. glaucopsis* larvae from predation by *P. laesipennis* larvae

No. prey/ tree	Prey mortality by predation ¹⁾	No. trees
1-10	0.030±0.015 a	13
11-20	0.060±0.016 a	13
21≤	0.091±0.009 b	7
Total	0.055±0.010	33

¹⁾ Defined by means±s.e.

Means with different letters are significantly different (DUNCAN's multiple range test, $p<0.05$).

level (SOKAL and ROHLF, 1981). I therefore, suggest that this carabid predator aggregates on trees with high prey density. Almost all predators observed were attacking prey. Prey mortality by

predation tended to grow with prey density and was significantly different between less than 10 and more than 21 prey/tree density at the 5% level (Table 1). Density-dependent mortality of the prey might have resulted from aggregation of the predator on trees with high prey density.

I wish to thank Drs. M. SHIGA and S. MIYAI of the National Institute of Agro-Environmental Sciences for their valuable suggestions and helpful criticism of the manuscript.

REFERENCES

- HABU, A. and K. SADANAGA (1967) *Kontyû* **35**: 391-397 (in Japanese with an English summary).
 HABU, A., K. SADANAGA and J. MINAMIKAWA (1963) *Kontyû* **31**: 305-308 (in Japanese with an English summary).
 SOKAL, R. R. and F. J. ROHLF (1981) *Biometry*. Second edition. Freeman, San Francisco, 859 pp.

Control of the Beet Armyworm, *Spodoptera exigua* (HÜBNER) (Lepidoptera: Noctuidae), Using Synthetic Sex Pheromone IV. Effect of Communication Disruption in Welsh Onion Fields in 1988¹

Sadao WAKAMURA,^{2,3} Mikio TAKAI,⁴
Akira YAMAMOTO,⁵ Hitoshi INOUE²
and Mitsuru KAWAMURA⁶

² Shikoku National Agricultural Experiment Station,
Zentsuji, Kagawa 765, Japan

⁴ Kochi Prefectural Institute of Agricultural and
Forest Science, Ino, Kochi 781-21, Japan

⁵ Research and Development Lab., Shin'Etsu
Chemical Co., Ltd., Kubiki, Niigata 942, Japan

⁶ Yokohama 1647-6, Kochi 781-02, Japan

(Received July 5, 1989)

(Accepted January 19, 1990)

Communication disruption experiments with synthetic sex pheromone were successful against several pests on fruit trees, tea and cruciferous vegetables in Japan (OHTAISHI, 1986; FURUNO, 1986; SATO,

1986). Subsequently, some pest control agents have been developed.

The beet armyworm, *Spodoptera exigua*, has been a serious pest of vegetables and ornamental crops in southwestern Japan since the early 1980's (HORIKIRI, 1986; TAKAI, 1988a, 1989). This insect is difficult to control by spraying insecticides because of insecticide resistance (TAKAI, 1988b). In 1987, communication disruption using synthetic sex pheromone was demonstrated to be an effective tool for control of the beet armyworm in Welsh onion, *Allium fistulosum* L., fields (WAKAMURA et al., 1989).

In 1988, we conducted follow-up experiments in which sex pheromone was released at a higher rate into smaller areas than in 1987 to reconfirm the population suppression effect.

MATERIALS AND METHODS

Experiment area. Experiments were conducted in 2 areas, Nii and Kitahara, Tosa city, Kochi Prefecture, Japan, which were the same places as in the 1987 experiment (WAKAMURA et al., 1989). The Nii area was ca. 155 ha of which Welsh onion plots comprised ca. 24 ha (Fig. 1). This area seemed to be isolated from other agricultural areas. The area

¹ Appl. Ent. Zool. **25** (2): 320-323 (1990)

³ Present address: National Institute of Sericultural and Entomological Science, Tsukuba, Ibaraki 305, Japan

Fig. 1. Map showing area treated with synthetic sex pheromone in 1988 (Nii, Kochi Prefecture, Japan). Treated area in 1988 (ca. 60 ha) is marked by thick solid line, and that treated in 1987 (ca. 155 ha) by thick broken and solid lines. A and B indicate the survey areas of the *Spodoptera exigua* population.

treated with the synthetic sex pheromone was the northern third of the Nii site (ca. 60 ha, cultivated plots: ca. 50 ha) of which Welsh onion plots comprised ca. 20 ha (Fig. 1). The untreated area (Kitahara) was ca. 9 km from the treated area.

Application of the synthetic sex pheromone in a field. The dispensers used were supplied from Sin'Etsu Chem. Co., Ltd.; a sealed polyethylene tube (20 cm long) containing 80 mg of a 7:3 mixture of (Z,E)-9,12-tetradecadienyl acetate and (Z)-9-tetradecen-1-ol. Dispensers were set evenly in Welsh onion plots and other cultivated plots at the rate of 1,500 and 600 tubes/ha, respectively. The onion plots in the outside of the treated area of Nii (ca. 4 ha) were also treated with 1,500 tubes/ha. Each release point had 3 (onion plots) or 2 (other plots) dispensers attached to the top of a 60 cm plastic stick with vinyl adhesive tape. Dispensers were set in the plots on July 6 to 8 and removed on September 30, 1988.

Survey of field density. Onions were planted on ca. 1 m wide ridges in the plots (5–10 a) which were scattered in the experimental areas. Larval density was surveyed in every 6 plots in 2 survey areas in

the treated area (Fig. 1; A, B) and in 5 plots in the untreated area. Survey plots were arbitrarily selected where onion hills were 30–60 cm high. Since most larvae were inside hollow leaves, damaged leaves were collected and dissected to recognize instars and count the number of larvae. In each plot, the survey was stopped when the number of infested hills reached 25 or when the total number of hills surveyed reached 500, and the density per 100 hills was calculated. The mean density of each survey area was then calculated. Surveys were conducted once a week from July 13 through September 27.

Farmers sprayed insecticides such as methomyl, EPN, permethrin and fenvalerate-dimethoate against *S. exigua* larvae, both in the treated and untreated areas, independently from the experiment. However, these insecticides appeared ineffective (TAKAI, 1988b), and were not considered to have an effect on population density.

Light trap. A light trap (lamp: BLB 30 W) was set at the center of the survey area A. *S. exigua* moths caught were collected every 2 or 3 days.

RESULTS AND DISCUSSION

The mean densities of egg masses, 1st and 2nd instar larvae, and 4th and 5th instar larvae are shown in Fig. 2.

Densities of egg masses and larvae increased gradually until late August, and rapidly increased in early September in the untreated area; maximum density of 1st and 2nd instar larvae was more than 400 individuals/100 hills. The mean infestation rate of hills was more than 50% in mid-September; in some plots, every hill was observed to be infested by the larvae.

Conversely, population density was low in the treated area throughout the treatment period. No egg mass was found throughout this period. First instar larvae were found in survey area A on September 20 (0.9 larvae/100 hills). No young larvae was found in survey area B. Few 4th and 5th instar larvae (less than 0.2 individuals/100 hills; Fig. 2) were found in both survey areas A (mid-July and late August) and B (early September). Infestation rate of hills was less than 0.2% throughout the treatment period.

Few males and no females were caught with the light trap throughout the experimental period, indicating that adult *S. exigua* density was very low.

In 1987, Welsh onion fields were treated with 990 dispensers/ha, and rice fields, greenhouses,

Fig. 2. Population densities of eggs and larvae of *Spodoptera exigua* in Welsh onion plots in areas treated and not treated with synthetic sex pheromone. Broken and dotted lines indicate the densities in survey areas A and B in the treated area, respectively. Solid line indicates density in the untreated area. Arrows ↓ and ↑ show the times of setting and removing pheromone dispensers, respectively.

orchards, home gardens and forests in the treated area were treated with 320 dispensers/ha. The release rate of synthetic sex pheromone decreased by about 50% during 2 months exposure (YAMAMOTO, unpublished data) and the rate of mated females captured with a light trap increased from

about 50% to 80% during the same period (WAKAMURA et al., 1989) (The real rate of mated females was tentatively estimated to have increased from 20% to 50%; WAKAMURA and TAKAI, 1990).

In 1988, the 50 ha field was treated with more dispensers/ha than in 1987. The initial density in the treated area was considered to be much lower in 1988 than in 1987, which was indicated by the population survey (Fig. 2) and the light trap capture data. Increased concentration of synthetic sex pheromone and low initial density were thought to have caused a near-zero population throughout the treated period. Low initial density was a possible effect of the sex pheromone treatment of the previous year (WAKAMURA et al., 1989).

It was confirmed again that permeation of the synthetic sex pheromone reduced the egg mass density and consequently reduced the field population of *S. exigua* larvae.

ACKNOWLEDGEMENTS

We wish to sincerely thank Dr. Juro KOYAMA of the Shikoku National Agricultural Experiment Station (currently of the National Institute of Sericultural and Entomological Science), Dr. Yoshio TAMAKI of the National Institute of Sericultural and Entomological Science for critical review of the manuscript, Dr. Takeshi YUSHIMA of the Tokyo University of Agriculture for useful advice throughout the experiments, and Shin'Etsu Chemical Industry, Co., Ltd. for the supply of synthetic sex pheromone dispensers. We are also grateful to Messrs. Yoshiro MATSUOKA and Mitsuhiro OKUBO of the Nii Agricultural Cooperative Association, Mr. Tatsuya KADOTA of the Kitahara Agricultural Cooperative Association, Messrs. Hisanori SUGIMOTO and Satoshi ISHIMOTO of the Susaki Pest Control Station, and Messrs. Nobuhiro MATSUKI, Hiroaki MORI, Akimitsu WANABE and Ms. Mayumi YAMASAKI of the Tosa Agricultural Extension Office for their cooperation in this work.

REFERENCES

- FURUNO, T. (1986) *Shokubutsu bōeki* (Plant Protection) **40**: 55–58 (in Japanese).
- HORIKIRI, M. (1986) *Shokubutsu bōeki* (Plant Protection) **40**: 472–475 (in Japanese).
- OHTAISHI, M. (1986) *Shokubutsu bōeki* (Plant Protection) **40**: 51–54 (in Japanese).
- SATO, R. (1986) *Shokubutsu bōeki* (Plant Protection) **40**: 63–66 (in Japanese).

- TAKAI, M. (1988a) *Bull. Kochi Inst. Agric. Forest Sci.* No. 20: 1–6 (in Japanese).
- TAKAI, M. (1988b) *Bull. Kochi Inst. Agric. Forest Sci.* No. 20: 7–10 (in Japanese).
- TAKAI, M. (1989) *Shokubutsu bōeki (Plant Protection)* **43**: 315–318 (in Japanese).
- WAKAMURA, S. and M. TAKAI (1990) *Jpn. J. Appl. Ent. Zool.* **34**: 161–163 (in Japanese).
- WAKAMURA, S., M. TAKAI, S. KOZAI, H. INOUE, I. YAMASHITA, S. KAWAHARA and M. KAWAMURA (1989) *Appl. Ent. Zool.* **24**: 387–397.

Hormonal Control of Melanization in Newly Hatched Larvae of the Saturniid Silkmoth, *Samia cynthia ricini* DONOVAN (Lepidoptera: Saturniidae)¹

Hitoshi SAITO and Fumio MUKAIYAMA

*Department of Sericulture, Faculty of Agriculture,
Tokyo University of Agriculture and Technology,
Fuchu, Tokyo 183, Japan*

(Received September 20, 1989)

(Accepted January 16, 1990)

It is well known that some species of insects show morphological color changes and polymorphism in relation to environmental conditions and to developmental stages. Most of the morphological color changes are controlled by insect hormones, such as ecdysteroids, juvenile hormones and neurohormones (FUZEAU-BRAESCH, 1985). The first report on the presence of a hormonal control in cuticular tanning was described by FRAENKEL and HSIAO (1962, 1963, 1965) in the blowfly, *Sarcophaga bullata*. This tanning hormone is called "bursicon" (FRAENKEL and HSIAO, 1965). In the case of *Schistocerca gregaria*, it has been demonstrated that the melanization of the 1st instar larvae relates to hormonal control and also elucidated that this hormone is identified as an analogue to bursicon (PADGHAM, 1976a, b). In the armyworm larvae, *Leucania separata*, the dark coloration has been shown to be controlled by melanization and reddish coloration hormone (MRCH; OGURA, 1975).

In this paper, we investigated the relationship between the hormonal control and the cuticular melanization of newly hatched larvae in the saturniid silkmoth, *Samia cynthia ricini*.

MATERIALS AND METHODS

The eri-silkworm *Samia cynthia ricini* larvae were reared on *Ailanthus glandulosa* leaves at 25°C under a natural photoperiod. After pupation, the pupae were kept 16L–8D, 25±1°C. After adult emergence, female moths copulated with males for 12 hr. Oviposition was carried out in a dark room for 4 hr at 25°C. The eggs were then incubated at 25±1°C, 70–80% R.H., 16L–8D until hatching 8 days after oviposition.

In an attempt to locate the release site of the factor inducing melanization, pharate 1st instar larvae were obtained from eggs by cutting the egg shell with a micro-blade. Ligature was applied with a fine cotton thread between the head and the thorax region. The larvae of each group were assessed for melanization and non-melanization about 3 hr after the presumed hatching time.

RESULTS AND DISCUSSION

Embryonic development extended over 9 days. *Samia* started feeding on their egg-shells when the embryos were fully grown. About 45–60 min of feeding time is required until escape from the egg-shell. Larval hatching occurred within 2–3 hr after light-on (day 8). After hatching, the newly hatched larvae were pale yellowish except for the head capsule (Fig. 1a). These larvae darkened progressively in larval markings, at knobs and around the caudal legs at 2–3 hr after hatching (Fig. 1b). These results show that cuticular melanization is synchronized with the hatching time.

To confirm the hormonal control of larval melanization in this species, ligatures were applied between the head and the thorax segment at 2 different stages; 10±1 hr before hatching and within 5 min after hatching. When ligature was applied behind the head 10±1 hr before hatching, all larvae showed non-melanization (Fig. 2a). However,

¹ *Appl. Ent. Zool.* **25** (2): 323–325 (1990)