Quality Problems in the Mass-Rearing for the Melon Fly, *Dacus cucurbitae* Coquillett

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The mass-rearing of insects is necessary for the integrated pest management using augmentation of parasites or predaters and release of sterile or genetically altered insects. In the earlier time, the primary problem in the mass-rearing was how to enhance the productivity of the rearing under low cost conditions[6]. For this purpose, individuals having high fecundity were selected from the wild population in the course of colonization in laboratory and mass-rearing. However, this selection may also alter other characteristics of the insects. Boller[2] pointed out the importance of behavioral aspects of mass-rearing of insects. Insects mass-reared should perform their typical behavior after released in the field. Some signs of deterioration in this typical behavior have been detected from the mass-reared insects. From the above point of view, quality problems have been concerned in the mass-rearing of insects[3].

In the sterile insect technique (SIT), the quality of sterile insects should be evaluated ultimately as sexual competitiveness under the field conditions[5]. Huettel[4] defined two types of quality, those are, 'overall quality' and 'quality of specific traits'. The sexual competitiveness of sterile insects in the field conditions seems to correspond to 'overall quality'. When we consider the quality monitoring, 'quality of specific traits' should be measured. If quality of each specific trait for sterile insects released resemble that for the wild insects, we can expect the flies released have high 'overall quality', then they perform well their role in the field. If we find deterioration in a specific trait, the cause of such deterioration should be investigated and the method for mass-rearing should be improved.

In the SIT program of the melon fly, *Dacus cucurbitae* Coquillett, on Kume Island, Okinawa, Japan, the wild melon flies were collected and colonized in 1972. The flies had been reared in the laboratory with an artificial conditions for 13 generations, and then mass-reared in the mass rearing facility in Yaeyama Branch of Okinawa Prefectural Agricultural Experiment Station, Ishigaki, Okinawa, Japan, for about 44 generations till November, 1979 (old strain). The rearing conditions were described by Nakamori and Kakinohana[7]. From 1978 to 1979, a new strain was colonized in the mass-rearing facility, and was replaced for the old strain[10]. From the stand point of quality problems, experiments were conducted for comparing several traits among mass-reared strains (old and new) and wild ones. In this report, the results of these experiments will be reviewed. In the following sections, 'wild strain' is adult flies collected from field in Okinawa or Ishigaki Islands as larvae and reared in the laboratory conditions for 0–3 generations with pumpkin fruit, a natural diet, for larvae, and sugar, protein hydrolysate and water for adult diets. The number of generations reared under mass-rearing conditions for mass-reared strains will be shown in each experiment.

Reproduction characteristics

The high productivity of the flies in the mass-rearing is indispensable for enhancing rearing efficiency. Figs. 1–3 show the results of experiment comparing survivorship, copulation and oviposition curves among the wild

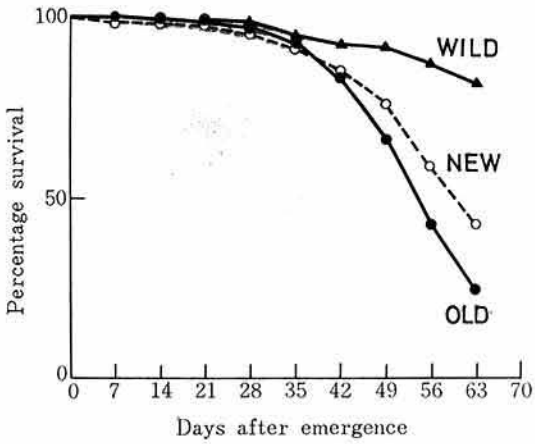

Fig. 1. Survivorship curves of adults of old, new and wild strains[10].
Old and new strains were reared for about 61 and 13 generations, respectively, after colonization. Wild strain was reared for 1 generation with pumpkin fruits after collection from infested fruits in Ishigaki Is..

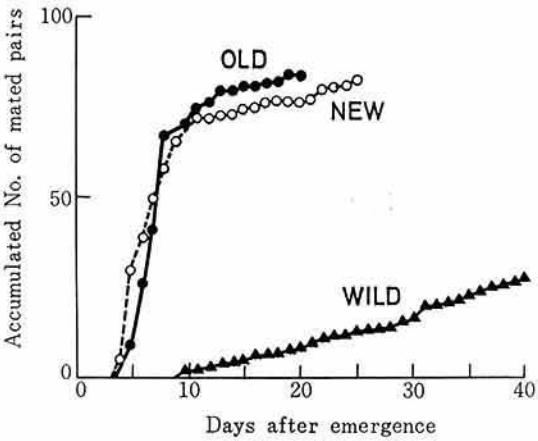

Fig. 2. Accumulated copulation curves of old, new and wild strains[10].
One hundred pairs were used for the experiment in each time. Old and new strains were reared for about 60 and 12 generations, respectively, after colonization. Wild strains was obtained as larvae from infested fruits in Ishigaki Is..

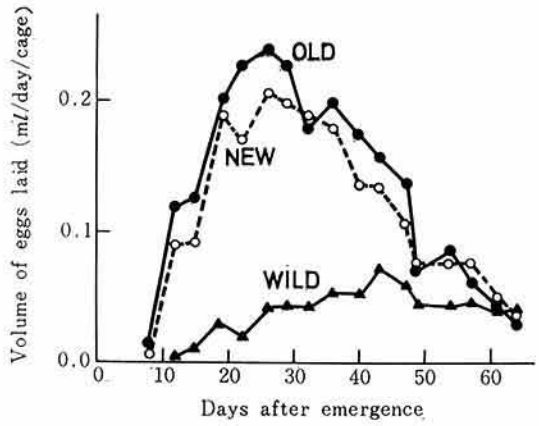

Fig. 3. Oviposition curves of old, new and wild strains[10].
Each strains were the same as in Fig. 1.

and mass-reared strains (old and new) of the melon fly[10]. The longevity, pre-copulation period of the mass-reared strains (old and new) are shorter than those of the wild strain. The pre-oviposition period of the mass-reared strains is also shorter and the number of eggs laid is larger than those of the wild strain. There are no substantial differences in the reproductive characteristics between old and new mass-reared strains.

Flight and dispersion ability

Flight ability of flies is one of essential traits in the field. The sterile flies released should fly well to look for suitable habitat, natural food and wild counterparts for mating, as soon as possible. To examine the flight ability of the flies, a flight mill was designed by Nakamori (unpublished). Fig. 4 shows the brief sketch of the flight mill. An adult fly fixed on an end of a rod horizontally held with an iron needle turns round the rod by its flight. The duration and speed of rotation of the rod recorded photo-electrically reflect the flight ability of the fly. Fig. 5 shows the frequency distribution of duration of continual flight for the wild and mass-reared

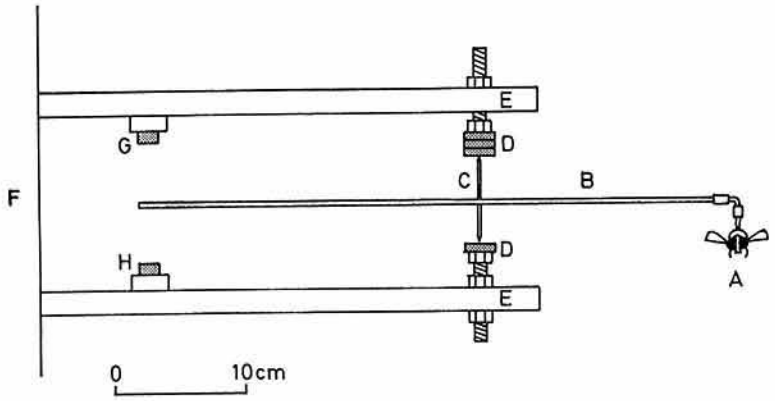

Fig. 4. The brief sketch of a flight mill designed by Nakamori (unpublished)
A: adult fly attached for testing its flight ability, B: rotary rod, C: iron needle, D: magnets, E: supporting bars, G and H: emiter and detecter for ultrared light, respectively, by which number of rotation of the rod is counted, F: wall

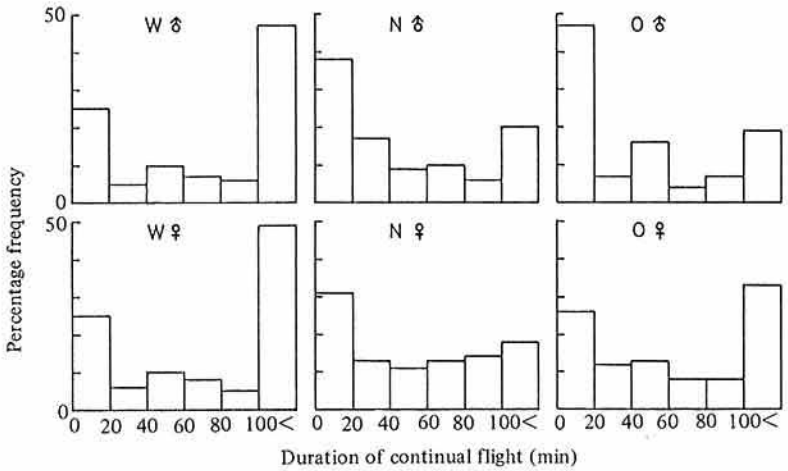

Fig. 5. Frequency distribution of the duration of continual flight for wild (W), new (N) and old (O) strains
Wild strain was reared for 3 generations with pumpkin fruit after collection from infested fruits in Ishigaki Is. New and old strains were reared for about 15 and 51 generations after colonization (Nakamori's unpublished data).

strains (old and new). The frequency of flies flying more than 100 min for the mass-reared strains is less than that for the wild strain, that is, the mass-reared ones have less flight ability than wild one. Judging from the frequency distribution pattern, little difference in the flight ability between old and new strains is found.

The dispersion ability of the flies in the field conditions was compared by a mark and recapture method[8]. In this experiment, about 1000 male flies of the wild and mass-reared

Table 1. Percentage of recaptured flies and mean distance of dispersal from the release point for the wild and mass-reard flies[a]

Experiment	Strain	No. of generations after colonization	Percentage recapture[b]	Mean distance of dispersal (m)[c]
I	Wild	3	15.17	171.8
	Mass-reared	28.5 ± 1.1	9.16	149.0
II	Wild	3	2.38	90.1
	Mass-reared	31.2 ± 1.2	1.02	57.9
III	Wild	3	13.33	70.46
	Mass-reared	38.7 ± 1.4	5.06	51.05

a Modified table from that in Nakamori and Soemori[8]

b Percentage of flies recaptured in all traps after 20 days (in experiment II) or 21 days (in experiments I and III) from the time of release out of the number of flies released.

c Mean distance of dispersal $\bar{X}$ is calculated by following formula:

$$\bar{X} = \frac{\sum_{j=1}^{n} X_j \cdot N_j}{\sum_{j=1}^{n} N_i}$$

where n is the number of traps, X_j is the distance between the release point and trap j, and N_j is the total number of flies recaptured in trap j in 20 days (in experiment II) or in 21 days (in experiment I and III).

strains (old) with different marking were released at a point in the field then recaptured by Steiner type traps[11] baited with cue-lure, an attractant for the male melon fly, and naled placed at varous distances from the release point. Table 1 shows the percentage recapture and mean distance of dispersion of flies during 20–21 days from the time of release. In each of three experiments, the values of the percentage recapture and mean distance of dispersion show that the mass-reared strain was inferior in dispersion ability to the wild strain.

Diurnal rhythm of mating behavior

The melon fly mates only at dusk[1]. It is desirable that the time of mating is synchronous between the wild and the mass-reared strain for the success of SIT. Suzuki and Koyama[12] compared the diurnal activity of mating behavior between wild and mass-reared strain (old) (Fig. 6). Each 10 pairs of both strains were confined in respective cages under the natural light conditions, and stridulation, a typical pre-copulation behavior, of males and copulation were observed every 5 min. The stridulation of male flies begins earlier (namely under higher light intensity) in the mass-reared strain than in the wild one. Copulation also starts earlier in the mass-reared strain. Fifty percent of the mass-reared strain flies copulate before the start of copulation of the wild strain.

Mating competitiveness

In SIT program, sterile males released should have high mating competitiveness against the wild males under field conditions. Soemori et al.[9] examined mating competitiveness for the mass-reared strain (old) (L) against wild one (W) under laboratory conditions. As shown in Table 2, four combinations of three different kinds of flies were confined in each cage (30×30×45 cm) and pairs mated were scored. In the all combinations, L♂×L♀ matings are most frequent (67–73%), L♂×W♀ or W♂×L♀ matings are not so frequent (7–33%) and no W♂×W♀ mating is observed. These results of

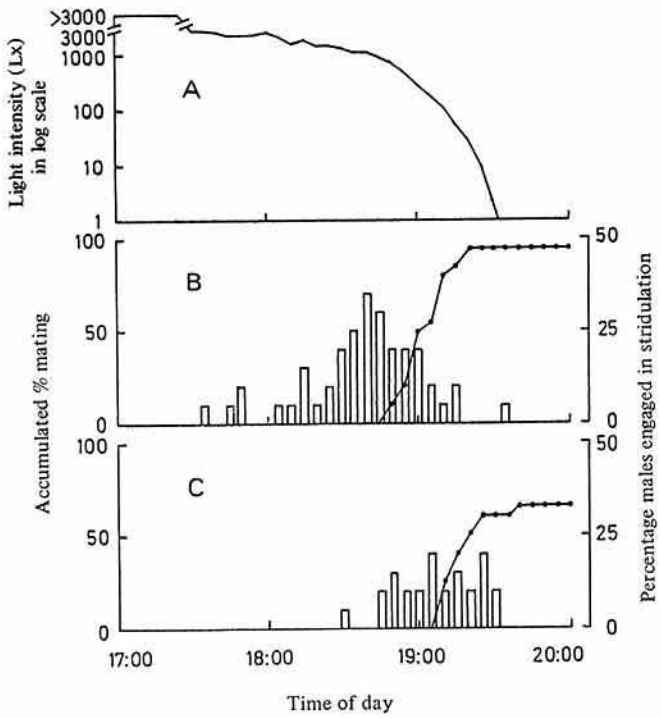

Fig. 6. Accumulated percentage mating and percentage males engaged in stridulation (histogram) at different times between 17:00 and 20:00 hr in L-strain (B) and W-strain (C) batches, each containing 10 males and 10 females. Averages of the two replications are presented.
Changes in light intensity (A) are also shown[12]. W-strain was obtained as larvae from infested bitter cucumber, *Momordica charantia* var. *pevel* Cranz, collected at Okinawa Is.. L-strain was reared for 49 generations from colonization.

experiment indicate apparently the high mating competitiveness of the mass-reared strain against the wild one in the cage. Soemori et al.[9] conducted another type of experiment. In this experiment, (1) 1L♀+1L♂+1W♂, (2) 10L♀+10L♂+10W♂, (3) 100L♀+100L♂+100W♂, were confined in three types of cages in different volume (1.4 *l*, 40.5 *l* and 5832 *l*). Namely, mating competition took place in different space conditions. Fig. 7 shows the results of the experiments. When the space provided for each flies is small, the competitiveness for the mass-reared males is higher than for the wild males. However, as the space per fly increases, the differences in competitiveness between both strains become smaller. Whether the competitiveness of the mass-reared males becomes inferior to the wild males under the wider space conditions is unknown, but this result of experiment suggests that the mating competitiveness of the mass-reared strain is not always higher than the wild one under the field conditions.

Table 2. Mating competitiveness of mass-reared and wild strains when 3 different kinds of flies were confined in a cage (30×30×45 cm)[9]

Experiment	Combination of flies[a]	No. of replication	Kind of pairs	No. of pairs	% of pairs
I	W♀ × W♂ / L♂	15	W♂×W♀	0	0
			L♂×W♀	3	20
			unmated[b]	12	80
II	L♀ × W♂ / L♂	15	W♂×L♀	1	7
			L♂×L♀	11	73
			unmated	3	20
III	W♂ × W♀ / L♀	15	W♀×W♂	0	0
			L♀×W♂	5	33
			unmated	10	67
IV	L♂ × W♀ / L♀	15	W♀×L♂	2	13
			L♀×L♂	10	67
			unmated	3	20

a W: Reared for one generation with pumpkin fruit after collection from infested fruit in Miyako Is.. L: Reared for about 46 generations after colonization.
b "Unmated pairs" refers to the number of cases where no mating took place.

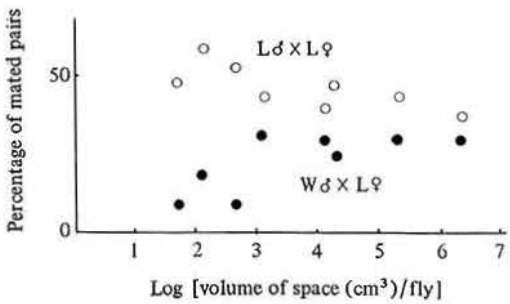

Fig. 7. Relation between volume of space per fly and mating competitiveness in mass-reared (L) and wild (W) strains[9]. Mass-reared strain was reared for 51–54 generations after colonization. Wild strain was collected as adult by a cue-lure trap in Ishigaki Is..

Discussion

In the mass-rearing of the melon fly conducted in the SIT program of Okinawa Prefecture, Japan, high productivity of the flies had been achieved by selecting offsprings from eggs oviposited in earlier age of females during course of rearing[7] (Figs. 1–3). For the new strain, this high productivity was attained during the course of selection for about 7 generations from the colonization of the wild flies[10]. Since the reproductive characteristics and the flight ability are substantially same between old and new strains (Figs. 1–3 and 5), the character of the mass-reared strain seems to be fixed during early generations in the mass-rearing conditions.

As compared with the wild strain, the mass-reared strains are inferior in the flight and dispersion ability (Fig. 5, Table 1). This inferiority of the mass-reared strain will be overcome by some manner of artificial distribution of the sterile flies in the field. However, the difference in the diurnal activity of mating between the wild and mass-reared strains (Fig. 6) seems to be inhibitive to the successful mating between the wild females and sterile males released. The experiment for the mating competitiveness for the mass-reared flies against the wild strain in different space conditions (Table 2, Fig. 7) suggests that flies of the mass-reared strain seem to be adapted to narrower space condition in the mating behavior. Whether or not the mass-reared flies perform fully normal mating behavior under the field conditions should be investigated in future.

Unlikely in the natural conditions, the

mass-reared flies are confined in narrower space in high density, fed some artificial diets, and provided artificial egging device under constant temperature conditions. Only diurnal rhythms of light condition are maintained same as natural light condition[7]. What kind of elements of these artificial rearing conditions are responsible for the above-mentioned qualitative change of the mass-reared flies is still unknown. But, if the causes of the change are clarified in future, it will be possible to improve the quality of the mass-reared flies by altering some elements of the mass-rearing procedure.

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