

# Effects of Age and Body Size on the Mating Success of Diamondback Moth

Hideo Uematsu

Faculty of Agriculture, Miyazaki University, Miyazaki 889-21, Japan

## Abstract

When female diamondback moth, *Plutella xylostella* (L.), were individually placed with a male in a glass tube, some (20-35%) laid only unfertilized eggs. To study this phenomenon, and in order to clarify the effect of age on mating, each of the 0-8-day-old females was placed with each of the 0-8-day-old males in a glass tube for 2 days. Successful copulation was determined by checking the embryonic development of the eggs the female laid. The number of females laying eggs increased from 65% in the 0-day-old age-group to 93.5% in the 8-day-old group. However, the number of females laying fertile eggs was unchanged at about 50%. The proportion of mating success was also independent of the age of the male. The effect of body size on mating success was also examined. Each of the females (3-8 mg) was placed with a male (size varied). When the difference in body weight between the paired insects was 2 mg or less, 79.8-88.1% of the females successfully mated. When the difference was 3 mg or more, the mating success was reduced to 63.5%. This suggests that large intersexual differences in body weight has some ill-effects on the mating behavior of the pair.

## Introduction

In the course of studies on the fecundity of diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), the author found that some females laid only unfertilized eggs. Yamada and Umeya (1972) also observed this phenomenon, and found that some females laid only unfertilized eggs even when two males were placed with the female in a container. Many workers (Sakanoshita and Yanagita 1972; Ohira 1979; Maa et al. 1985) have studied mating behavior of DBM, but the effects of age and body size on mating success are still unknown. This paper describes the results of laboratory experiments on this aspect of DBM mating.

## Materials and Methods

### Effects of Age on Mating Success

A large number of pupae were continuously collected from cabbage fields in Miyazaki, in the southern part of Japan, between January and March 1990. They were individually placed in a glass tube (15 × 150 mm) and reared at 20°C, 14L:10D until the day of testing. After emergence adults were provided with water. Each of the 0-, 2-, 4-, 6-, and 8-day-old females was paired with 0-, 2-, 4-, 6-, and 8-day-old males in a glass tube (30 × 200 mm). A piece of Japanese radish leaf was placed in the glass tube because DBM laid eggs on it more frequently than on other cruciferous plants such as cabbage or broccoli (Uematsu and Sakanoshita 1989). The glass tubes were placed in the chamber for a period of 2 days. Successful copulation was determined by checking the embryonic development of the eggs laid. Forty pairs were examined in each of the combinations.

## Effects of Body Size on Mating Success

DBM pupae were collected in a cabbage field in Miyazaki in May 1989. The progenies were reared on the Japanese radish leaves at 15-25°C to obtain insects of various sizes. Before pupae were individually placed in the glass tubes, they were weighed and separated into five size groups of 3.0-3.9, 4.0-4.9, 5.0-5.9, 6.0-6.9, and 7.0-7.9 mg. Pupal weight was used as an indicator of the adult size. Until the day of test, they were reared under the conditions above. Each of the females of five groups was paired with various-sized males for a period of 2 days. Although the ages of moths were not strictly arranged, they ranged from 0 to 5 days. I examined 855 pairs (Table 1). Successful copulation was determined by checking the embryonic development of the eggs laid.

Table 1. Size class of DBM and number of pairs tested in each of the combinations.

Size class of female (mg)	Size class of male (mg)				Total
	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	
3.0-3.9	20	36	16	5	77
4.0-4.9	78	79	80	11	248
5.0-5.9	64	80	80	21	245
6.0-6.9	15	80	79	32	206
7.0-7.9	6	35	21	17	79
Total	183	310	276	86	855

## Results and Discussion

### Effects of Age on Mating Success

The number of pairs that laid eggs varied from 22 to 40, averaging 32.5 (Table 2). This was not correlated to the age of the male, but was significantly correlated to that of the female ( $P < 0.01$ ). This indicates that older females lay eggs more easily than younger females when they are paired with males. Since virgin DBM females also lay eggs (Uematsu, unpublished data), the values in Table 2 do not mean the number of successful matings. Of course, in the cases where females laid no eggs, it was impossible to determine whether they had mated or not. Therefore, the data on female egg-laying were used to analyze the effect of age on mating. The proportion of females laying fertile eggs to females laying eggs irrespective of their fertility is given in Table 3. The proportion was independent of the age of the male, but dependent on that of the female ( $P < 0.05$ ). The youngest age-group of females shows the highest value of mean, 0.800, though the other age-groups show no difference in the mean values. Two combinations, 2-day-old-female:6-day-old-male and 6-day-old-female:0-day-old-male, gave very small values. The reason for this is unknown. However, these values were not responsible for the significance, because reanalysis of the data excluding these combinations also showed highly significant differences ( $P < 0.001$ ). Therefore, it is concluded that the eggs laid by younger females have a higher possibility of being fertile than those laid by older ones. However, it does not always follow that the younger females are more easily fertilized than the older ones, because the number of females laying fertile eggs was independent of the age of the females ( $P > 0.05$ ). Therefore, it can be concluded that every individual within 8 days after emergence has an equal ability to mate. The differences shown in Table 3 probably are caused by the abnormal egg deposition of older virgin females, since it is probable that their urge to lay eggs increases with age in spite of their virginity.

Harcourt (1957) found that mating began at dusk on the day of emergence. Sakanoshita and Yanagita (1972) also found that female DBM copulated at night on the day of emergence. Sarthoy et al. (1989) reported that the preovipositional period was short and less than 1 day

Table 2. Number of DBM females that laid eggs irrespective of their fertility. Forty pairs were tested in each of the combinations.

Female age (days)	Male age (days)					Total	%
	0	2	4	6	8		
0	24	29	28	22	27	130	65.0
2	31	29	35	24	30	149	74.5
4	39	37	29	36	29	170	85.0
6	32	35	40	35	35	177	88.5
8	37	38	37	38	37	187	93.5
Total	163	168	169	155	158	813	
%	81.5	84.0	84.5	77.5	79.0	81.3	

Table 3. Proportion of DBM females that laid fertile eggs.

Female age (days)	Male age (days)					Mean
	0	2	4	6	8	
0	.667	.862	.893	.727	.852	.800
2	.677	.690	.657	.292	.667	.597
4	.462	.852	.655	.556	.724	.650
6	.250	.514	.600	.743	.571	.536
8	.459	.710	.649	.553	.459	.566
Mean	.503	.726	.691	.574	.655	.630

when they were reared at 23.3°C. These studies clearly indicate that a female DBM mates at an early adult stage. The early mating and oviposition appear to contribute to their high reproductive rate. Both sexes maintain the physiological conditions possible to mate for a long period even if they fail in early mating.

Ohira (1979) studied the relationship between mating ability and degree of the development of ovarian eggs, and estimated the proportions of the individuals having mating ability. According to his estimation, 54% of 1-day-old, 40% of 2-day-old, 68% of 3-day-old and 98% of 4-day-old individuals mated. These figures show that the mating abilities of virgin females change with age, and differ from the results of this study. This disagreement probably stems from the simple assumption on mating ability which is determined by a single factor: degree of development of ovarian eggs.

### Effect of Body Size on Mating Success

Of the 855 pairs tested, 100 pairs laid no eggs. Those pairs that failed to lay eggs were more frequently small females, i.e. 27.3% in the case of the smallest females, 5.1% in the case of the largest females, and about 10% in the case of females of intermediate size. This suggests that large females easily lay eggs.

The proportions of females laying fertile eggs to total number of females laying eggs irrespective of their fertility is shown in Table 4. Although they varied from 0.50 to 1.00, they were independent of the size of both sexes ( $P > 0.05$ ). This suggests that the females have an equal chance to mate regardless of their body size.

The relationship between the degree of the size difference of paired insects and their mating success is shown in Table 5. When the difference was 2 mg or less, most of the females succeeded in mating and laid fertile eggs. When the difference was 3 mg or more, the probability of mating success was reduced to 63.5%. This suggests that large intersexual differences in body size has some ill effects on mating behavior of the pair. However, this factor seems unable to work

Table 4. Proportion of DBM females that laid fertile eggs.

Size class female (mg)	Size class male (mg)				Mean
	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	
3.0-3.9	.895	.808	(1.00) <sup>a</sup>	(.667)	.843
4.0-4.9	.817	.877	.788	(1.00)	.874
5.0-5.9	.845	.750	.847	.706	.787
6.0-6.9	(.500)	.800	.843	.966	.777
7.0-7.9	(.667)	.677	.857	(.824)	.756
Mean	.747	.782	.867	.833	.807

<sup>a</sup>Values in parentheses indicate data from small samples less than 20.

Table 5. Effects of size difference between both sexes in DBM on mating success.

Difference between female and male (mg)	No. of pairs tested	No. of pairs laying eggs		A/(A+B) × 100
		Fertile (A)	Unfertile (B)	
0	211	170	23	88.1 (83.4-92.7) <sup>a</sup>
1	391	273	69	79.8 (75.4-84.2)
2	192	142	26	84.5 (79.2-89.9)
3 or more	61	33	19	63.5 (50.0-76.9)

<sup>a</sup>Ranges for 95% confidence limit.

in natural populations, as the mean difference in weight between both sexes was less than 2 mg throughout the year (Uematsu et al., unpublished data).

In the present study, proportions of the females laying fertile eggs were considerably lower in contrast to those of previous studies (Uematsu, unpublished data). The reason for this seems to be in the methods used. If most of the females began to lay eggs the night after the day of mating (Sakanoshita and Yanagita 1972), females in the present study would not have had enough time for mating and oviposition. Because a period of 2 days was fixed for the experiment, if the females copulated during the night of the second day, they would not have had a chance to lay fertile eggs. They might then be recorded as ones not laying eggs, or ones laying unfertilized eggs if oviposition occurred at the first night. This is probably the reason for a small number of females laying fertile eggs in the present study.

Unfortunately, the reason why some females failed to lay fertile eggs was not determined in this study. Maa et al. (1985) reported that humidity is an important factor in inducing male response to the synthetic sex pheromone. Other physical factors, such as size of container, may also influence the process. Investigation of these factors needs to be done.

## References

- Harcourt, D. G. 1957. Biology of the diamondback moth, *Plutella maculipennis* (Curt.) (Lepidoptera: Plutellidae), in eastern Ontario. II. Life-history, behavior, and host relationships. *Can. Entomol.*, 89, 554-564.
- Maa, W. C. J., Lin, Y. M., and Ying, Y. J. 1985. Temperature and humidity effect on sex behavior of the male adults elicited by the synthetic sex pheromone of the diamondback moth, *Plutella xylostella* (L.). *Bull. Inst. Zool. Academia Sinica*, 24, 75-84.
- Ohira, Y. 1979. Mating behavior and egg maturation of the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae). *Proc. Assoc. Plant. Prot. Kyushu*, 25, 104-106. (In Japanese with English summary).

- Sakanoshita, A., and Yanagita, Y. 1972. Fundamental studies on the reproduction of diamondback moth, *Plutella maculipennis* Curtis (I). Effects of environmental factors on emergence, copulation, and oviposition. Proc. Assoc. Plant Prot. Kyushu, 18, 11-12. (In Japanese with English summary).
- Sarnthoy, O, Keinmeesuke, P., Sinchaisri, N., and Nakasuji, F. 1989. Development and reproductive rate of the diamondback moth *Plutella xylostella* from Thailand. Appl. Entomol. Zool., 24,202-208.
- Uematsu, H., and Sakanoshita, A. 1989. Possible role of cabbage leaf wax bloom in suppressing diamondback moth *Plutella xylostella* (Lepidoptera: Yponomeutidae) oviposition. Appl. Entomol. Zool., 24,253-257.
- Yamada, H., and Umeya, K. 1972. Seasonal changes in wing length and fecundity of the diamondback moth, *Plutella xylostella* (L.). Jpn. J. Appl. Entomol. Zool., 16,180-186. (In Japanese with English summary).