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Influence of Food Plants in Larval Stage on the Host Plant
Preference of Adult Lady Beetles, *Henosepilachna*
vigintioctomaculata Complex (Coleoptera,
Coccinellidae)*

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Synopsis Three forms of *Henosepilachna pustulosa* (KÔNO) and one of *Henosepilachna vigintioctomaculata* (MOTSCHULSKY) in Hokkaido, as well as the so-called Western Tokyo form were reared with thistle and potato throughout one generation. The influence of the two plants as food during larval stage upon the host plant preference of newly emerged adults of these groups were studied. Adult *Henosepilachna pustulosa* reared with potato throughout larval stage increased potato consumption without decreasing that of thistle. Western Tokyo form reared with thistle in larval stage increased thistle consumption not decreasing that of potato.

In *Henosepilachna vigintioctomaculata* complex (Hv-complex), two distinct groups, *H. vigintioctomaculata* (MOTSCHULSKY)** (Hv) and *H. pustulosa* (KÔNO)** (Hp) are found in Japan (KATAKURA, 1974 b). Under field conditions, the former almost depends on potato while the latter on thistles. In addition to them, however, there is another puzzling form called Western Tokyo form (Ht=Tokyo west-suburb form by others), which is morphologically similar to Hp but resembles Hv in food preference. Therefore, this form has been regarded as different from both Hp or Hv (YASUTOMI, 1966). Feeding experiments proved that Hv could not grow with thistle, while Hp fed on both plants and their larvae successfully grew with both plants (WATANABE and SAKAGAMI, 1948; KUROSAWA, 1953; YASUTOMI, 1954; WATANABE and SUZUKI, 1965; etc.). Further, it has been reported that Hp showed difference in food preference among populations or even individuals in the same local population (SAKAGAMI and YAMAGUCHI, 1954; IWAO, 1959). Using several populations of Hp, YASUTOMI (1954) said that Hp adults reared with potato throughout larval stage preferred potato to thistle. Unfortunately, he did not present numerical data about the results. The present paper deals with experimental studies about the influence of food plants during larval stage upon the host plant preference of adults in Hv-complex.

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** Usage of these scientific names and abbreviations follows KATAKURA (1974 a).

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Materials and Method

The materials and their provenances studied are shown as follows, using abbreviations by KATAKURA (1974 b): Hp. P-II (Typical form: Kamuikotan), P-III (Sapporo form: Nakanosawa near Sapporo), P-IV (Ohnuma form: Ohnuma), Hv. V-II (Hokkaido form: Hiroshima near Sapporo), Ht. (Nakayama, northern suburbs of Yokohama). All Hp forms were collected from thistles (*Cirsium* spp.) in mid May, and Hv and Ht from potato in mid June and early in May respectively. Throughout the experiments food plants were leaves of fresh thistle (*Cirsium kamtschaticum* LEDEB.) and potato. All insects collected were kept under constant temperature (23–25°C) and humidity (70–80%). Adults and larvae were kept separately in plastic boxes (8×11×5.5 cm), bottoms of which were covered with moistened filter paper. Five adults, male and female separately, and about ten larvae were reared in each box. The photoperiod of experimental room was conditioned as 15 hours light (from 8:00 to 23:00) and 9 hours dark throughout experiments (20 May–25 July).

The present study consists of three experiments: Ex-1. Host plant preference of hibernated adults (abbreviated as *HA*). Ex-2. Comparison of larval development with two different food plants. Ex-3. Host plant preference of newly emerged adults (*NA*).

In Ex-1, 30 adults (15 males and 15 females) were examined for each form. After 24 hours of starvation was given for all insects either thistle or potato, from 10:00 to 16:00 for one day. Again followed by 24 hours of starvation, the same insects were fed on the alternate food during the same hours. The areas of leaves consumed by insects during 6 hours were measured to square millimeters and the area per individual (sq. mm) were calculated for each test.

In Ex-2, five egg masses from five different females were used for each form. About 20 larvae from each egg mass were divided into two groups. One of them was reared with thistle and the other with potato for all forms. In total about 50 larvae from five different egg masses were used for both thistle and potato in each form.

In Ex-3, *NA* grown with thistle throughout larval stage (*NA_t*) and those grown with potato (*NA_p*), both about 20 individuals (10 males and 10 females) in each form, were examined separately with the procedure adopted in Ex-1.

Results

Host plant preference of hibernated adults (HA) The amount of thistle consumption per individual in 6 hours on the first day and that of potato on the other day were summed up. The percentage potato consumption was calculated by $100 \times P/(P+T)$ (P, T; Consumed amount of potato or thistle per individual) and the results

for each form is given in Fig. 1 with black circles. In the case of Hp, potato consumption was relatively small, resulting in the ratios of P-II, P-III and P-IV were 0.7 (P-II), 0.2 (P-III) and 7.2% (P-IV) respectively. On the other hand, Hv and Ht consumed at least 86.5%, with the mean percentage consumption of 96.8% and 100% respectively. These results show that HA of the three forms of Hp prefer thistle to potato while Hv and Ht fed nearly exclusively on potato.

Comparison of larval development As shown in Table 1, the larvae of P-II and P-IV showed higher survival ratios when reared with thistle ($\cong 80\%$) than with potato ($\cong 40\%$), while P-III did not show significant difference in the survival ratio between groups reared with potato and thistle. The larvae of Hv all died in 1st instar without consuming thistle, whereas they showed a very high survival ratio (96%) with potato. Some larvae of Ht could complete development with thistle, giving about 15% survival which was far inferior to those reared with potato ($\cong 70\%$).

Table 1. Comparison of larval development fed on potato or thistle among five forms. T: reared with thistle. P: reared with potato.

Species	Form	Food plant	No. indiv. tested	No. survived in each instar					Survival ratio %	Larval period (days)		
				1st	2nd	3rd	4th	pupa		Min.	Mean	Max.
Hp	P-II	T	47	45	44	44	36	36	76.6	25	26.3	30
		P	47	46	43	39	17	17	37.4	25	27.5	32
	P-III	T	45	43	43	43	42	42	93.4	24	28.0	36
		P	45	43	42	42	41	38	84.4	24	26.3	31
P-IV	T	50	50	50	50	44	44	88.0	27	28.4	31	
	P	49	33	31	23	19	19	38.8	28	29.8	34	
Ht	T	46	27	21	12	7	7	15.2	32	36.1	43	
	P	48	47	45	43	33	32	66.7	24	25.3	31	
Hv	V-II	T	50	0	0	0	0	0	0	—	—	—
		P	50	50	50	50	48	48	96.0	23	24.5	27

The numbers of larvae succumbed in each instar tended to increase a little during 3rd and 4th instars in Hp/thistle and Hv/potato. In the case of Hp/potato, the tendency changed according to the forms: mortality was high in 4th instar in P-II, constant from 1st instar to pupa in P-III and high in 1st instar in P-IV. In Ht/potato, the larvae mainly died in 4th instar but many individuals died in 1st instar when reared with thistle.

The difference of the duration of larval stage and its variance reared with two plants were tested statistically (Table 2). The cases with significantly prolonged larval period are Ht/thistle > Ht/potato and Ht/thistle > P-II and P-III/thistle, P-IV/thistle > P-II/thistle, further P-IV/potato > V-II/potato, P-IV/potato > P-II/potato > P-III/potato > Ht/potato.

Consequently the larvae of Hv and Ht reared with potato showed higher survival ratio, significantly shorter larval period and smaller variance of larval period than

Table 2. Correlation of statistical difference of mean larval period among the forms studied ($p < 0.05$).

L, (S): Duration in the form given at the top is significantly longer (shorter) than that given at the left hand. l, (s): Longer (shorter) without significant difference. +, (-): Variance of duration are equal (different) for each other.

			Hp						Ht		Hv
			P-II		P-III		P-IV		T	P	V-II P
			T	P	T	P	T	P			
Hp	P-II	T	×	1-	1-	×	L+	×	L-	×	×
		P	s-	×	×	S+	×	L+	×	s-	s-
	P-III	T	s-	×	×	s-	1-	×	L+	×	×
		P	×	L+	1-	×	×	L+	×	S+	s-
	P-IV	T	S+	×	s-	×	×	1-	1-	×	×
		P	×	S+	×	S+	s-	×	×	S+	S+
Ht	T	S-	×	S+	×	s-	×	×	S-	×	
	P	×	1-	×	L+	×	L+	L-	×	s-	
Hv	V-II	P	×	1-	×	1-	×	L+	×	1-	×

those with thistle. Hp larvae, especially P-II and P-IV, showed better development, with higher survival ratios, shorter larval period and smaller variance when reared with thistle. But P-III larvae showed no significant difference in survival ratio, larval period between thistle and potato.

The body weight of *NAt* and *NAp* was measured in Hp and Ht (Table 3). Male *NAt* of P-IV were significantly heavier than *NAp*. In P-III, however, *NAp* were heavier than *NAt* of both sexes. On other forms and sexes no significant difference between *NAt* and *NAp* was detected. In general the result is still inconclusive within the limit of the present experiments.

Table 3. Body weight of newly emerged adults of Hp (mg).

T: Larvae thistle. P: Larvae potato.

Form	Food plant in larval stage	Females				Males				Total
		No. measured	max.	min.	mean	No. measured	max.	min.	mean	Mean
P-II	T	18	83.3	66.2	73.1	16	75.7	59.0	66.6	70.0
	P	7	83.7	40.3	62.1	6	71.6	53.4	63.7	62.8
P-III	T	25	77.0	44.3	57.5*	16	56.3	36.3	49.1*	54.2*
	P	15	78.0	53.1	63.7	16	70.0	49.6	59.7	61.6
P-IV	T	19	97.9	82.8	90.7	23	82.4	54.4	73.7*	81.4
	P	8	96.1	69.2	82.6	5	75.8	54.7	66.1	76.2
Ht	T	8	66.1	36.2	48.1	8	46.5	17.9	32.5	40.3
	P	12	65.6	54.3	59.4	17	54.2	39.4	46.6	51.9

* Significant difference ($p < 0.05$).

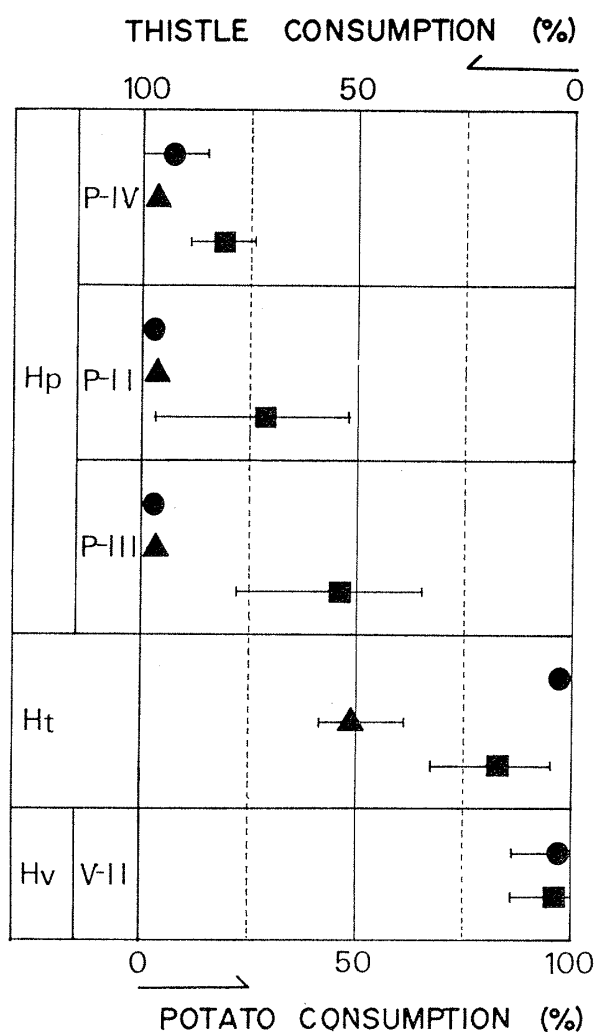


Fig. 1. Mean percentage potato or thistle consumption in respective forms. ●: Hibernated adults (*HA*); ▲ and ■: Newly emerged adults reared respectively with thistle or potato in larval stage (*NAt* and *NAp*). Horizontal bar added to each symbol means the range of the values obtained.

Host plant preference of newly emerged adults (NA) As shown in Fig. 1, *NAt* of three forms of *Hp* showed a very low percentage potato consumption, the values being nearly equal to those of *HA* in P-II and P-III which are less than in P-IV. This indicates a clear preference for thistle to potato in *Hp* both in *NAt* and *HA*. On the other hand, *NAp* showed a remarkable increase of potato consumption compared with both *HA* and *NAt*, especially in P-III (about 50%). The relative potato consumption of *Hp* seems to increase considerably by their complete development with potato. However, thistle consumption by *NAp* never decreased, so that their percentage potato consumption did not reach the level exhibited by *NAp* of V-II. In *Ht* the percentage potato consumption (above 67.4%) of *NAp* was slightly inferior to that of *HA*, but *NAt* showed a marked decrease of potato consumption ($\approx 50\%$)

compared with *HA* and *NAp*, resulting in similar percentage potato or thistle consumption between *NAp/P-III* and *NAt/Ht*. In other words *NAp/Hp* and *NAt/Ht* decidedly spread out the preference for potato and thistle but not so high as shown by *Hv* and *Hp* respectively.

Discussion

From the results described above, it was revealed that the host plant preference of *Hp* and *Ht* changed to some extent by larval conditioning. IWAO (1961) reported that in newly emerged adults of *Hp* in Serio near Kyoto the proportion of potato acceptance was significantly higher in individuals which completed their development on potato than those on thistle. However, he remarked that it was still difficult to determine whether the result was brought by pre-imaginal conditioning to potato or by the high larval mortality ($\cong 50\%$ against about 25% in control) of those insects which had inferior ability to eat potato. WATANABE and SUZUKI (1965) assumed *Ht* as a form of *Hp* adapted to potato. In the present study *NAp* of P-III increased potato consumption compared with *NAt* and *HA* showing high survival ratio ($\cong 84\%$) with potato in larval stage, further *NAp/P-III* and *NAt/Ht* showed similar percentage potato or thistle consumption. It is likely that larval conditioning to particular food plant affects the host plant preference after emergence. But *NAp/Hp* and *NAt/Ht* did not decrease respectively thistle or potato consumption. Therefore, the food preference in *Hv*-complex may basically be determined by genotypes, though larval conditioning can modify their phenotypic expression to some extent.

The experiments also revealed the different host plant preference among three groups namely *Hp*, *Hv* and *Ht* with one another. P-II, P-III and P-IV all consumed more thistle than potato. Even *NAp* of *Hp* tended to consume more thistle than potato. *NAp* of *Hp* spread out their potato consumption, but did not decrease thistle consumption. On the other hand, V-II and *Ht* consumed little thistle in both *HA* and *NA*. But *NAt/Ht* increased thistle consumption to the amount nearly same to that of *NAp/P-III*. The percentage potato consumption of V-II were far higher than in *Hp* even in *NAp/Hp*.

Furthermore, among three forms of *Hp*, the host plant preference seemed to be different from one another. The percentage potato consumption in *NAp* was higher in P-III than in P-II and P-IV. The larval development of P-III also differed from that of P-II or P-IV. Survival of V-II/potato was very high and larval period was very short with small variance, all emerging within 5 days. In P-III/potato, the survival ratio was high and the larval period tended to be shorter than those reared with thistle. Body weight in *NAp/P-III* was heavier than that of *NAt*. Consequently, among three forms of *Hp* P-III relatively resembles V-II in their host plant preference in spite of a distinct preference for thistle. In P-II and P-IV/potato, the survival ratio did not reach 50% . Most individuals emerged within 5 days when reared with thistle but more days were required with potato. Therefore in spite of its ability to survive with potato, thistle is decidedly more favorable for

P-II and P-IV.

These results confirm that host plant preference is different not only between Hp and Hv but also among three of Hp. Thus, the order of adaptation to potato in the Hv-complex studied is expressed as $P-IV \cong P-II < P-III < Ht < V-II$. Ht larvae reared with potato showed a high survival ratio and their larval period was short, further the variance of larval period was small compared with those with thistle. But some larvae of Ht could complete development with thistle and *NA*t increased thistle consumption. From these results Ht seems to be intermediate between Hv and Hp as to their food preference.

Finally the results are compared with some previous contributions. Several previous studies agree with the present results as follows: *Adults*:— Hp from Nopporo and Kamuikotan differed by the low percentage potato consumption from Hv (SAKAGAMI and YAMAGUCHI, 1954), V-II did not consume thistle (WATANABE and SAKAGAMI, 1948), V-I (Hv in Honshu, cf. KATAKURA, 1974 b) did not consume thistle (KOYAMA, 1950; YASUTOMI, 1954; IWAO, 1959; TSUNEKI and KUBO, 1960). In *NA* of Hp in Kyoto the proportion of potato-accepted beetles was significantly higher in individuals which completed their development on potato than those on thistle (IWAO, 1961). *Larvae*:— V-II did not develop with thistle (WATANABE and SAKAGAMI, 1948; SAKAGAMI and YAMAGUCHI, 1954; WATANABE and SUZUKI, 1965), V-I did not also develop with thistle (YASUTOMI, 1954; KOYAMA, 1957; IWAO, 1959), Hp from Nopporo and Kamuikotan showed different mean potato consumption compared with Hv respectively (SAKAGAMI and YAMAGUCHI, 1954), Ht from Kodaira could complete development with thistle (WATANABE and SUZUKI, 1965). Especially the avoidance of and inability to develop with thistle by Hv, both V-I and V-II are nearly conclusively from these results.

On the other hand, there are some discrepancies between previous and present results: *Adults*:— Some population of Hp preferred potato to thistle if they were reared with potato in larval period (YASUTOMI, 1954), the potato consumption of Hp from Nopporo was ca. 40–50% in most cases (SAKAGAMI and YAMAGUCHI, 1954), Ht did not consume thistle till the death except for the population from Kodaira (YASUTOMI, 1973). *Larvae*:— Hp from Sapporo reared with potato showed a lower emergence than with thistle (KUROSAWA, 1953), the mortality of P-II reared with potato did not differ significantly from that with thistle, and their larval period reared with potato was shorter than that with thistle (WATANABE and SUZUKI, 1965). These discrepancies may partly depend on the difference in experimental design, and of thistle species used (*Cirsium kamtschaticum* LEDEB. in KUROSAWA, 1953, SAKAGAMI and YAMAGUCHI, 1954, WATANABE and SUZUKI, 1965, and the present study, and *Cirsium comosum* MATSUMURA var. *incomptum* KITAMURA in YASUTOMI, 1954, 1973.), but also would suggest the occurrence of individual difference on food preference even within the same population. IWAO (1959) also mentioned a considerable variation in potato consumption of Hp among individuals of a local population studied in Kyoto.

On the difference of food preference among forms of Hp SAKAGAMI and YAMAGUCHI (1954) reported that Kp (Hp from Kamuikotan) and Sv (V-II) stood each on the opposite side of Np (Hp from Nopporo) with respect to the refusal for potato or thistle. The present result coincides with this statement.

Consequently it is concluded that as to the two host plants Hv depends only on potato, P-III has a relatively high tolerance for potato and Ht is relatively tolerable to thistle compared with Hv. The P-II and P-IV of Hp seem less tolerable to potato than P-III, but further analysis is required as to its variability both between and within local populations. For any future studies on Hv complex, it must be stressed the importance of distinguishing the food preference of adults and larvae clearly and to perform both with the same strain. It is also recommended to describe precisely the type and provenance of the population used for experiments and to present the results in quantitative terms enabling the comparison among them.

Summary

1. The influence of larval food on the host plant preference of newly emerged adults of *Henosepilachna vigintioctomaculata* complex (Hv-complex), three forms of *H. pustulosa* (Hp) (P-II: Typical form from Kamuikotan, P-III: Sapporo form from Nakanosawa and P-IV: Ohnuma form from Ohnuma) and one form of *H. vigintioctomaculata* (Hv) (V-II: Hokkaido form from Hiroshimacho) and Ht from Nakayama northern suburbs of Yokohama, was studied using two alternate foods, potato and thistle.

2. On the percentage potato consumption of hibernated adults, Hp consumed more thistle but Hv and Ht consumed more potato.

3. The larval survival and larval period reared with thistle or potato differed among five forms. The survival ratio in P-II and P-IV was higher with thistle than with potato. P-III did not show significant difference of survival ratio according to foods. Ht showed a high survival ratio with potato but some larvae of them could complete development with thistle.

4. In the Hp, *NAp* (newly emerged adults reared with potato during larval stage) increased potato consumption but did not decrease thistle consumption. *NAt* (newly emerged adults reared with thistle in larval stage) of Ht increased thistle consumption but did not decrease potato consumption. The percentage potato or thistle consumption of *NAp* of Hp and *NAt* of Ht did not reach by far respectively to that of Hv and Hp.

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