The Effect of Temperature on the Development and Longevity of the Andromeda Lace Bug, *Stephanitis takeyai* (Heteroptera: Tingidae) on Its Two Main Host Plants, *Pieris japonica* and *Lyonia elliptica*¹

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The rate of development of the andromeda lace bug, *Stephanitis takeyai*, reared on two of its main host plants, *Pieris japonica* and *Lyonia elliptica*, was measured at various temperatures. The overall pattern of the effects of temperature were similar on the two hosts and in both sexes. The developmental period was slightly shorter on *P. japonica* than on *L. elliptica* in both eggs and nymphs. However, adult longevity was much longer on *L. elliptica*. It was suggested that *L. elliptica* is therefore likely to be a better host than *P. japonica*. Except for a generally shorter development time at low temperatures, the developmental pattern was similar to that found in the azalea lace bug, *S. pyrioides*, as previously reported by NEAL and DOUGRASS (Environ. Entomol. 17: 827–831, 1988).

Key words: Tingidae, Japanese andromeda, development, temperature, host plants

INTRODUCTION

The andromeda lace bug, *Stephanitis takeyai*, is one of the most serious pests of the Japanese andromeda, *Pieris japonica* (Ericaceae) (JOHNSON and LYON, 1988). In addition to the Japanese andromeda, the persimmon tree (*Diospyros kaki*), the camphor tree (*Cinnamomum camphora*), the Chinese onise (*Illicium religiosum*) and many other useful plants also suffer damage (TAKEYA, 1963). However, *P. japonica* and *Lyonia elliptica* (Ericaceae) are thought to be the bug's main hosts in Japan (MIYAMOTO, 1965). The genus *Stephanitis* includes many other species that also cause serious injury to ornamental and orchard plants (TAKEYA, 1963). Of these, the azalea lace bug, *S. pyrioides*, is a noxious pest of azaleas and has been studied relatively well (NEAL and DOUGRASS, 1988). However, despite its importance as a pest of the Japanese andromeda, *S. takeyai* has rarely been studied. The aim of this study was 1) clarifying the effect of temperature on the development of eggs and nymphs, and adult longevity, 2) detecting any difference in the suitability of the two hosts, and 3) comparing the developmental pattern of *S. takeyai* and *S. pyrioides* to use this information for improving the pest management.

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MATERIALS AND METHODS

Sample collection and nymphal development on P. japonica. This bug, like the majority of other Tingid species, lays eggs in the healthy leaves of its host plants. Overwintering eggs were collected along with the shoots of *P. japonica* from the Kamigamo Forest Experimental Station of Kyoto University, Kyoto city on April 9, 1991. The shoots containing the eggs were maintained in water in 200 ml vials and kept at 15°C. All experiments were carried out under the photoperiod of 16L:8D. Newly hatched nymphs were individually confined to a single leaf of *P. japonica*. The leaves used here were collected from plants planted in the campus of Kyoto University. First the petiole of the leaf was wrapped with wet cotton. They were then transferred to chambers controlled at 15, 18, 20 and 25°C. Water was added to the cotton when required. The instar of each nymph on the leaves was recorded every day.

Nymphal developments on L. elliptica. A part of the eggs collected from the field was kept at 27.5°C. After eclosion, more than a hundred adults were allowed to oviposit in a small number of *L. elliptica*, collected on May 14 from Yoshida-yama hill, near the campus of Kyoto University. Newly hatched nymphs from the shoots were isolated individually, and transferred to chambers kept at 15, 20, 25 and 30°C. The host plant and bug were maintained in the same way as in the experiment on *P. japonica*.

Development of eggs on the two hosts. A proportion of the adults obtained in the experiment on *L. elliptica* were confined to a leaf of either *P. japonica* or *L. elliptica* for oviposition. Then the eggs were transferred to 15, 20, 25 and 30°C chambers along with the leaf within 24 h after oviposition. The duration of the egg stage on the two hosts species was recorded. Both the sexes were not discriminated in this experiment.

Adult longevity on the two hosts. Adults obtained in the experiment of nymphal development on *P. japonica* were kept under the same condition as mentioned earlier and their longevity was recorded. A proportion of the teneral adults obtained from the 27.5°C chamber of the experiment of nymphal development on *L. elliptica* were kept isolated in either of 15, 20 and 25°C chambers and their longevity was also recorded.

Application of the temperature summation law to the data on developmental period. The developmental period for each instar was totaled to get the developmental zero and the total effective temperature on the two hosts. The developmental zero (T_0) was estimated from a linear regression of developmental rate ($1/D$, where D represents the duration of development) against temperature. The total effective temperature (K) was calculated by the equation $K=(T-T_0)*D$, where T represents temperature. The egg data was analyzed in the same way.

Comparison with the developmental record of S. pyrioides. The nymphal period and egg period at the four temperatures were plotted against temperature. Corresponding data on *S. pyrioides*, obtained from NEAL and DOUGRASS (1988) were also plotted with the data from *S. takeyai*. In this procedure, data of both sexes were combined in order to simplify the analysis. The data on *P. japonica* was not used here due to the lack of information at 30°C. These graphs were used to compare the development of the two species.

RESULTS AND DISCUSSION

The results of the experiment of nymphal development time on *P. japonica* showed that the fifth instar took the longest time to develop while either the second or third instars took the shortest time (Table 1). This pattern was similar to that found in *Stephanitis pyrioides* (NEAL and DOUGRASS, 1988). This might therefore be a common pattern in the *Stephanitis* bugs. Overall, the pattern of nymphal developmental period on *L. elliptica* was similar to that on *P. japonica* (Table 2). Except for females at 15°C, however, the duration of the nymphal stage on *L. elliptica* was slightly but significantly longer than that on *P. japonica* for both sexes (*t*-test, $p < 0.001$ for each sex at 20 and 25°C, $p < 0.05$ for males at 15°C). The duration of female nymphs at 15°C was also longer on *L. elliptica*, though the difference was not significant. This tendency of a longer developmental time on *L. elliptica* was reflected in the result of the analysis of the temperature summation law as a larger total effective temperature on *L. elliptica* (Table 3). The developmental zero of nymphs was lower on *L. elliptica*. However,

Table 1. Nymphal development time of *S. takeyai* on *P. japonica* at four temperatures

Temp. (°C)	Instar (mean±S.D., days)					Total
	1	2	3	4	5	
Males [<i>N</i>] ^a						
15 [25]	7.00±1.50	6.36±1.11	6.56±1.04	7.40±1.15	11.72±1.43	39.04±5.22
18 [05]	5.20±0.84	3.80±0.84	4.40±0.55	5.20±0.84	8.40±1.14	27.00±2.00
20 [26]	3.53±0.90	2.62±0.50	2.96±0.72	3.35±0.94	5.50±0.95	17.96±2.13
25 [27]	2.81±0.62	1.96±0.59	2.19±0.40	2.74±0.66	4.03±0.52	13.74±1.13
Females [<i>N</i>] ^a						
15 [28]	7.43±1.55	6.50±1.35	6.86±1.21	7.71±1.27	12.11±1.45	40.61±5.43
18 [13]	4.54±0.97	4.15±0.38	4.00±0.58	4.46±0.52	7.69±0.63	24.85±1.99
20 [41]	3.49±0.98	2.73±0.50	3.04±0.59	3.21±0.72	5.73±0.78	18.22±2.06
25 [18]	2.50±1.10	2.38±0.61	1.72±0.46	2.72±0.57	4.39±0.70	13.72±1.41

^a Number of individuals.Table 2. Nymphal developmental time of *S. takeyai* on *L. elliptica* at four temperatures

Temp. (°C)	Instar (mean±S.D., days)					Total
	1	2	3	4	5	
Males [<i>N</i>] ^a						
15 [27]	7.48±0.95	6.80±0.70	7.01±0.65	7.91±0.73	12.53±0.91	41.74±3.31
20 [74]	3.95±0.84	2.93±0.47	3.31±0.67	3.75±0.37	6.16±0.89	20.11±1.99
25 [79]	3.04±0.80	2.12±0.74	2.37±0.50	2.96±0.83	4.36±0.65	14.86±1.42
30 [51]	2.37±0.62	1.65±0.57	1.85±0.39	2.31±0.64	3.40±0.50	11.59±1.10
Females [<i>N</i>] ^a						
15 [34]	7.71±0.90	6.74±0.78	7.12±0.70	8.00±0.73	12.56±0.83	42.12±3.15
20 [75]	3.82±1.01	2.98±0.52	3.32±0.61	3.51±0.74	6.26±0.81	19.92±2.13
25 [71]	2.73±1.08	2.58±0.60	1.90±0.45	2.97±0.56	4.80±0.69	14.99±1.38
30 [51]	2.16±0.89	1.87±0.50	1.42±0.37	2.24±0.46	3.63±0.57	11.33±1.14

^a Number of individuals.

Table 3. The developmental zero (T_0) and the total effective temperature (K) of eggs and nymphs on *P. japonica* and *L. elliptica*

Stage	Host plants			
	<i>P. japonica</i>		<i>L. elliptica</i>	
	T_0 (°C)	K (°C day)	T_0 (°C)	K (°C day)
Egg	6.9457	226.2	6.7059	235.2
Nymph (male)	9.6701	206.1	8.6137	244.4
(female)	9.5773	206.1	8.8801	238.1

Table 4. Comparison of egg development time of *S. takeyai* at several temperatures, on the two host plants

Host	Temp. (°C)	N^a	Days		
			Mean±S.D.	Min	Max
<i>P. japonica</i>	15	71	30.47±0.97	28	34
	20	50	15.78±1.00	15	18
	25	44	12.98±0.82	12	14
<i>L. elliptica</i>	15	335	30.91±0.95	29	34
	20	518	16.04±0.87	14	20
	25	501	13.34±0.88	12	17
	30	165	10.10±0.99	9	14

^a Number of individuals.Table 5. Adult longevity of *S. takeyai* on the two main host plants, *P. japonica* and *L. elliptica* at various temperatures

Host	Temp.	Sex	N^a	Days alive		
				Mean±S.D.	Min	Max
<i>P. japonica</i>	15	M	25	31.52±19.34	7	87
		F	28	43.00±20.02	4	73
	18	M	5	21.40± 9.94	10	33
		F	13	44.84±19.11	21	80
	20	M	26	34.04±21.02	1	79
		F	41	38.63±13.11	13	66
	25	M	27	38.96±16.32	14	71
		F	18	41.44±15.07	2	63
<i>L. elliptica</i>	15	M	14	82.29±26.81	37	113
		F	26	81.38±28.87	42	138
	20	M	14	75.00±28.91	17	107
		F	24	75.08±14.74	47	93
	25	M	18	76.44±21.05	41	100
		F	26	44.85±20.60	9	79

^a Number of individuals.

because the bug never experiences such low temperatures on *L. elliptica* which is a deciduous shrub, the developmental zero seems not to be significant in this case. In addition, nonlinear relationship between the developmental rate and temperature have affected the results of the analysis since the estimated value of developmental zero on *L. elliptica* becomes higher if the data at 30°C is omitted from the analysis.

The difference in the developmental time of eggs on the two hosts showed patterns similar to those in nymphal development, i.e. they also took longer on *L. elliptica*, and the difference at each of 15, 20 and 25°C was significant (t -test, $p < 0.001$; Table 4). The result of the application of the temperature summation law to this data was similar to that of the nymphal data, though the difference was small (Table 3). In general, eggs of an insect are unlikely to be affected in their development by the host plant since there is usually no interaction between the two. In this bug, however, the eggs are laid in the living tissue of the host plants. The difference in developmental period

Fig. 1. (A) The relationship between nymphal developmental time (days) and temperature on *L. elliptica*. The data of the two sexes were combined. (B) The relationship between the developmental time of eggs (days) and temperature on *L. elliptica*. The data on *S. pyrioides* are obtained from NEAL and DOUGRASS (1988).

of eggs in this bug might thus be due to the difference of factors that affect host plant quality such as water contents or toxic substance.

The lowest temperature for *S. pyrioides* was examined at by NEAL and DOUGRASS (1988) was 20.6°C, where the developmental period would be expected to be shorter than at 20°C. Despite this conservativeness, the nymphal development time of *S. takeyai* at 20°C was shorter than that of *S. pyrioides* at 20.6°C (*t*-test, $p < 0.001$, Fig. 1A), though at higher temperatures, the differences between the two species were negligible. This tendency was also shown in the developmental time of eggs (*t*-test, $p < 0.001$, Fig. 1B). It can therefore be concluded that *S. takeyai* has a higher potential to develop during cold seasons in field than *S. pyrioides*.

Adult longevity in this bug was much longer on *L. elliptica* than on *P. japonica* (Table 5). This experiment did not examine differences in fecundity on the two hosts since it was carried out using isolated virgin individuals. However, if we suppose that the longevity pattern obtained here reflects the one seen under natural conditions, this large difference on the two hosts may have significant effect on the fecundity of this bug, which oviposits throughout its lifetime (TSUKADA, unpubl. data). Compared with this large difference in adult longevity, the differences in developmental period of both eggs and nymphs seems to be less significant. Therefore, *L. elliptica* can be concluded to be a better host than *P. japonica*.

Currently, a number of phylogenetical trees for Japanese lace bugs have been proposed (LEE, 1969; TSUKADA, 1994). Comparative studies of life history traits based on these phylogenetical trees will in addition be very useful in the understanding of the evolution of the life histories of these bugs.

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