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Life-history and Oviposition Preference of the Willow Spittlebug *Aphrophora pectoralis* (Homoptera: Aphrophoridae)

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Abstract. The life-history of the willow spittlebug *Aphrophora pectoralis* on two willow species, *Salix miyabeana* and *S. sachalinensis*, was studied in Hokkaido, northern Japan. *A. pectoralis* has a univoltine life-cycle overwintering in the egg stage. There were no significant differences in the duration of nymphal stages between the two willow species. Mating and oviposition occurred from early August to mid-October, and at the start of this period adult females had about 10 mature oocytes. Thereafter, the number of mature oocytes increased, peaking in late September. The cumulative number of egg masses per shoot on *S. sachalinensis* was significantly greater than that on *S. miyabeana*. This result suggests that female spittlebugs prefer *S. sachalinensis* to *S. miyabeana* as an oviposition plant despite no difference in the growth performance between the two host species.

Key words: xylem sucker, nymphal development, fecundity, oviposition preference, *Salix*.

Introduction

Spittlebugs (Homoptera: Cercopidea) are xylem-sucking insects with about 2380 species in the world (Hodkinson & Casson, 1991). Nymphs produce froth masses in which they live and which protect the nymphs from natural enemies, desiccation, and high temperatures (Marshall, 1966; Whittaker, 1970; Kuenzi & Coppel, 1985). A single species of spittlebug is known to feed on a wide variety of host species (Hodkinson & Casson, 1991). The meadow spittlebug *Philaenus spumarius* (Linnaeus), for example, has 140 documented host plants (Owen, 1988).

The Salicaceae is a group of common woody plants with about 550 species (Takahashi & Katsuyama, 2000) that provide food for various herbivorous insects. Many studies have been conducted on various herbivorous insects with different feeding modes on willows (Craig *et al*., 1989; Preszier & Price, 1993; Price *et al*., 1995; Larsson *et al*., 1997; Ishihara *et al*., 1999; Kagata & Ohgushi, 2001). Although spittlebugs are the main herbivores on willows, their life-histories have not been studied. Therefore, clarifying the life-history of spittlebugs would contribute to the understanding of insect-plant interactions on willows.

The spittlebug *Aphrophora pectoralis* Matsumura (Homoptera: Aphrophoridae) is widely distributed over Japan, Korea, Russia, and Europe, and feeds on Salicaceae (Komatsu, 1997). This species is one of the most common herbivorous insects on willows in our study site in Hokkaido, northern Japan. In this paper, we report on the life-history characteristics of *A. pectoralis* and its oviposition pattern on two host plant species, *Salix miyabeana* and *S. sachalinensis.*

Materials and Methods

Study site

This study was conducted on the banks of the Ishikari River in Hokkaido, northern Japan (43° 11′ N, 141°24′ E). In the study site, six willow species (*Salix miyabeana, S. sachalinensis, S. integra, S. hultenii, S. subfagilis,* and *S. pet-susu*) occurred with relative abundances of 54% for *S. miyabeana*, 26% for *S. sachalinensis*, and 12% for *S. integra* (Ishihara *et al*., 1999). These willow species usually grow in mixed stands and form patches. This study was conducted within one patch (50 m × 50 m).

Willows

We examined life history characteristics of the spittlebug on *S. miyabeana* and *S. sachalinensis*, both of which are common along rivers or in open areas. *S. miyabeana* grows to 3–5 m in height, and *S. sachalinensis* up to 10–15 m in height. In Hokkaido they

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flower from April to early May. Female trees develop their inflorescences during May, and disperse seeds in mid-June. Budbreak occurs when catkins are blooming, and leaf expansion and shoot elongation continue until mid-July. Secondary expansion of leaves and shoots occurs occasionally after September. Most leaves become senescent by late October, and new buds appear on leaf axils at that time.

To examine shoot growth throughout the season, we randomly selected 6 clones from *S. miyabeana* and 4 clones from *S. sachalinensis* and then selected 5 one-year shoots from each clone in 1999 at the study site. We recorded the total number of current-year shoots on each of the selected one-year shoots and measured their length every two weeks from late May to early September.

Growth of A. pectoralis

Nymphs of *A. pectoralis* produce froth masses on leaf axils and grow up within them throughout the nymphal stages. Early nymphs produce froth masses on the attacked shoots and tend to aggregate in the same froth (Nozawa, personal observation). This aggregative tendency weakens with the advance of nymphal development.

The duration of each nymphal stadium was determined on potted willows. In spring 1997, we took six one-year shoots from one *S. miyabeana* tree and five shoots from one *S. sachalinensis* tree, and planted them individually in pots (160 mm diameter and 200 mm deep). When nymphs hatched in spring 1998, we immediately placed one nymph on one shoot of each potted willow, which was then placed in a small greenhouse. We recorded the instar of each nymph every day until they reached adulthood. The duration of each stadium was compared between the two willow species using unpaired *t*-test.

To compare body size between the host willow species throughout development, we collected nymphs from ten randomly selected froth masses every two days from mid-May to early July, and 56 adults (30 males and 26 females) in mid-July 1999 from the field. The body length of each adult or nymph was measured to the nearest 0.05 mm using digital calipers (Mitutoyo Corporation, Code NO: CD-20C). Body length of adult males and females was compared using unpaired *t*-test.

Oviposition schedule

We censused seasonal changes in the number of egg masses laid on *S. miyabeana* and *S. sachalinensis* in the field. Adult females lay eggs inside the current-year shoots of willows. We arbitrarily selected five *S. sachalinensis* trees and seven *S. miyabeana* trees and randomly selected 100 current-year shoots from each tree. Then, we counted the number of oviposition scars as egg masses on these shoots once a week from early August to mid-October. The number of egg masses on each census date was compared between two willow species using unpaired *t*-test.

In 1999, we collected ca. 30 adult females every two weeks from early August to early October in the study site to count the number of matured oocytes in ovarian tubes. The number of mature oocytes per female was compared among dates using one-way ANOVA and Scheffe's multiple range test.

Results and Discussion

Nymphal development

A. pectoralis has a univoltine life cycle overwintering in the egg stage. The bud burst of willows began in late April and new leaves were produced from early May. Then, shoot elongation began in mid-May. The overwintered eggs began to hatch in mid-May just before the beginning of shoot elongation (Fig. 1). Development from hatch to adult emergence required 36.8 ± 2.7 (mean$\pm$SE) days in *S. miyabeana* and 34.0 ± 0.5 days in *S. sachalinensis*, and there was no significant difference between the two willow species (*t*-test, $t=1.03, P=0.33$; Table 1). There were also no significant differences in the duration of each nymphal stage between the two willow species (Table 1). The size of adult females was significantly larger than that of males (unpaired *t*-test, $t=8.52$, $P<0.0001$; Table 2).

Oviposition pattern

Mating and oviposition occurred from early August when the length of current-year shoots reached maximum size (Fig. 1). Adult females had ten mature oocytes in early August when oviposition began. Thereafter, the number of mature oocytes increased and peaked in late September, being more than twice the number of early August (Fig. 2). The mean number of ovarian tubes per female was 23 ± 3.8 (mean$\pm$SD, N=41). On *S. sachalinensis*, the cumulative number of egg masses consistently increased from early August to late September (Fig. 3). On *S. miyabeana*, on the other hand, it reached a maximum in early September and then leveled off. The cumulative number of egg masses on *S. sachalinensis* was significantly greater than that on *S. miyabeana* after September (Fig. 3). Although we did not compare the

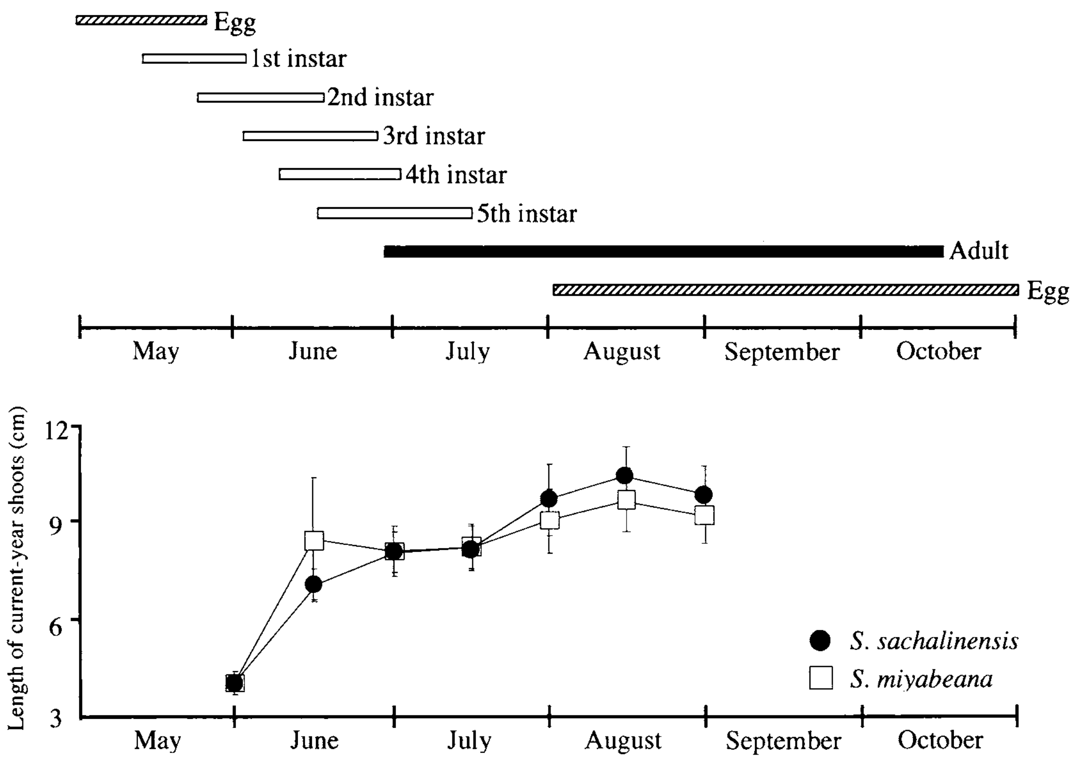

Fig. 1. Life cycle of *A. pectoralis* (top) and seasonal changes in length of current-year shoots in *S. miyabeana* (N=30) and *S. sachalinensis* (N=20) (bottom). Horizontal bars indicate the duration of each stadium. Mean and SE are presented.

Table 1. Duration (days) of each nymphal stage (mean ±SE). Nymphs developed on potted willows.

Instar	Duration		Unpaired *t*-test	
	S. miyabeana	*S. sachalinensis*	*t*-Vaule	*P*-Vaule
1st	6.7±0.6 (6)	5.4±0.3 (5)	1.93	0.09
2nd	4.5±0.3 (6)	4.8±0.2 (5)	−0.72	0.49
3rd	5.2±0.6 (6)	4.2±0.2 (5)	1.40	0.19
4th	7.0±0.5 (6)	6.8±0.4 (5)	0.30	0.77
5th	13.4±0.5 (5)*	12.8±0.6 (5)	0.78	0.46
Overall	36.8±2.7 (5)	34.0±0.5 (5)	1.03	0.33

* One 5th instar larva was lost.

Table 2. Body length (mm) of nymphal and adult stages (mean±SE). Nymphs were randomly collected in the study site.

Instar	Body length
1st	2.19±0.02 (146)
2nd	3.38±0.04 (87)
3rd	4.99±0.05 (113)
4th	6.49±0.06 (82)
5th	7.58±0.08 (77)
Adult	8.89±0.09 (56)
Male	8.43±0.05 (30)
Female	9.42±0.11 (26)

number of eggs per egg mass between two willow species, no significant difference was found in the length of oviposition scars (mm) (*S. miyabeana*: 3.66 ±0.07 (mean±SE), N=40; *S. sachalinensis*: 3.57± 0.06, N=40; unpaired *t*-test; $t=0.88$, $P=0.38$). The number of eggs was highly correlated with the length of oviposition scars ($y=-5.71+2.99x$, $r^2=0.68$, df= 111, $P<0.0001$). This suggests that there was no difference in the number of eggs per egg mass between the two willow species.

A low flight ability was not responsible for the difference in oviposition preference between the willow species. As adult spittlebugs frequently moved among willow species (Craig & Ohgushi, personal communication), the higher density of egg masses on *S. sachalinensis* suggests that female spittlebugs prefer *S. sachalinensis* to *S. miyabeana* as an oviposition plant. Higher plant quality in terms of nitrogen and amino acids may explain the oviposition preference for *S. sachalinensis.* Other xylem feeders utilize plant quality as a cue to plant choice (Prestidge & McNeill, 1983; Brodbeck *et al.*, 1990; Rossi & Strong, 1991; Thompson, 1994). For example, an oligophagous xylem-feeding leafhopper, *Carneocephala floridana* Ball, prefers host plants with higher nitrogen content (Rossi & Strong, 1991). Nitrogen concentration im-

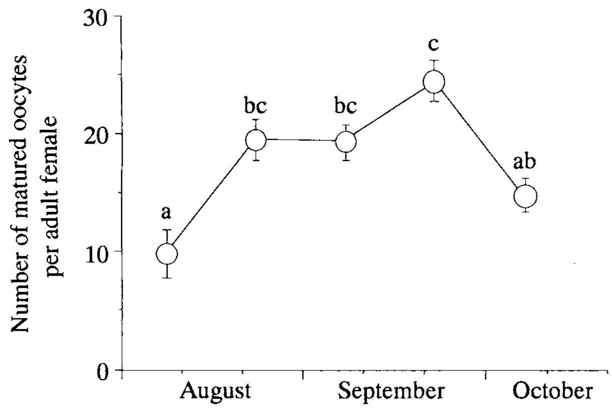

Fig. 2. Seasonal changes in the number of matured oocytes. Mean and SE are presented (N=134). Different letters show significant difference at the 5% level by Scheffe's multiple range test.

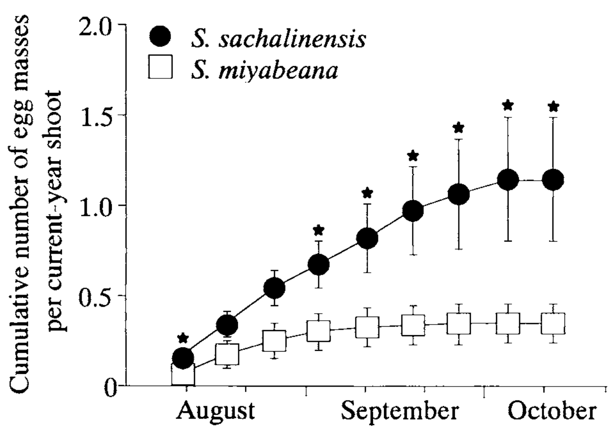

Fig. 3. Seasonal changes in the cumulative number of egg masses per current-year shoot in *S. miyabeana* (N=7) and *S. sachalinensis* (N=5). Mean and SE are presented. Asterisks show significant difference at the 5% level by unpaired *t*-test.

proves the fitness components of herbivorous insects, such as survival rate, growth rate, fecundity and adult size (Scriber & Slansky, 1981; Stiling *et al.*, 1982). Although in this study we did not find differences in the duration of nymphal stadia between the two willow species, plant quality (nitrogen or amino acids) may have affected other fitness components such as larval survival and fecundity. Therefore, to determine why female spittlebugs prefer ovipositing in *S. sachalinensis*, the effects of the quality of the two willow species on fitness components have to be assessed.

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