Factors Controlling Oviposition Activities of Two Pierid Butterflies, *Pieris rapae crucivora* and *P. napi nesis*, Living Sympatrically at Open Habitats

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Synopsis: Relations between the number of eggs laid per day per female and the age of ovipositing females, and several climatic factors, were studied on two pierid butterflies living sympatrically at open habitats. In *Pieris rapae crucivora* the age of ovipositing females seems to decide the number of eggs laid per day per female, while in *P. napi nesis* climatic factors do.

Two pierid butterflies, *Pieris rapae crucivora* BOISDUVAL and *P. napi nesis* FRUHSTORFER, both living sympatrically at open habitats in northern Japan, show species-specific daily rhythms of oviposition activities. The former has a peak of oviposition activities in the morning, the latter in early afternoon (YAMAMOTO, 1985). Furthermore, the vigorousness of oviposition activities may change day by day, being affected by some of climatic or non-climatic factors. The present paper deals with climatic (air temperature, sunshine intensity, and a few supplementary meteorological factors) and non-climatic factors (the age of ovipositing females) controlling oviposition activities of the same butterflies.

Materials and Methods

Females were captured and marked individually soon after emergence. Their oviposition activities were successively traced every day from the start of their activities in the morning to their ceasing in the evening on the campus of Hokkaido University from mid May to mid June (the post-hibernating generation = G_h), in July (the 1st generation = G_1), and in August (the 2nd generation = G_2) for *P. rapae*, and from mid June to late June (G_1) for *P. napi*, 1976. The number of eggs laid per day per female, the duration of oviposition per day (min), and the frequency of oviposition per minute (= oviposition speed) were recorded daily during the observations (N = 22 in *P. rapae,* N = 8 in *P. napi*). The maximum air temperature (°C), the duration of sunshine (hr), the maximum hourly solar radiation (cal/cm^2/h), wind velocity (m/sec), and the minimum relative humidity (%) on the day in which oviposition activities were observed were cited from the records taken at Sapporo Regional Meteorological Observatory, about 2 km south-west of the area surveyed.

Results

The number of eggs laid per day per female can be regarded as an index of the vigorousness of oviposition activities, being probably affected both by maintenance of a favorable body temperature (climatic factor) and the number of mature ovarian eggs (non-climatic factor). Effects both of air

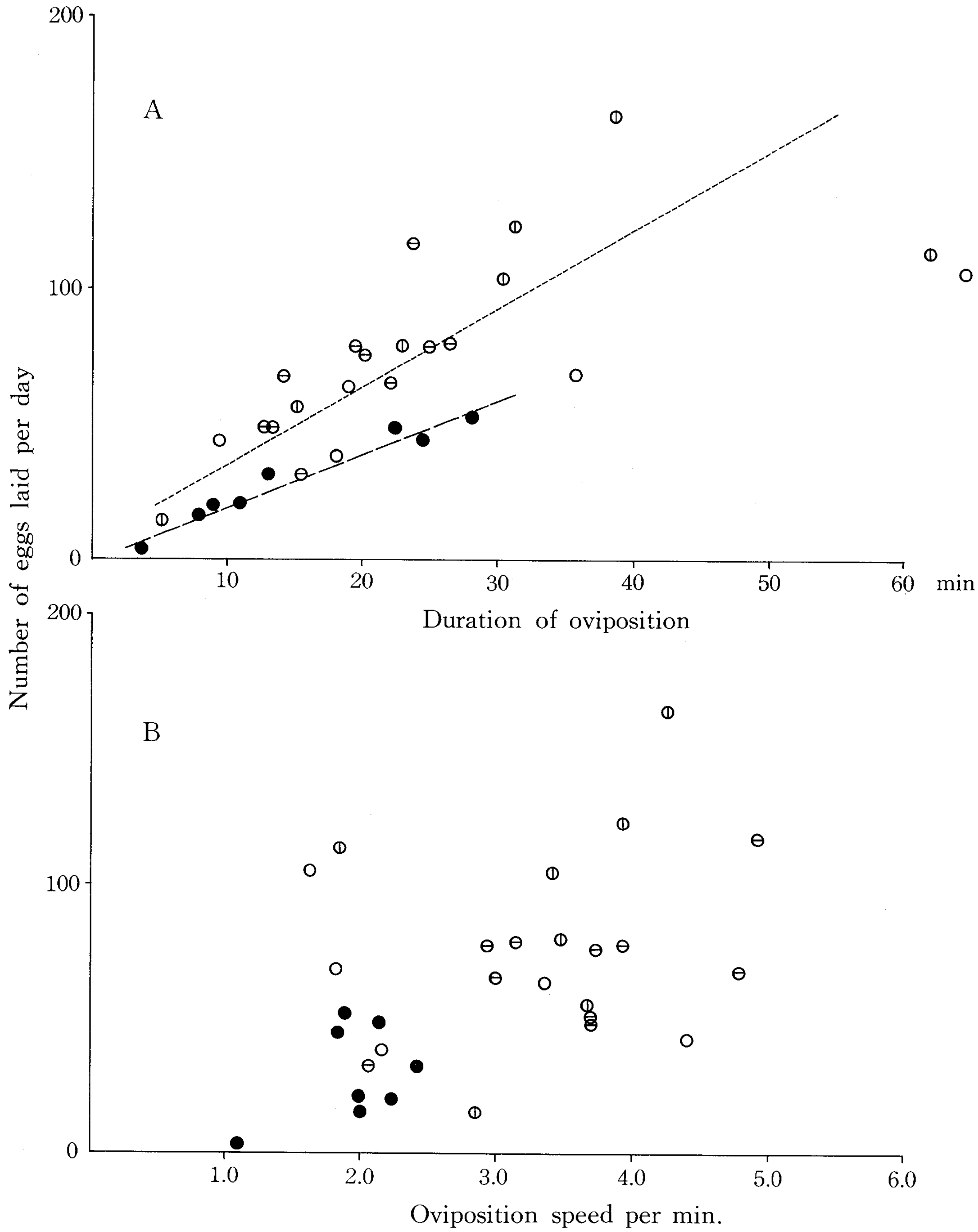

Figure 1 Relation between the number of eggs laid per day per female and duration of oviposition (A), and the oviposition speed (B). *P. rapae* : ○= post-hibernating generation (G_h), ⦶= 1st generation (G_1), ⊖= 2nd generation (G_2). *P. napi*: ●.

temperature and sunshine intensity (sunshine duration and solar radiation) probably result in maintenance of a favorable body temperature of butterflies (OHSAKI, 1983; SUZUKI et al., 1985). The number of mature ovarian eggs is probably related to the age of ovipositing females (cf. YAMAMOTO & OHTANI, 1979).

The multiple regression equations between the number of eggs laid per day per female and climatic factors were calculated by using the stepwise regression method, $F_{in} = F_{out} = 2.0$ (OKUNO et al., 1971),

$$N = 34.2 + 0.69R \text{ in } P.\ rapae\ (R^2 = 0.118)$$

$$N = -74.1 + 4.05T + 2.62S \text{ in } P.\ napi\ (R^2 = 0.821)$$

where N = the number of eggs laid per day per female, R = solar radiation, T = the maximum air temperature, S = the duration of sunshine. A low value of R^2 (= coefficient of determination) in *P. rapae* indicates unsuccessful predictability of the equation.

The number of eggs laid per day per female consists of two factors multiplied: (The duration of oviposition) × (The oviposition speed = the observed frequency of oviposition per minute). With different manners these two factors affect the number of eggs laid per day per female as reported separately in the following sections.

1. *Relations between the number of eggs laid per day per female and the oviposition duration, and the oviposition speed*

Figure 1 shows relation of distribution patterns between the number of eggs laid per day per female and duration of oviposition, and the oviposition speed.

In Fig. 1A the number of eggs laid per day is plotted to the duration of oviposition (min), showing a linear increase with the duration of oviposition in both species ($p < 0.01$, Table 1). Except for a few cases observed, *P. rapae* showed a higher increase rate than *P. napi* did.

The number of eggs laid per day is plotted to the oviposition speed in Fig. 1B. In *P. rapae* it may roughly form a V-shaped curve with a trough at the speed of 2.6 ~ 2.8; the number of eggs laid per day decreased in the range of 1.6 ~ 2.8 of the oviposition speed, but it increased with the oviposi-

Table 1. Correlation coefficients among eight expectant factors relating to oviposition activities.
N = the number of eggs laid per day per female, D = the duration of oviposition, O = the oviposition speed, T = the maximum air temperature, S = the duration of sunshine, R = solar radiation, W = wind velocity, H = relative humidity.

	N	D	O	T	S	R	W	H	
N		0.693**	0.194	0.134	0.291	0.344	−0.006	−0.017	
D	0.980**		−0.488*	0.165	0.411	0.409	0.193	−0.291	
O	0.414	0.257		−0.038	−0.337	−0.254	−0.084	0.401	
T	0.854**	0.817*	0.217		−0.133	−0.089	−0.210	0.147	*P. rapae*
S	0.805*	0.730*	0.462	0.684		0.725**	−0.005	−0.593**	
R	0.720*	0.684	0.377	0.549	0.716*		0.186	−0.521*	
W	0.699	0.684	−0.020	0.815*	0.751*	0.615		−0.243	
H	−0.433	−0.418	−0.190	−0.214	−0.703	−0.640	−0.311		
			P. napi						

* $0.05 > p > 0.01$ with significant level.
** $p < 0.01$ with singnificant level.

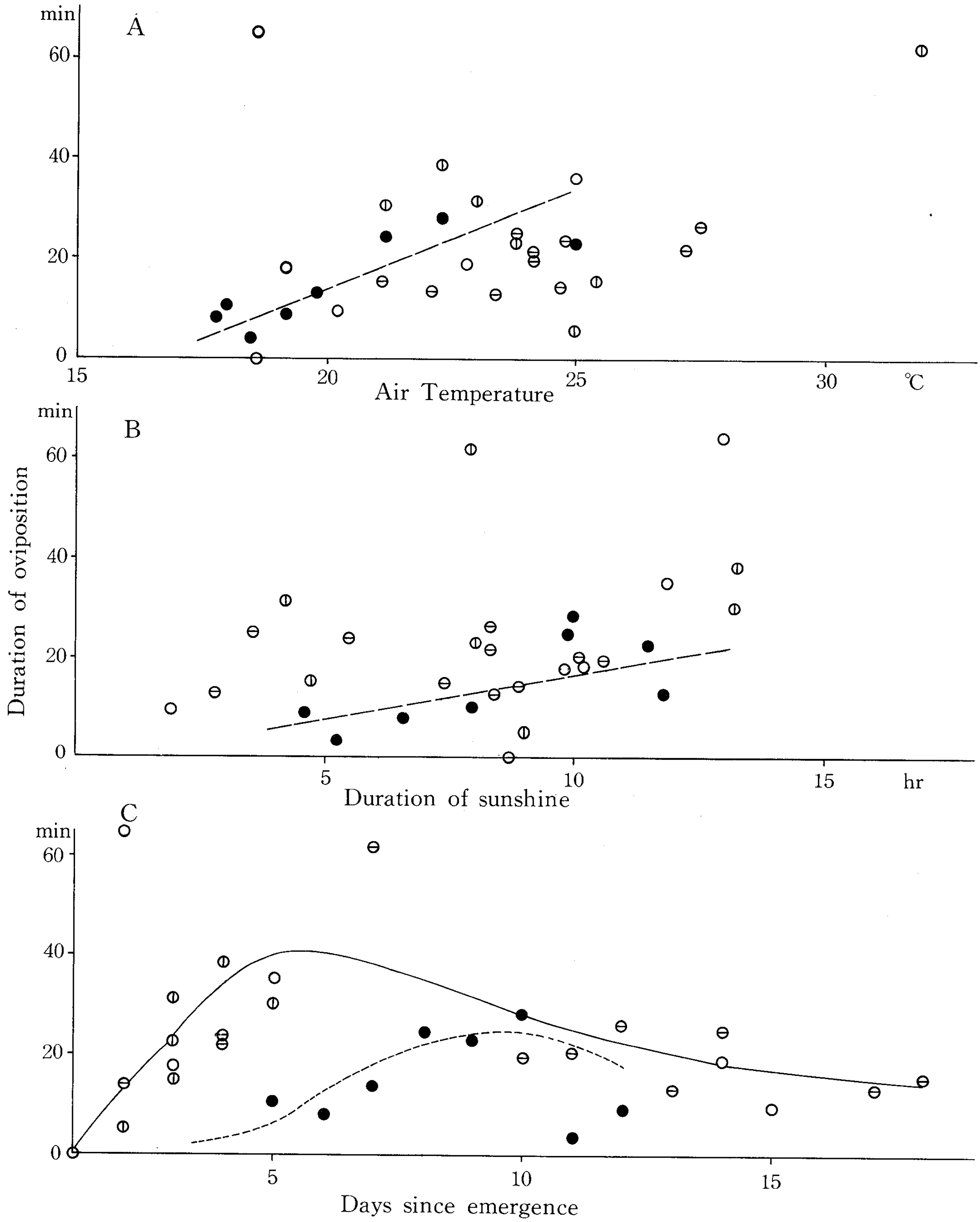

Figure 2 Relation between the duration of oviposition (min) and the maximum air temperature (A), the duration of sunshine (B), and the age of ovipositing females (C). *P. rapae* : ○= Gh, ⦶= G1, ⊖= G2. *P. napi*: ●.

tion speed over 2.8. On the other hand, in *P. napi* the number of eggs laid per day was unrelated to the oviposition speed.

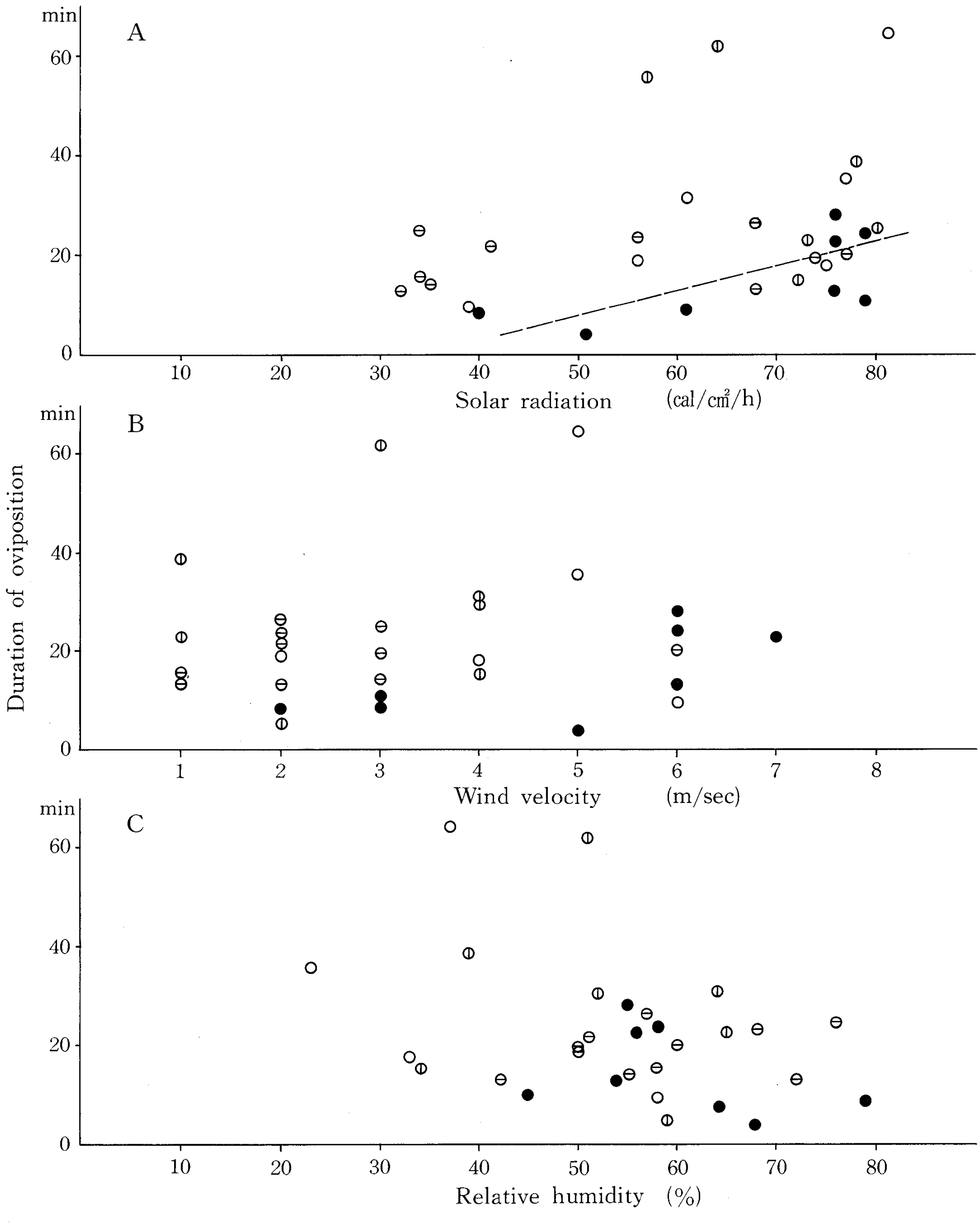

Figure 3 Relation between the duration of oviposition (min) and solar radiation (A), wind velocity (B), and relative humidity (C). *P. rapae* : ○= G_h, ⦶= G_1, ⊖= G_2. *P. napi*: ●.

2. *Effects of climatic and non-climatic factors on the duration of oviposition*

Figures 2 ~ 3 show relation of distribution patterns between the duration of oviposition and climatic factors (air temperature, the duration of sunshine, solar radiation, wind velocity, relative humid-

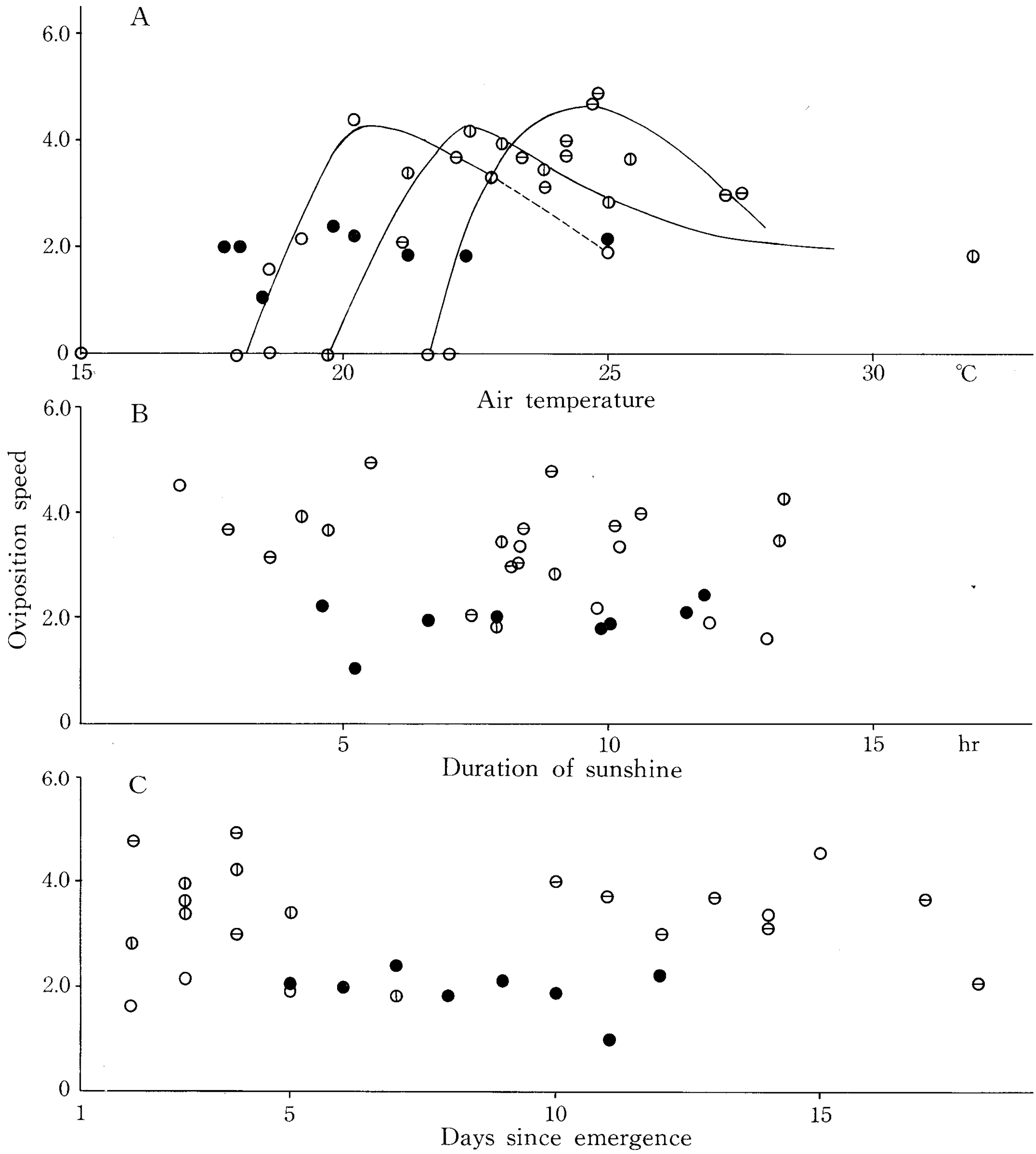

Figure 4 Relation between the oviposition speed and the maximum air temperature (A), the duration of sunshine (B), and the age of ovipositing females (C). *P. rapae* : ○= Gh, ⦶= G1, ⊖= G2. *P. napi*: ●.

ity), and non-climatic factor (the age of ovipositing females). Correlation coefficients between the duration of oviposition and climatic factors, each showing an approximation to normal distribution on the probability paper, are shown in Table 1 for each species.

In *P. rapae* the duration of oviposition was not related to any climatic factors (Figs. 2A, 2B, 3A ~ C) ($p > 0.05$), but to the age of ovipositing females (Fig. 2C): The duration increased gradually till the peak shown several days after emergence, then decreased with an increasing age of females (Fig. 2C). This distribution pattern was similar to their oviposition curve (cf. YAMAMOTO & OHTANI, 1979).

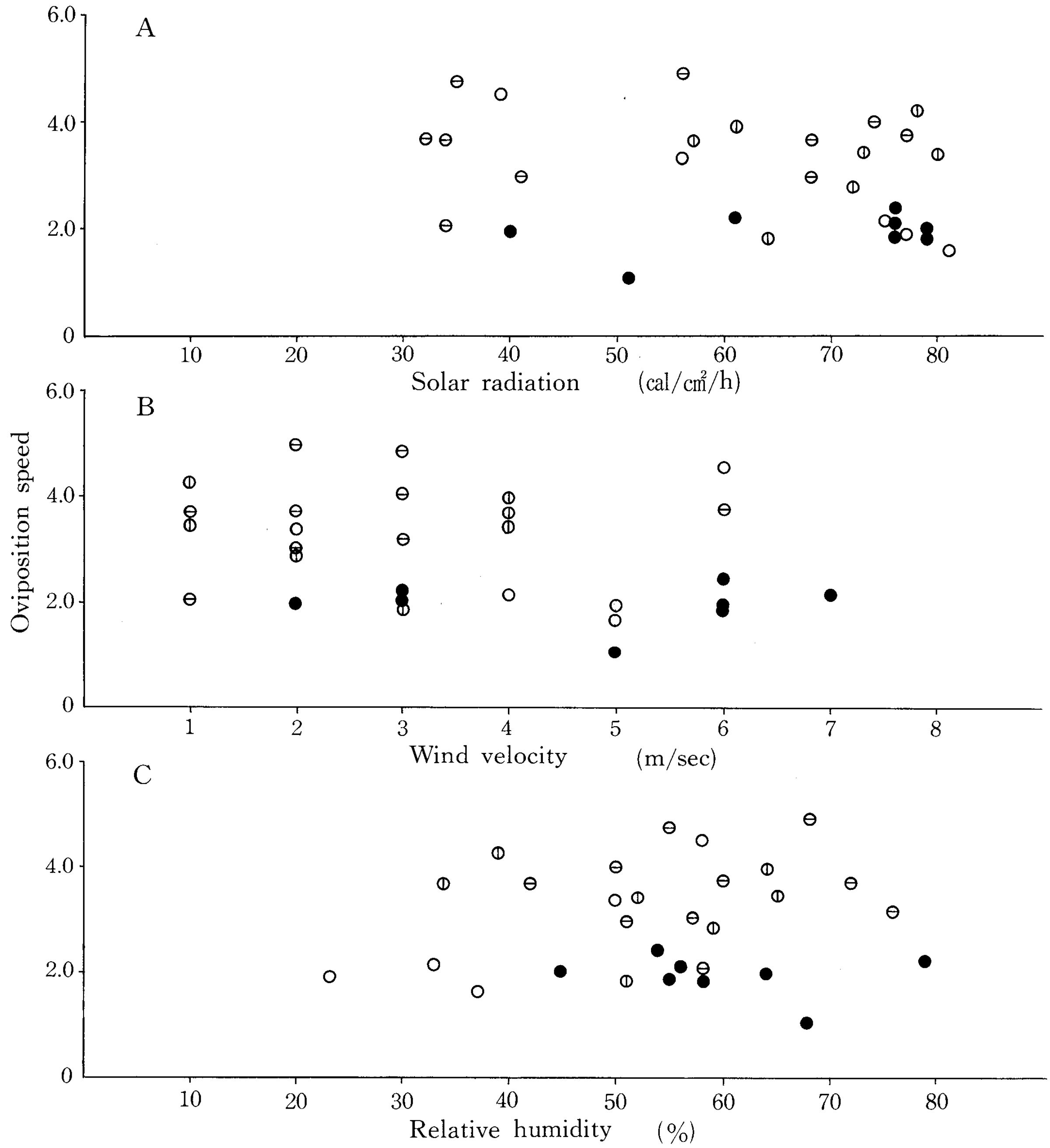

Figure 5 Relation between the oviposition speed and solar radiation (A), wind velocity (B), and relative humidity (C). *P. rapae* : ○= G_h, ⦶= G_1, ⊖= G_2. *P. napi*: ●.

On the other hand, in *P. napi* the duration of oviposition was linearly related both to air temperature (Fig. 2A) and sunshine duration (Fig. 2B), though the duration — age relation was obscure (Fig. 2C).

3. *Effects of climatic and non-climatic factors on the oviposition speed*

Figures 4 ~ 5 show relation of distribution patterns between the oviposition speed and climatic factors, and nonclimatic ones.

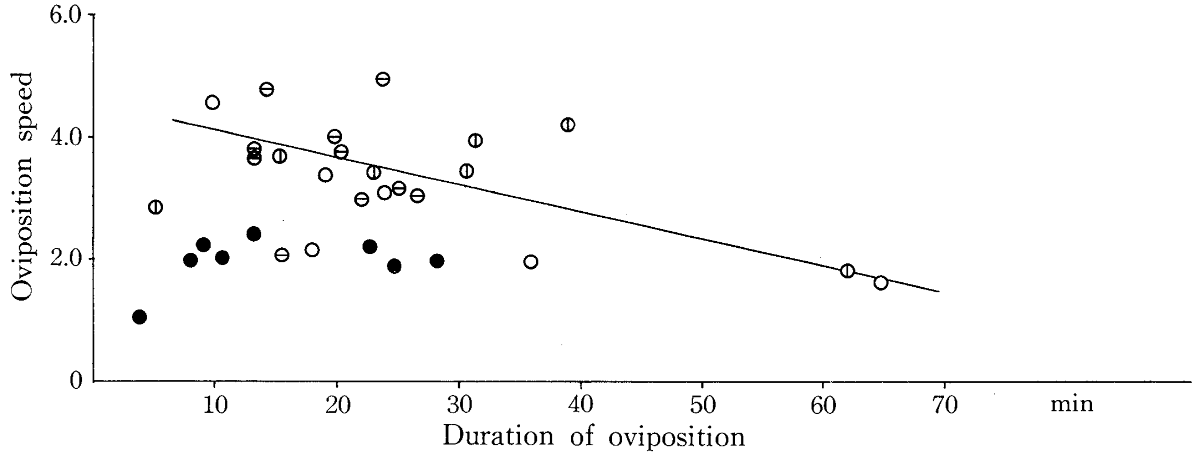

Figure 6 Relation between the oviposition speed and the duration of oviposition. *P. rapae* : ○= G_h, ⦶= G_1, ⊖= G_2. *P. napi*: ●.

In *P. rapae* the oviposition speed was related to air temperature; the speed — temperature curve became bell-shaped with a peak at 19.5 ~ 23.5 °C in G_h, at 21.0 ~ 25.0 °C in G_1, and at 22.0 ~ 27.0 °C in G_2 (Fig. 4A). The other climatic factors did not give any trends to the oviposition speed (Figs. 4B, 5). The speed — age curve did not show any trends, either, though it fell down at the start and end of their life span (Fig. 4C).

On the other hand, in *P. napi* the oviposition speed was unrelated to the climatic and non-climatic factors, air temperature (Fig. 4A), the duration of sunshine (Fig. 4B), solar radiation (Fig. 5A), wind velocity (Fig. 5B), relative humidity (Fig. 5C), and the age of ovipositing females (Fig. 4C).

4. *The relation between the duration of oviposition and oviposition speed*

The speed — duration relation showed a linear decrease in *P. rapae* (Fig. 6): A low oviposition speed seemed to be compensated by a long duration of oviposition. On the other hand, in *P. napi* it was unrelated to the duration of oviposition.

Discussion

The interspecific differences of oviposition activities so far known are summarized in the next items:

1. Oviposition sites are sunny places in *P. rapae,* while shaded areas in *P. napi.*
2. *P. rapae* oviposits in the morning, while *P. napi* in the afternoon (Yamamoto, 1985).
3. *P. rapae* thermoregulates its body temperature by opening or closing the wings in sunny places, while *P. napi* by shuttling between the sunny and shaded areas (Ohsaki, 1986).

In these two sympatric butterflies the number of eggs laid per day per female was linearly related to the duration of oviposition. Furthermore, in *P. rapae* the duration of oviposition was affected not by climatic factors but mainly by the age of ovipositing females; the body temperature seems to be kept at the same level as far as possible by wing movement and time controlling, and oviposition activities in an adverse thermal condition causing a low oviposition speed (Fig. 4A) may be compensated by a long duration of oviposition (Fig. 6), though oviposition activities are naturally arrested in an excessively low or high air temperature. This mode of oviposition may make it possible for *P. rapae* to oviposit a number of eggs next to the physiological limit of her fecundity in spite of climatic unstableness occurring at open habitats (Table 1). On the other hand, in *P. napi*, living at the same habitats as *P. rapae,* the duration of oviposition was affected mainly by climatic factors, especially air temperature and sunshine duration; in the more favorable climatic conditions the female can stay at shaded areas for the longer period to oviposit. This suggests that in this species the number of eggs laid per day per female is easy to be affected by unstable climate of open habitats.

Acknowledgement

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摘　　要

札幌周辺域で，キレハイヌガラシ(*Rorippa sylvestris*)を共通の食草とする同所性モンシロチョウ属の２種，モンシロチョウとエゾスジグロシロチョウとは，１日当りの１雌産卵数を決定する要因が異なっている。モンシロチョウは，気温や日射が極端に悪い条件でない限り，産卵数は日齢によって決められていて，気象条件の影響を受けない。このため，このチョウは，生理的限界に近い多数の卵を産むことができる。一方，エゾスジグロシロチョウの産卵は，気象条件，特に気温と日射時間によって大きく影響される。このため，１雌が一生の間に産み出す卵数は，その生理的限界をかなり下回ることが予想される。両種ともに，開けた，環境的に不安定な場所を生息地としているが、産卵数に関しては，モンシロチョウの方が，安定多数を保つ機構を備えていることを示唆している。