Comparison of Longevity and Flight
Ability in Wild and Laboratory-reared
Male Adults of the Diamondback Moth,
Plutella xylostella (L.)
(Lepidoptera: Yponomeutidae)¹

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Mark-recapture methods are effective for estimating population density and dispersal of many insects. The fundamental precondition underlying the use of any mark-recapture method is that the marking treatment should not influence the survival or behavior of the insect (SOUTHWOOD, 1978). Marked and released insects should also possess biological characteristics (e. g. flight ability, behavior and longevity) equal to those of unmarked (wild) conspecific insects. Some small lepidopterous insects with a wing length of less than 10 mm (e. g. the diamondback moth, *Plutella xylostella*, and the cabbage webworm, *Hellula undalis*) can be marked successfully with some fluorescent dyes (SHIRAI and MURATA, 1987; SHIRAI and KAWAMOTO, 1990).

Adult *P. xylostella* moths show large seasonal changes in forewing length, longevity and flight ability (YAMADA and UMEYA, 1972; SHIRAI, 1991). A mark-recapture study in early autumn inevitably depends on moths reared successively for some generations, because the population density of this moth decreases in the summer in most parts of Japan. Therefore, it is important to pre-evaluate some of the biological characteristics of wild moths and ones reared for mark-recapture experiments in the field.

In general, the flight ability of wild and reared insects is compared by using a flight mill or flight balance (HUETTEL, 1976; McKIBBEN et al., 1988). In the present study, the longevity and flight ability of wild and reared *P. xylostella* adults were evaluated, and the larval rearing conditions of

moths suitable for mark-recapture experiments in the field were determined for summer and autumn.

MATERIALS AND METHODS

Moths reared for successive generations. Four populations of *P. xylostella* with different rearing generations (1, 3, 10, and 200) were reared at 20°C and 16L-8D by the method of KOSHIHARA and YAMADA (1976). Approximately 30 hatched larvae were kept in a plastic dish (9-cm dia. 5-cm deep) containing fully-germinated radish seeds. The parent moths for three laboratory populations were collected from a cabbage field in Tsukuba in June 1990, and their progeny were reared over one, three and ten generations, respectively. The population reared for 200 generations was taken from a strain that had been reared successively at 23°C and 16L-8D since October 1981.

Wild moths in summer and autumn. For the summer and autumn wild populations, pupae were collected from a cabbage field in Tsukuba in early July 1991 and early November 1990, respectively. The adults were allowed to emerge in the laboratory.

Forewing length and longevity. To record the longevity of reared and wild male moths, 30 individual unmated moths were transferred to test tubes (2-cm dia. × 18-cm long, plugged with absorbent cotton), supplied with water and kept at 23°C and 16L-8D. Their forewing length was also measured.

Flight ability. The flight ability of unmated male moths (one day after emergence) was determined using a flight mill device for 48 h at 23°C in darkness (SHIRAI, 1991, 1993).

RESULTS AND DISCUSSION

Effects of rearing for successive generations on longevity and flight ability

The forewing length, longevity and flight ability parameters except flight velocity tended to decrease with increasing generations of successive rearing; there were significant differences for all these factors between the 1st and 10th generations (Table 1). However, the 200th generation showed the maximum flight velocity. From these results, it is estimated that the harmful influence of successive rearing occurs by the 3rd generation for longevity, and by the 10th generation for flight

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Table 1. Effects of rearing for successive generations on forewing length, longevity and flight ability in male adults of *Plutella xylostella*^{a, b}

Number of generations	n	Forewing length (mm)	Longevity (days)	Flight duration (min)	Flight velocity (m/min)	Flight distance (km)	Rate of long-term consecutive flight (%)
1	30	5.84±0.32 a	13.1±3.6 a	737.5±543.0 a	15.1±3.4 ab	10.7±7.8 a	40.0 a
3 ^d	30	5.88±0.27 a	9.4±3.7 b	685.6±358.6 ab	13.7±2.3 ab	9.3±4.9 a	43.3 a
10	30	5.49±0.26 b	9.5±2.4 b	419.2±222.6 c	13.5±1.9 b	5.6±3.0 b	13.3 b
200	30	5.53±0.30 b	6.5±2.1 c	455.5±242.4 bc	15.6±3.0 a	6.7±3.3 ab	26.7 ab

^a Mean±SD. Mean followed by different letters in the same column are significantly different at the 5% level.^b Statistical significance: DUNCAN's multiple range test for forewing length, KRUSKAL-WALLIS's test, DUNN's multiple comparison for longevity, flight duration, velocity and distance, and χ^2 -test for rate of long-term consecutive flight.^c All rearings were at 20°C and 16L-8D photoperiod.^d Data for 3rd generation: SHIRAI (1993)Table 2. Forewing length, longevity and flight ability of wild male adults of *P. xylostella* in summer and autumn^{a, b}

Season	n	Forewing length (mm)	Longevity (days)	Flight duration (min)	Flight velocity (m/min)	Flight distance (km)	Rate of long-term consecutive flight (%)
Summer	30	5.56±0.36 a	7.1±2.5 a	360.0±295.8 a	13.7±2.3	4.7±3.4 a	10.0
Autumn	30	6.26±0.34 b	11.7±2.8 b	700.2±505.6 b	14.9±2.8	9.9±6.8 b	26.7

^a Mean±SD. Means followed by different letters in the same column are significantly different at the 5% level.^b Statistical significance: *t*-test for forewing length, MANN-WHITNEY's *U*-test for longevity, flight duration, velocity and distance, and χ^2 -test for rate of long-term consecutive flight.

Table 3. Comparison of some parameters related to flight between laboratory-reared and field-collected male adults of *P. xylostella*

Rearing conditions ^a		Items tested ^b		
Number of generations	Temperature (°C)	Forewing length	Longevity	Flight duration
Comparison with summer wild adults				
1	20	○	×	×
3 ^c	15	×	×	×
	20	×	×	×
	25	○	○	○
	30	×	○	○
	20	○	×	○
Comparison with autumn wild adults				
1	20	×	○	○
3 ^c	15	○	○	○
	20	×	○	○
	25	×	×	○
	30	×	×	○
	20	×	○	×

^a All rearings were at a 16L–8D photoperiod.

^b Comparisons were made using the values in Tables 1 and 2. ○: not significantly different, ×: significantly different from wild male adults at the 5% level.

^c Data for 3rd generation: SHIRAI (1993).

ability. The significant reduction in flight ability observed in the 10th generation may be related to the smaller adult body size (wing length), because flight ability in terms of flight duration and distance is highly correlated with the forewing length of both wild and reared *P. xylostella* adult moths (SHIRAI, 1991, 1993).

The longevity of adults of the 200th generation was significantly shorter than that of the 10th generation, but their flight ability (flight duration and distance) was not significantly different (Table 1). These two populations should not be compared strictly, because the original population of the 200th generation was different from that of the 1st to 10th generations. However, the result suggests that individuals with high flight ability are rapidly selected out within approximately ten generations of laboratory rearing. Rapid selection of unfavorable flight characteristics may be fairly common in laboratory insect colonies, because similar results have also been observed in the Caribbean fruit fly, *Anastrepha suspensa* (SHARP, 1976), the melon fly, *Dacus cucurbitae* (NAKAMORI and SHIMIZU, 1983), and the boll weevil, *Anthonomus grandis* (McKIBBEN et al., 1988).

Rearing conditions of the moths for the field mark-recapture experiment

Table 2 shows the longevity and flight ability of wild male adults collected in summer and autumn. Summer wild moths had significantly lower longevity, flight duration and flight distance than autumn ones, but there were no significant differences in flight velocity and rate of long-term consecutive flight between moths from the two seasons.

Table 3 compares the forewing length, longevity and flight duration of *P. xylostella* reared under different conditions (number of generations successively reared and larval rearing temperature) with those of wild moths to determine the rearing conditions for moths favorable for mark-recapture field experiments. Flight ability is presented solely in terms of flight duration, because flight distance measured using a flight mill is strongly correlated with flight duration, and the flight velocity and rate of long-term consecutive flight shows no distinct seasonal changes in the field (SHIRAI, 1991).

Comparison of the three parameters (forewing length, longevity and flight duration) indicates that

adults of the 3rd generation reared at 25°C are best for mark-recapture experiments in summer, and those of the 3rd generation reared at 15°C are appropriate for autumn experiments (Table 3). However, when the longevity and flight ability are not markedly different between laboratory-reared and wild adults, reared adults could be used in mark-recapture experiments, without distorting the estimates of population density or dispersal.

For practical purposes, laboratory colonies reared from one to three generations, showing similar longevity and flight duration to wild adults can be used in mark-recapture experiments. Adults reared at about 25°–30°C are best for summer experiments, and those reared at about 15°–20°C are best for autumn experiments.

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Effect of Pollen-Substitute Feeding Site on Brood Rearing in Honeybee Colonies¹

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Honey and pollen are basic foods for honeybee colonies. Pollen is collected from a number of floral sources and is consumed to satisfy the dietary requirement for proteins, lipids, minerals and

vitamins. Since pollen is a limiting factor in colony development, beekeepers are concerned with providing an effective pollen substitute or supplement when natural pollen supplies are insufficient.

Pollen supplements contain honeybee-collected pollen (usually 5%–10%) mixed with other protein sources such as yeast, soybean flour, and/or other materials; pollen substitutes replace pollen totally with nutritionally-adequate materials (SHIMANUKI and HERBET, 1985).

When a moist patty of pollen substitute is placed inside a hive either on the top-bars or in the brood area, bees consume it, but never stored as bee bread. A part of ingested substitute is regurgitated and transferred to nestmates but majority is consumed by own and utilized for own nutrients and for royal jelly synthesis (ZAITOUN, 1990). The effect of the hive feeding site on diet consumption and production of royal jelly and queens

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