Distribution and host range of an aphidophagous species of Cecidomyiidae, *Aphidoletes aphidimyza* (Diptera), in Japan

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Abstract

Aphidoletes aphidimyza, an aphidophagous species of Cecidomyiidae, has been used in many countries as a biological control agent against aphids, particularly in glasshouses. The species had been reported previously in Japan but a mass-rearing method has not yet been established. Recently, preliminary tests started in Japan to evaluate its effect on aphids using mass-produced cocoons imported from the Netherlands and United Kingdom. Therefore, the natural distribution and host range of *A. aphidimyza* in Japan was studied before Japanese populations are contaminated by mating with imported individuals. Field surveys in 25 prefectures revealed that *A. aphidimyza* is distributed commonly in Japan, except in Okinawa, the most southern prefecture. Nineteen aphid species were observed to be attacked by the Japanese populations of *A. aphidimyza* and the larvae of imported *A. aphidimyza* were reared to adults on 7 aphid species. As a result, at least 80 host aphid species have now been recorded in the world. Most of the host aphids found in Japan belonged to the tribes Aphidini or Macrosiphini of the subfamily Aphidinae. The host plants of these aphids were also recorded.

Key words: *Aphidoletes aphidimyza*, distribution, host range, aphidophagous Cecidomyiidae, biological control

INTRODUCTION

Aphidoletes aphidimyza (Rondani) is widely distributed in the world, being recorded from Canada, Chile, China, Egypt, Hawaii, India, Israel, Japan, Russia, Sudan, Tunisia, Turkey, U.S.A., and many European countries (Gagné, 1971; Harris, 1973; Meadow et al., 1985; Kulp et al., 1989; Grover et al., 1988; Zhao and Cheng, 1990; Halima-Kamel and Hamouda, 1993). Larvae of this species feed upon a wide variety of aphids, at least 61 species having been known as hosts (Nijveldt, 1969; Harris, 1973). Most of the aphid species belong to the subfamily Aphidinae, some to Chaitoporidae and Callaphidinae, and a few to other subfamilies. In many countries, *A. aphidimyza* has been used extensively as a biological control agent against aphids, particularly in glasshouses, and has been proved effective (Meadow et al., 1985; Morse and Croft, 1987; Nijveldt, 1988).

The potential for use of *A. aphidimyza* has at-

tracted increasing attention in Japan during recent years but a method for mass-rearing has not yet been established. Recently, preliminary tests have been started in some Agricultural Experiment Stations, using mass-produced cocoons imported from the Netherlands and United Kingdom to Japan, in order to evaluate the effect of *A. aphidimyza* on aphid populations in glasshouses.

In Japan, the occurrence of an aphidophagous species of Cecidomyiidae was recorded, for the first time, by Ninomiya (1959), who tentatively identified it as a North American species, *Aphidoletes meridionalis* Felt, which has since been synonymized with *A. aphidimyza* by Gagné (1971). Subsequently, Yukawa (1971) confirmed the presence of *A. aphidimyza* in Kagoshima Prefecture, but other distribution records based on reliable identification were limited to those of Kato (1974, 1976) from Yamaguchi Prefecture. Therefore, it is now necessary to survey the natural distribution and

abundance of *A. aphidimyza* in Japan before Japanese populations are contaminated by imported individuals. In addition, finding suitable and unsuitable species of host aphid as well as host plants is essential in order to develop mass-rearing methods using Japanese populations and to grow banker plants (Bennison, 1992) and associated aphids in glasshouses. In particular, the use of Japanese populations is an urgent necessity since they do not cause severe genetic contamination and distributional disturbance in Japan.

In this paper we report the natural distribution, abundance, and host range of *A. aphidimyza* in Japan, based chiefly on recent collection data, together with notes on some other observations.

MATERIALS AND METHODS

In order to search for larvae of aphidophagous Cecidomyiidae, field surveys were performed, from June 1996 to May 1997, in the following 12 prefectures in Japan: Ibaraki, Yamanashi, Osaka, Wakayama, Okayama, Fukuoka, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima, and Okinawa (arranged from north to south). In Kagoshima Prefecture more intensive and frequent surveys were performed at the Kagoshima University Campus and its vicinity from October 1994 to December 1996. In addition, Okinawa Prefecture was visited twice, the first visit in July 1996 and the second in November 1996, since no aphidophagous cecidomyiid larvae were found there during the first visit.

During field surveys, aphid colonies were searched for on various crops and wild plants that were suspected to be possible habitats of both aphids and cecidomyiid predators. When larvae of aphidophagous Cecidomyiidae were found in aphid colonies, they were collected, together with aphids and host plants, and some of them were reared in cylindrical glasses (12 cm in diameter, 18 cm in height) under laboratory conditions in order to obtain adult specimens of both aphidophagous Cecidomyiidae and associated parasitoids, if any.

In response to our request, aphid colonies were surveyed in 1996 at various crop fields or in glasshouses in Agricultural, Horticultural, and

Fruit Tree Experiment Stations (hereafter, AES, HES, FES, respectively) of the following 10 prefectures: Hokkaido, Aomori, Akita, Yamagata, Tokyo, Niigata, Nara, Kagawa, Ehime, and Okinawa. Field surveys were also performed in Hokkaido National Agricultural Experiment Station (hereafter, Hokkaido NAES) and Shikoku National Agricultural Experiment Station (hereafter, Shikoku NAES), of which the latter extended the surveys to 2 neighbouring prefectures, Tokushima and Kochi. The collected midge larvae were forwarded to the laboratory of Kagoshima University together with aphids and host leaves for rearing and identification.

Prior to the present study, larvae of *A. aphidimyza* were sent to J. Yukawa, the senior author of the present paper, for identification, in 1973 from the Ooshima Citrus Branch, Yamaguchi AES and in 1994 from Shimane AES. These collecting data are included in the present study.

In addition to assessing Japanese populations of *A. aphidimyza*, the host range of those imported in May 1995 from Koppert B.V., the Netherlands through Tomen Corporation, Japan was studied by feeding the larvae with several aphid species collected from the Kagoshima University campus. Rearing experiments were performed from May to June 1995 under laboratory conditions using Petri-dishes (4 cm in diameter, 2 cm in depth) containing aphid colonies on a host leaf together with a piece of moistened paper.

Some of the collected larvae and reared adults were mounted on slides, for microscopic study, in Canada balsam using ethanol and xylene. Species identification was made by J. Yukawa relying upon the detailed, illustrated descriptions of *A. aphidimyza* by Roberti (1946) and Harris (1966) in addition to the original description by Rondani (1847). The specimens are kept in the collection of the Entomological Laboratory, Kyushu University, Fukuoka. Aphid species were identified mostly by O. Setokuchi, one of the co-authors of this paper and partly by Prof. M. Sorin (Kôgakkan Univ.). The aphid specimens are kept in the collection of Kagoshima Agricultural Experiment Station. Ants attending aphid colonies that were attacked by larvae

of *A. aphidimyza* were also collected, if any, from the fields. They were identified by Mr. K. Tsuda (The Association of Kagoshima Environmental Research and Service).

RESULTS

Identification

All aphidophagous cecidomyiid larvae collected through the present surveys and adults reared from some of them were identified as *A. aphidimyza*. In addition, there were no clear diagnostic differences to distinguish Japanese from European specimens at the subspecific level. Besides *A. aphidimyza*, no other Palearctic or Nearctic relatives, such as *Aphidoletes urticae* (Kieffer), *Aphidoletes abietis* (Kieffer), and *Aphidoletes thompsonii* Möhn, were found during the surveys.

Distribution and abundance of *A. aphidimyza*

A. aphidimyza larvae were collected from 21 (84%) out of 25 prefectures where field surveys were performed (Fig. 1). This is equivalent to 44.7% of all 47 prefectures in Japan. The 4 prefectures where *A. aphidimyza* larvae were not found were Aomori, Nara, Ehime, and Okinawa.

Table 1. Percentage of sites where the larvae of *A. aphidimyza* were found

Prefecture	No. of sites surveyed	Sites where <i>A. aphidimyza</i> was found (%)
Ibaraki	10	8 (80.0)
Yamanashi	5	2 (40.0)
Osaka	2	2 (100.0)
Wakayama	6	3 (50.0)
Okayama	2	1 (50.0)
Fukuoka	12	8 (66.7)
Nagasaki	10	9 (90.0)
Kumamoto	8	4 (50.0)
Oita	1	1 (100.0)
Miyazaki	3	1 (33.3)
Kagoshima	10	6 (60.0)
Subtotal	69	45 (65.2)
Okinawa (July)	6	0 (0)
(Nov.)	11	0 (0)
Total	86	45 (52.3)

In Aomori Prefecture, no dipterous larvae, except those of the family Chamaemyiidae, were found. However, the occurrence of *A. aphidimyza* was confirmed in its 2 neighbouring prefectures, Hokkaido and Akita (Fig. 1). Similarly, *A. aphidimyza* was collected from Osaka and Wakayama both of which are neighbouring prefectures to Nara.

In Ehime Prefecture, *A. aphidimyza* larvae were collected in September 1996 from the colonies of *Macrosiphum euphorbiae* (Thomas) on *Lycopersicon esculentum* (Solanaceae) at Kuma Branch of Ehime AES. However, the collection record was excluded from Fig. 1, since mass-produced cocoons imported from the Netherlands were released there in 1995 to evaluate its effects on aphids (Y. Yamasaki, 1996, personal comm.).

A. aphidimyza was not found in Okinawa Prefecture, in spite of the intensive surveys performed twice in different seasons at a total of 17 different sites (Table 1).

Through the field surveys made by ourselves in the 12 prefectures, the larvae of *A. aphidimyza* were collected at 45 (65.2%) out of 69 sites (Table 1). They were found frequently in household vegetable gardens where insecticides have been seldom used.

Aphid species and their host plants

Nineteen aphid species that were fed upon by Japanese *A. aphidimyza* are listed in Table 2, together with their host plants. All the aphids, except *Myzocallis kuricola* (Matsumura) which is a member of the subfamily Drepanosiphinae, belong to the tribes Aphidini or Macrosiphini of the subfamily Aphidinae. Sixteen of them, except *Aphis gossypii* Glover, *Hyalopterus pruni* (Geoffroy), and *Myzus persicae* (Sulzer), were not found in the list of 61 species known as hosts of *A. aphidimyza* in Harris (1973). Most of the aphids collected in Japan are pests of crops, since the field surveys were performed chiefly in crop fields and household vegetable gardens. In particular, *A. gossypii* was attacked most frequently on various host plants in many localities (Table 2).

The larvae derived from *A. aphidimyza* imported from the Netherlands to Japan were reared to adults by feeding with 7 Japanese

Fig. 1. Collection sites of *Aphidoletes aphidimyza* in Japan. Numerals indicate collection data as follows: 1, Toyohira, Sapporo City, 2. Aug. 1996; 2, Naganuma, Yubari, Hokkaido, 1. Sep. 1996; 3, Shinsei, Memuro, Hokkaido, 16. Aug. 1996; 4, Niita, Akita City, 30. Aug. 1996; 5, Minorigaoka, Yamagata City, 5. Oct. 1996; 6, Iwama, Nishiibaraki, Ibaraki Pref., 27. Jul. 1996; 7, Hanari, Tsukuba City, 28. Jul. 1996; 8, Inatoi, Toride City, 28. Jul. 1996; 9, Fujimi, Tachikawa City, 7. Aug. 1996; 10, Mano, Seiro, Niigata Pref., 26. Aug. 1996; 11, Tenjin, Kofu City, 1. Aug. 1996; 12, Yoshizawa, Shikishima, Yamanashi Pref., 1. Aug. 1996; 13, Kaminogo, Izumisano City, 3. Aug. 1996; 14, Uchita, Naga, Wakayama Pref., 3. Aug. 1996; 15, Kurusu, Wakayama City, 3. Aug. 1996; 16, Sunayama, Wakayama City, 4. Aug. 1996; 17, Takeya, Matsue City, 27. May 1994; 18, Tamashima, Kurashiki City, 3. Jul. 1996; 19, Agenosho, Tachibana, Yamaguchi Pref., 1. Aug. 1973; 20, Komatsushima City, 10. Sep. 1996; 21, Bussyozan, Takamatsu City, 19. Sep. 1996; 22, Nakaoi, Ino, Kochi Pref., 20. Sep. 1996; 23, Mt. Yukawa, Genkai, Fukuoka Pref., 30. May 1997; 24, Yoshiki, Chikushino City, 18. Jun. 1996; 25, Saifu, Dazaifu City, 18. Jun. 1996; 26, Mt. Tatera, Tsushima, Nagasaki Pref., 30. May 1997; 27, Kaizu, Isahaya City, 20. Jun. 1996; 28, Onihashi, Omura City, 20. Jun. 1996; 29, Kaminoda, Kamitsue, Oita Pref., 19. Jun. 1996; 30, Koshi, Kikuchi City, 6. Jul. 1996; 31, Nishigoshi, Kikuchi City, 6. Jul. 1996; 32, Miike, Miyakonojo City, 26. Jun. 1996; 33, Hayato, Aira, Kagoshima Pref., 26. Jun. 1996; 34, Kirishima, Aira, Kagoshima Pref., 26. Jun. 1996; 35, Kagoshima Univ. Campus, 16. Mar. 1995–25. Oct. 1995; 36, Shiroyama, Kagoshima City, 19. Sep. 1996.

aphid species (Table 3). Among them, 3 species, *Aphis gossypii* Glover, *Aphis spiraecola* Pach, and *Toxoptera odinae* (Van der Goot), were also fed upon by Japanese populations, whilst

the remaining 4 were not recorded as hosts of Japanese *A. aphidimyza* (Table 2).

In contrast, some aphid species have never been found to be attacked by *A. aphidimyza*, al-

Table 2. Aphid species attacked by Japanese populations of *Aphidoletes aphidimyza*

Aphid species	Host plant	Collection data ¹
[Aphidinae: Aphidini]		
<i>Aphis clerodendri</i> Matsumura	<i>Clerodendrum trichotomum</i> (Verbenaceae)	36
<i>Aphis craccivora</i> Koch	<i>Phaseolus vulgaris</i> (Fabaceae)	25
<i>Aphis glycines</i> Matsumura	<i>Glycine max</i> (Fabaceae)	5
<i>Aphis gossypii</i> Glover	<i>Abelmoschus esculentus</i> (Malvaceae)	20
	<i>Cayratia japonica</i> (Vitaceae)	9
	<i>Chrysanthemum morifolium</i> (Asteraceae)	27
	<i>Colocasia esculenta</i> (Araceae)	13
	<i>Commelina communis</i> (Commelinaceae)	35
	<i>Cucumis melo</i> (Cucurbitaceae)	30
	<i>Cucumis sativus</i> (Cucurbitaceae)	2, 6, 10, 13–15, 27
	<i>Fragaria xananassa</i> (Rosaceae)	21
	<i>Hibiscus mutabilis</i> (Malvaceae)	22
	<i>Lycopersicon esculentum</i> (Solanaceae)	17
	<i>Polymnia sonchifolia</i> (Asteraceae)	1
	<i>Solanum melongena</i> (Solanaceae)	3, 6, 11, 12, 16, 25
	<i>Solanum tuberosum</i> (Solanaceae)	27
<i>Aphis spiraecola</i> Pach	<i>Citrus unshiu</i> (Rutaceae)	19, 24
	<i>Pyrus pyrifolia</i> (Rosaceae)	6
	<i>Viburnum suspensum</i> (Caprifoliaceae)	35
<i>Hyalopterus pruni</i> (Geoffroy)	<i>Prunus persica</i> (Rosaceae)	28
<i>Melanaphis formosana</i> (Takahashi)	<i>Sorghum bicolor</i> (Poaceae)	35
<i>Melanaphis sacchari</i> (Zehntner)	<i>Sorghum bicolor</i> (Poaceae)	35
<i>Toxoptera odinae</i> (Van der Goot)	<i>Viburnum suspensum</i> (Caprifoliaceae)	35
[Aphidinae: Macrosiphini]		
<i>Macrosiphum euphorbiae</i> (Thomas)	<i>Lycopersicon esculentum</i> (Solanaceae)	7, 8
	<i>Solanum melongena</i> (Solanaceae)	8
<i>Micraphis artemisiae</i> (Takahashi)	<i>Artemisia princeps</i> (Asteraceae)	25, 29, 32
<i>Myzus persicae</i> (Sulzer)	<i>Brassica oleraceae</i> (Brassicaceae)	4
	<i>Nicotiana tabacum</i> (Solanaceae)	30
	<i>Prunus mume</i> (Rosaceae)	24
	<i>Sesamum indicum</i> (Pedaliaceae)	7
<i>Myzus siegesbeckiae</i> Takahashi	<i>Prunus</i> × <i>yedoensis</i> (Rosaceae)	23, 26, 28, 31
<i>Myzus varians</i> Davidson	<i>Prunus mume</i> (Rosaceae)	33, 34
	<i>Prunus persica</i> (Rosaceae)	28
<i>Neotoxoptera formosana</i> (Takahashi)	<i>Allium fistulosum</i> (Liliaceae)	18, 24
	<i>Allium tuberosum</i> (Liliaceae)	27
<i>Phorodon japonensis</i> Takahashi	<i>Humulus japonicus</i> (Moraceae)	35
<i>Semiaphis heraclei</i> (Takahashi)	<i>Apium leptophyllum</i> (Apiaceae)	27
<i>Uroleucon</i> sp.	<i>Solidago altissima</i> (Asteraceae)	36
	<i>Solidago virgaurea</i> var. <i>asiatica</i> (Asteraceae)	30
[Drepanosiphinae]		
<i>Myzocallis kuricola</i> (Matsumura)	<i>Castanea crenata</i> (Fagaceae)	10

¹See caption of Fig. 1 for collection data indicated by numerals.

though their colonies were encountered frequently during the field surveys. They are listed in Table 4, together with their host plant records and the intensity of field surveys.

Aphid species that were attacked by *A. aphidimyza* were found on 34 plant species (Table 2). Among them those belonging to the families Rosaceae and Asteraceae were most

Table 3. Japanese aphid species and host plants on which the larvae of imported *Aphidoletes aphidimyza* were reared to adults

Aphid species	Host plant
Aphidinae: Aphidini	
<i>Aphis gossypii</i> Glover	<i>Cucumis sativus</i> (Cucurbitaceae)
<i>Aphis spiraeicola</i> Pach	<i>Citrus unshiu</i> (Rutaceae)
<i>Aphis rumicis</i> L.	<i>Rumex japonicus</i> (Polygonaceae)
<i>Toxoptera aurantii</i> (Boyer de Fonscolombe)	<i>Distylium racemosum</i> (Hamamelidaceae)
<i>Toxoptera odinae</i> (Van der Goot)	<i>Viburnum suspensum</i> (Caprifoliaceae)
Aphidinae: Macrosiphini	
<i>Hyperomyzus lactucae</i> (L.)	<i>Sonchus oleraceus</i> (Asteraceae)
<i>Megoura crassicauda</i> Mordvilko	<i>Vicia faba</i> (Fabaceae)

Table 4. Aphid species which were not attacked by *Aphidoletes aphidimyza* in Japan

Aphid species and associated host plant	No. sites surveyed	Colonies examined
Aphidinae: Macrosiphini		
<i>Acyrtosiphon nipponicum</i> (Essig et Kuwana) on <i>Paederia scandens</i> (Rubiaceae)	5	>30
Lachninae		
<i>Lachnus tropicalis</i> (Van der Goot) on <i>Castanea crenata</i> (Fagaceae)	4	>100
Drepanosiphinae		
<i>Neophyllaphis podocarpi</i> Takahashi on <i>Podocarpus macrophyllus</i> (Podocarpaceae)	2	>30
Thelaxinae		
<i>Neothoracaphis yanonis</i> (Matsumura) on <i>Quercus glauca</i> (Fagaceae) ¹	1	>50
Hormaphidinae		
<i>Pseudoregma bambucicola</i> (Takahashi) on <i>Bambusa multiplex</i> (Poaceae)	>60	>200

¹ Secondary host from May to December. Leaf galls are produced on the primary host, *Distylium racemosum* (Hamamelidaceae).

abundant, whilst there was only 1 species in the family Poaceae.

Parasitoids and predators

No hymenopterous parasitoids were reared from the larvae of *A. aphidimyza* but several mature larvae of the genus *Lestodiplosis*, another group of predacious Cecidomyiidae, were found in the collection from Nishigoshi, Kumamoto Prefecture. In addition, a female midge with mottled wings, which are characteristic of some *Lestodiplosis* species, was observed ovipositing near a colony of *Phorodon japonensis* Takahashi on *Humulus japonicus* Sieb. et

Zucc. (Moraceae) in the Kagoshima University Campus.

Ants attending upon aphid colonies

During the course of field surveys, 3 species of ant, *Paratechia flavipes* (F. Smith) (Formicinae), *Pristomyrmex pungens* Mayr and *Tetramorium caespitum* (L.) (Myrmicinae), were occasionally observed attending upon aphid colonies. Even when the colonies were attacked by larvae of *A. aphidimyza*, these ants did not show any defensive action to remove the predators from the colonies.

DISCUSSION

Identification

It was in the book 'Illustrated Insect Larvae of Japan' (Ninomiya, 1959) that an aphidophagous species of Cecidomyiidae first appeared in Japanese literature. Ninomiya, one of the co-authors of that book, published an illustration of a larva and tentatively identified it as *A. meridionalis*, a North American species. Since the name *A. meridionalis* was included in a catalogue (Yasumatsu and Watanabe, 1964), that name has been used on many occasions for any aphidophagous larvae of Cecidomyiidae found in Japan. Although Ninomiya's specimens have been lost and the larval illustration does not give sufficient detail, his specimens may be identical with *A. aphidimyza*, since no other Palearctic or Nearctic species have yet been detected in Japan through the present field surveys (see Harris, 1973 for the distribution and host range of the other species). Furthermore, Ninomiya's identification is considered to be supported by the fact that *A. meridionalis* was later synonymized with *A. aphidimyza* by Gagné (1971).

Since there are no clear diagnostic morphological differences at the subspecies level between Japanese and European specimens, intraspecific variations should be studied at the DNA level before Japanese populations are contaminated by mating with individuals imported from foreign countries.

Distribution and abundance of *A. aphidimyza*

A. aphidimyza in Japan was first identified by Yukawa (1971), who reared adults from larvae feeding upon *Melanaphis sacchari* (Zehntner) (= *Longiunguis*) on *Sorghum* leaves in Kanoya City, Kagoshima Prefecture. Thereafter, aphidophagous cecidomyiids were recorded from Yamaguchi (Kato, 1974, 1976, as *A. aphidimyza*), Shimane (T. Murai, 1994, personal comm., as *A. aphidimyza*), and Wakayama Prefecture (Morishita et al., 1994, as *Aphidoletes* sp.). The present study added collection data from 21 prefectures, indicating clearly that *A. aphidimyza* is distributed widely in Japan, except Okinawa Prefecture (Fig. 1). The field surveys also indicated that *A.*

aphidimyza is not rare, since the larvae were found at 45 (65.2%) of 69 sites (Table 1). These results were not unexpected in view of its known polyphagy and cosmopolitan distribution as shown in Harris (1973).

A. aphidimyza was not found in Okinawa Prefecture during the present study. Generally speaking, a species may be erroneously recorded as absent when collecting has been insufficient or at the wrong season, or when a species is rare. In the case of *A. aphidimyza*, it is not a rare species, as mentioned in the preceding paragraph, and the collection in Okinawa Prefecture was attempted twice in different seasons (first in July and second in November) at a total of 17 sites (Table 1). Therefore, the species may well be absent from Okinawa. However, considering the fact that *A. aphidimyza* occurs in Egypt, Sudan, and Hawaii (Harris, 1973), it is still worth continuing field surveys in Okinawa Prefecture, which is located between latitudes 24°N and 26°N, particularly in the hope of detecting a non-diapausing population of *A. aphidimyza*, which might be useful in short-day seasons.

Aphid species and their host plants

As has been noted in other countries, *A. aphidimyza* also has a wide host range in Japan consisting of at least 19 aphid species (Table 2). It was remarkable that 16 species were newly added to the known host range in the world. Of course, many more aphid species will be detected as hosts in the future, in particular when aphids inhabiting wild hosts are searched extensively.

In addition, the larvae derived from *A. aphidimyza* imported from the Netherlands to Japan were reared to adults by feeding with 7 Japanese aphid species (Table 3). When all these aphid species are regarded as hosts, the number of host aphid species totals at least 80 in the world.

Plant species of the family Poaceae, such as wheat and barley, have been used successfully as banker plants to aid establishment of aphid natural enemies (Bennison, 1992; Bennison and Corless, 1992) since aphids associated with Poaceae usually do not feed on crops of Dicotyledoneae including Rosaceae, Cucurbitaceae,

Solanaceae, etc. Therefore, further effort to find host aphids associated with Poaceae is necessary in order to provide suitable banker plants in Japan since only 2 aphid species, *Melanaphis sacchari* (Zehntner) and *Melanaphis formosana* (Takahashi), on sorghum are available at the moment (Table 1).

Some aphid species have never been found to be attacked by *A. aphidimyza* (Table 4), even though their colonies were frequently encountered in the field. This is unsurprising since they belong to subfamilies other than Aphidinae, except *Acyrtosiphon nipponicum* (Essig et Kuwana) which belongs to the tribe Macrosiphini of Aphidinae. The reason why *A. nipponicum* on *Paederia scandens* (Lour.) Merr. (Rubiaceae) is not attacked by *A. aphidimyza* may be explained by the fact that the aphid contains 'paederoside', an iridoid glycoside originating in the aphid host, *P. scandens*, which is a potent deterrent against predatory ladybird beetles (Nishida and Fukami, 1989).

Parasitoids and predators

At least 4 species of hymenopterous parasitoids, *Synopeas rhanis* (Walker) (Platygasteridae), *Aphanogmus fulmeki* Ashmead (Cerafronidae), *Gastrancistrus* sp. (Pteromalidae), and a braconid species (not yet identified) are known to attack *A. aphidimyza* (Gilkeson et al., 1993), but fortunately none were reared from the Japanese populations. However, several larvae of the genus *Lestodiplosis* were found in the collection from Nishigoshi, Kumamoto Prefecture. Larvae of this genus are known to prey on some species of mites, aphids, and certain beetle larvae but they are most commonly found feeding on the larvae of other cecidomyiids (Harris, 1966; Nijveldt, 1969). Therefore, it is probable that the larvae of *Lestodiplosis* prey on those of *A. aphidimyza* rather than on aphids. If so, though such evidence was not reported previously, the existence of *Lestodiplosis* larvae must be taken into consideration in the practical use of *A. aphidimyza* in Japan. Further observations are required for confirmation since larvae of *Lestodiplosis* that were collected could not be reared into adults in the laboratory.

Ant attending upon aphid colonies

Some ants are generally known to act as defenders against various species of predators attacking aphid colonies (e.g., Dixon, 1985), but the 3 species of ant observed during the present study did not show any defensive action, ignoring the existence of *A. aphidimyza* larvae in aphid colonies. The disturbance of larval activities by ants, if any, cannot be overlooked when *A. aphidimyza* is used as a biological control agent in glasshouses. Further data are needed to study the interactions between aphids, ants, and the predator.

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