Cecidomyiid galls found on Tsushima, a stepping stone island between the Korean Peninsula and Kyushu, Japan

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Abstract. Galls induced by cecidomyiids were surveyed from 2009 to 2012 on Tsushima, one of the stepping stone islands between the Korean Peninsula and Kyushu, Japan. We recognized 23 sorts of cecidomyiid gall occurring on Tsushima in association with 23 plant species belonging to 17 families. Among the 23 sorts, 22 (95.7 %) also occur in Kyushu and 11 (47.8 %) in the Korean Peninsula. These differences in percentages are attributed to the following two reasons: (1) different intensities of field surveys in Kyushu and the Korean Peninsula and (2) similarity of vegetation between Kyushu and Tsushima, which is characterized by plants growing in warm temperate forests, due to the Tsushima warm current. Tsushima is considered to play a more important role as a stepping stone island for Japanese insects to expand their range northwards rather than for Korean insects extending southwards.

Key Words: Cecidomyiidae, fauna, latitude, range expansion, vegetation, warm current.

Introduction

The area around the Japanese Archipelago was a continuous coastal margin of the ancient Asian continent until the end of the Carboniferous Period (about 289 mya), and thereafter the archipelago separate d from the continent during the Cretaceous and Paleogene Periods (25–130 mya) and was alternately connected and separated from the continent by the repetition of glacial periods until the Pleistocene Era (0.01–2.0 mya) (Taira & Tashiro 1987; Taira 1990). The Japanese Archipelago, including the Tsushima Islands, is now completely separated from the continent, and the distance between the Korean Peninsula and Kyushu (the nearest part of the mainland of Japan) is about 200 km (Fig. 1).

The Tsushima Islands consist of a major island and more than 100 small adjacent islets. The major island was artificially separated by the construction of canals, first in 1672 and later in 1900, into three islands, which are now connected with bridges. Therefore, we regard the three islands together as one major island ‘Tsushima’. The island is long and narrow, being 696km^2 in area, and the highest point is 648.5 m in altitude (the northern and southern most latitude: N 34°42' and N 34°05', respectively, and the eastern and western most longitude: E 129°30' and E 129°10', respectively) (Fig. 2). About 89% of the Tsushima Islands is covered with secondary forests of broad-leaved

evergreen and deciduous trees and plantations of conifers (Forestry Administration Division and Forest Department Office, Agriculture and Forestry Department, Nagasaki Prefecture 2015). The climate of the islands is relatively mild due to the influence of a warm current, the average of the annual temperature being 15.8˚C and the average annual precipitation being 2132.6mm (Meteorological data in Izuhara, Tsushima, Japan Meteorological Agency).

Tsushima is about 50 km south of the Korean Peninsula and about 100 km north of Kyushu, Japan. Because Tsushima has been regarded as one of the important stepping stone islands between the peninsula and the mainland of Japan, the entomofauna of the island has been surveyed for various insect taxa to compare with those of the Korean Peninsula and of the mainland of Japan: e.g. Nagasaki Biological Society (1976); Kobayashi (1985); Sasa & Suzuki (1999).

Gall-inducing cecidomyiids (Diptera: Cecidomyiidae) were not intensively surveyed on Tsushima until these surveys and only three species were previously recorded from the island, as follows: (Yukawa 2014): *Asphondylia sphaera* Monzen on *Ligustrum japonicum* Thunb. (Oleaceae), *Masakimyia pustulae* Yukawa & Sunose on *Euonymus japonicus* Thunb., and *Thecodiplosis japonensis* Uchida & Inouye on *Pinus thunbergii* Parl. and *Pinus densiflora* Sieb. & Zucc. (Pinaceae). Galls of *A. sphaera* were collected from Izuhara by T. Sunose on 7 March 1977. The occurrence of *M. pustulae* was indicated on a map of Tsushima in Sunose (1981) without collecting data. An infestation of pine trees by *T. japonensis* was reported by Inouye (1962). To fill some of the gaps in faunistic information, we visited Tsushima in 2012, 2013 and 2014 to survey cecidomyiid galls on various plant species. This paper presents the results of the field surveys and compares the percentage of cecidomyiid species on Tsushima that also occur in the Korean Peninsula or Japan. We also briefly refer to the role of Tsushima as a stepping stone island between the peninsula and Kyushu.

Methods

We surveyed cecidomyiid galls in various sites on Tsushima in October 2012, June 2013, May 2014 and September 2014 (Table 1; Fig. 2). In addition, Mr. T. Satonaka surveyed upon occasion cecidomyiid galls on Tsushima, in response to our request, during the period from December 2014 to February 2015.

In the results reported here, galls are arranged according to the order of plant families adopted in Yukawa and Masuda (1996) because it is easier to find galls with the gall numbers indicated in the book. Names of plant families follow the Angiosperm Phylogeny Group (APG) system of plant classification (Stevens 2008). Entries for each gall are arranged in the following order: (1) Galled organ, the name of the gall-inducing cecidomyiid and the names of host plants, (2) Japanese name of the gall together with gall number of Yukawa and Masuda (1996) in parenthesis, (3) Collecting data indicated with code numbers in Table 1 and Fig. 2, and (4) Remarks, if any. Gall reference numbers consisting of an alphabet letter and four figures are those proposed in Yukawa *et al*. (2013). If necessary, another alphabet letter is added at the end of the four figures

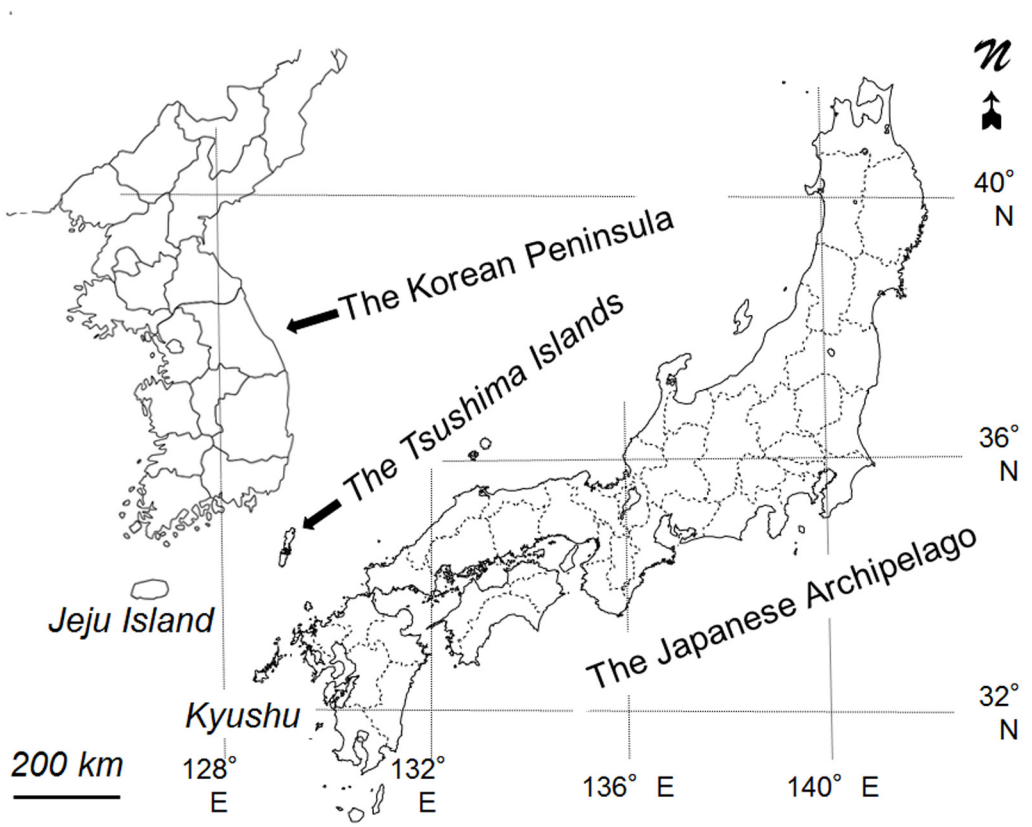


Figure 1. Map of the Korean Peninsula, the Tsushima Islands and the Japanese Archipelago (except Hokkaido and the Nansei Islands).

to distinguish two or more species/subspecies/varieties of host plants used by a single oligophagous species of gall midge. Photographs are provided for most galls found on the island.

Specimens of galls and gall midges collected from Tsushima during the course of this study are kept in the Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka, Japan or in the Laboratory of Systems Ecology, Faculty of Agriculture, Saga University, Saga, Japan.

Results

Cecidomyiid galls found on Tsushima

Through the previous and current field surveys, we recognized 23 sorts of cecidomyiid gall occurring on Tsushima in association with 23 plant species belonging to 17 families. They are listed as follows:

PINACEAE

1. Needle gall induced by *Thecodiplosis japonensis* Uchida & Inouye on *Pinus thunbergii* Parl. and *Pinus densiflora* Sieb. & Zucc. (See p. 18 in Yukawa & Masuda 1996 for a photograph of the needle gall).

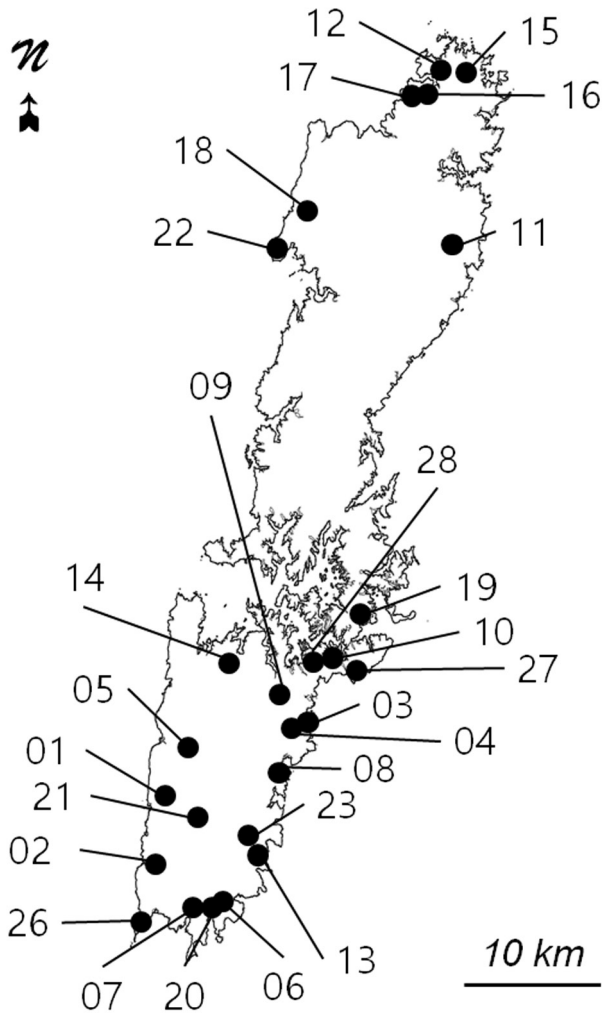


Figure 2. Map of Tsushima Island, indicating collecting sites with black circles and code numbers. See Table 1 for detailed collecting data. The code numbers are the same as those in the table.

Japanese name: Matsu-ba-tama-fushi (B-0060a, b).
Collecting data: Inouye (1962).
Remarks: We did not search for this gall throughout the current survey because Inouye (1962) had reported an infestation on the two species of *Pinus* by *T. japonensis*. This gall midge is recorded from Hokkaido, Honshu, Shikoku, Kyushu, Tsushima Island, the Nansei Islands, the Korean Peninsula and China. (Paik *et al*. 2004; Yukawa 2014).

FAGACEAE

2. Downwardly rolled leaf-margin gall induced by an unidentified cecidomyiid on

Table 1. Collecting data of cecidomyiid galls on Tsushima Island (Tsushima City, Nagasaki Prefecture), Japan, together with information on searching sites where no cecidomyiid galls were found (Code No. 23–28).

Code No.	Collecting site	Latitude (N)	Longitude (E)	Alt. (m)	Collecting date	Coll.*
01	Kotsuki, Izuhara-machi	34°11'32"	129°10'58"	23	11 Oct. 2012	MT
02a, b	Sasuse, Izuhara-machi	34°09'00"	129°10'38"	5	a:12 Oct. 2012 b:18 Jun. 2013	MT
03	Neo, Mitsushima-cho	34°14'37"	129°18'49"	34	12 Oct. 2012	MT
04	Neo, Mitsushima-cho	34°14'41"	129°18'53"	30	12 Oct. 2012	MT
05	Shimobaru, Izuhara-machi	34°13'50"	129°13'00"	159	18 Jun. 2013	MT
06	Tsutsunaiin, Izuhara-machi	34°07'19"	129°13'49"	135	18 Jun. 2013	MT
07	Azamo, Izuhara-machi	34°07'00"	129°12'44"	113	18 Jun. 2013	MT
08	Hiyoshi, Izuhara-machi	34°12'43"	129°17'38"	183	18 Jun. 2013	MT
09a, b	Sumo, Mitsushima-cho	34°16'18"	129°17'25"	59	a:16, 19 May 2014 b:18 Sep. 2014	WK
10	Takeshiki, Mitsushima-cho	34°17'22"	129°20'05"	75	16 May 2014	WK
11	Kin, Kamitsushima-cho	34°34'11"	129°26'21"	57	16 May 2014	WK
12	Waniura, Kamitsushima-cho	34°41'12"	129°25'56"	75	17 May 2014	WK
13	Oura, Izuhara-machi	34°09'36"	129°16'13"	268	18 May 2014	WK
14	Kashi, Mitsushima-cho	34°17'00"	129°14'57"	60	19 May 2014	WK
15	Toyo, Kamitsushima-cho	34°41'13"	129°27'19"	13	18–19 Sep. 2014	WK
16	Kawachi, Kamitsushima-cho	34°40'23"	129°25'17"	164	19 Sep. 2014	WK
17	Nishitsuya, Kamiagata-cho	34°40'07"	129°24'16"	1	19–20 Sep. 2014	WK
18	Sago, Kamiagata-cho	34°35'42"	129°18'39"	106	20 Sep. 2014	WK
19	Kofunakoshi, Mitsushima-cho	34°19'35"	129°21'53"	19	20 Sep. 2014	WK
20	Yoranaiin, Izuhara-machi	34°07'32"	129°14'00"	214	21 Sep. 2014	WK
21	Kotsuki, Izuhara-machi	34°11'19"	129°12'51"	120	21 Sep. 2014	WK
22	Shitaru, Kamiagata-machi	34°34'06"	129°17'46"	16	13 Feb. 2015	TS
23	Agami, Izuhara-machi	34°09'18"	129°15'37"	265	18 May 2014	WK
24	Mikata, Mitsushima-cho	34°16'49"	129°16'12"	26	19 May 2014	WK
25	Oura, Izuhara-machi	34°09'54"	129°17'01"	2	20 Sep. 2014	WK
26	Tsutsu, Izuhara-machi	34°06'16"	129°10'10"	65	21 Sep. 2014	WK
27	Ofunakoshi, Mitsushima-cho	34°16'42"	129°21'39"	40	21 Sep. 2014	WK
28	Kechi, Mitsushima-cho	34°17'05"	129°19'49"	56	May-June 2014	TS

* Names of collector are abbreviated as follows; M. Tokuda : MT, W. Kim : WK, T. Satonaka: TS.

Quercus serrata Thunb. ex Murray (Fig. 3) and *Quercus* sp. (Fig. 4).
Japanese name: Konara-haberi-ura-maki-fushi (C-0498a) **new name** for *Q. serrata.*
Collecting data: 09a for the galls on *Q. serrata* and 14 for those on *Quercus* sp.
Remarks: The downwardly rolled leaf-margin galls on *Q. serrata* have been found by Dr. T. Katsuda in Mie Prefecture, by Ms. K. Matsunaga in Fukuoka Prefecture, and by Mr. A Nagai in Miyazaki Prefecture (personal communications), but not recorded in the literature. Therefore, we give a new Japanese gall name to the gall in this paper.

CANNABACEAE

3. Leaf gall induced by *Asteralobia humuli* (Shinji) on *Humulus japonicus* Sieb. & Zucc. (Fig. 5).
Japanese name: Kanamugura-haura-kobu-fushi (C-2205a).
Collecting data: 17.
Remarks: This gall midge is recorded from Honshu, Kyushu and the Korean Peninsula (Paik *et al*. 2004; Yukawa 2014).
4. Leaf gall induced by *Celticecis japonica* Yukawa & Tsuda on *Celtis sinensis* Pers. (Fig. 6).
Japanese name: Enoki-ha-togari-tama-fushi (C-2020a).
Collecting data: 06, 09a.
Remarks: This gall midge is recorded from Honshu, Shikoku, Kyushu and China (Yukawa 2014).

MORACEAE

5. Leaf vein gall induced by an unidentified cecidomyiid on *Morus australis* Poir. (Fig. 7).
Japanese name: Yamaguwa-ha-myaku-kobu-fushi (C-2300b).
Collecting data: 09a.
Remarks: This gall has been found in Hokkaido, Honshu and Kyushu not only on *M. australis* but also on *M. alba* L. (Yukawa & Masuda 1996).

AMARANTHACEAE

6. Stem gall induced by *Lasioptera achyranthii* Shinji on *Achyranthes bidentata* Blume (Fig. 8).
Japanese name: Inokoduchi-kuki-maru-zui-fushi (C-2450a).
Collecting data: 17.
Remarks: This gall midge is recorded from Honshu, the Izu Islands, Sado Island, Shikoku, Kyushu, Jeju Island and the Korean Peninsula (Paik *et al*. 2004; Yukawa *et al*. 2012b; Yukawa 2014).

LAURACEAE

7. Leaf gall induced by an unidentified cecidomyiid on *Lindera glauca* (Sieb. & Zucc.) Blume (Fig. 9).
Japanese name: Yamakoubashi-ha-kobu-fushi (C-2657) **new name.**
Collecting data: 09a, 18.
Remarks: This gall was found, for the first time, in July 2014 in Sanda City, Hyogo

Prefecture, Honshu (H. Yoshimura, personal communication) but not recorded in the literature. Therefore, we give a new Japanese gall name to the gall.

THEACEAE

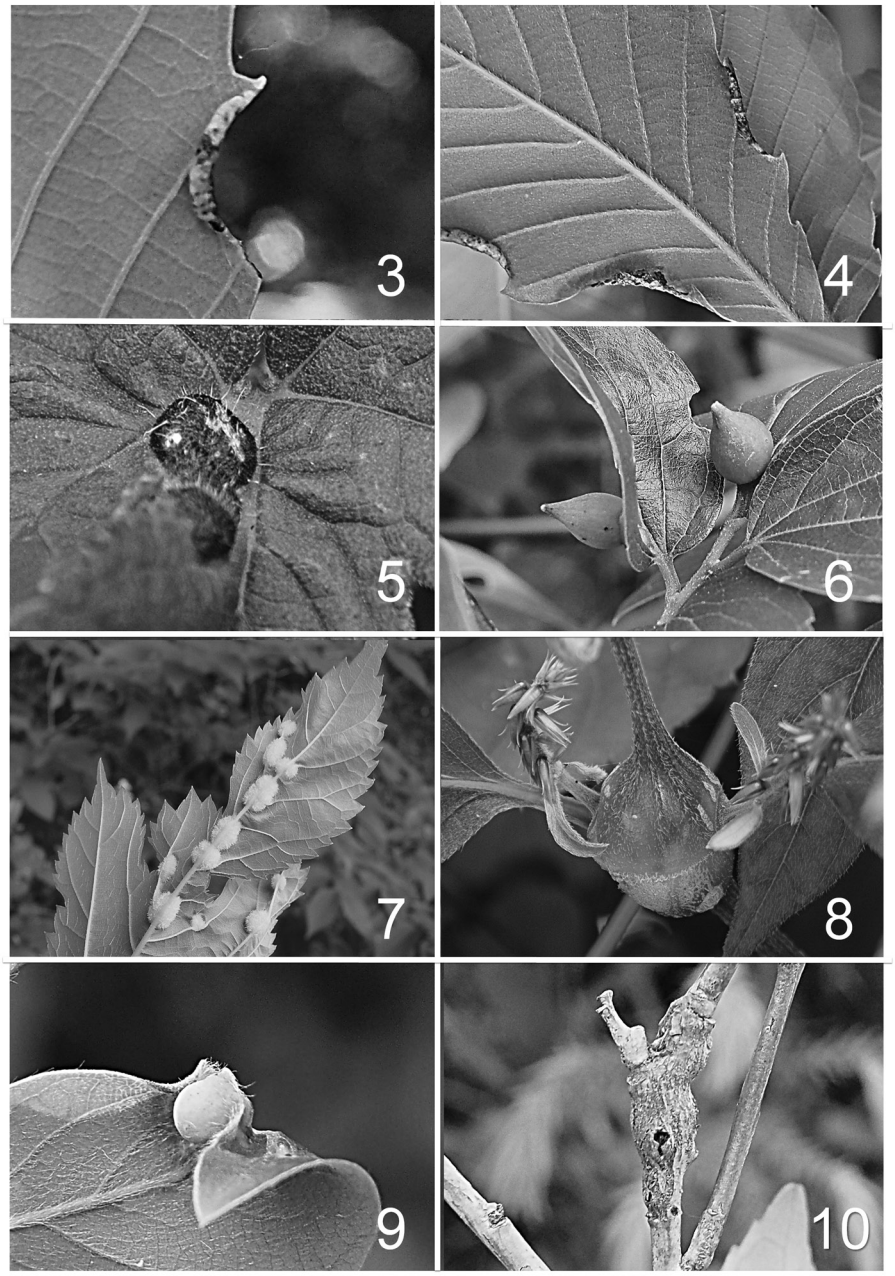
8. Stem gall induced by an unidentified cecidomyiid on *Eurya japonica* Thunb. (Fig. 10).
   Japanese name: Hisakaki-eda-kobu-fushi (C-2760).
   Collecting data: 11.
   Remarks: This gall has been found in Honshu, Shikoku, Kyushu, Yakushima Island, Okinawa Island and Ishigaki Island. A similar gall is known to occur also on *E. emarginata* (Thunb.) Makino (Yukawa & Masuda 1996).

FABACEAE

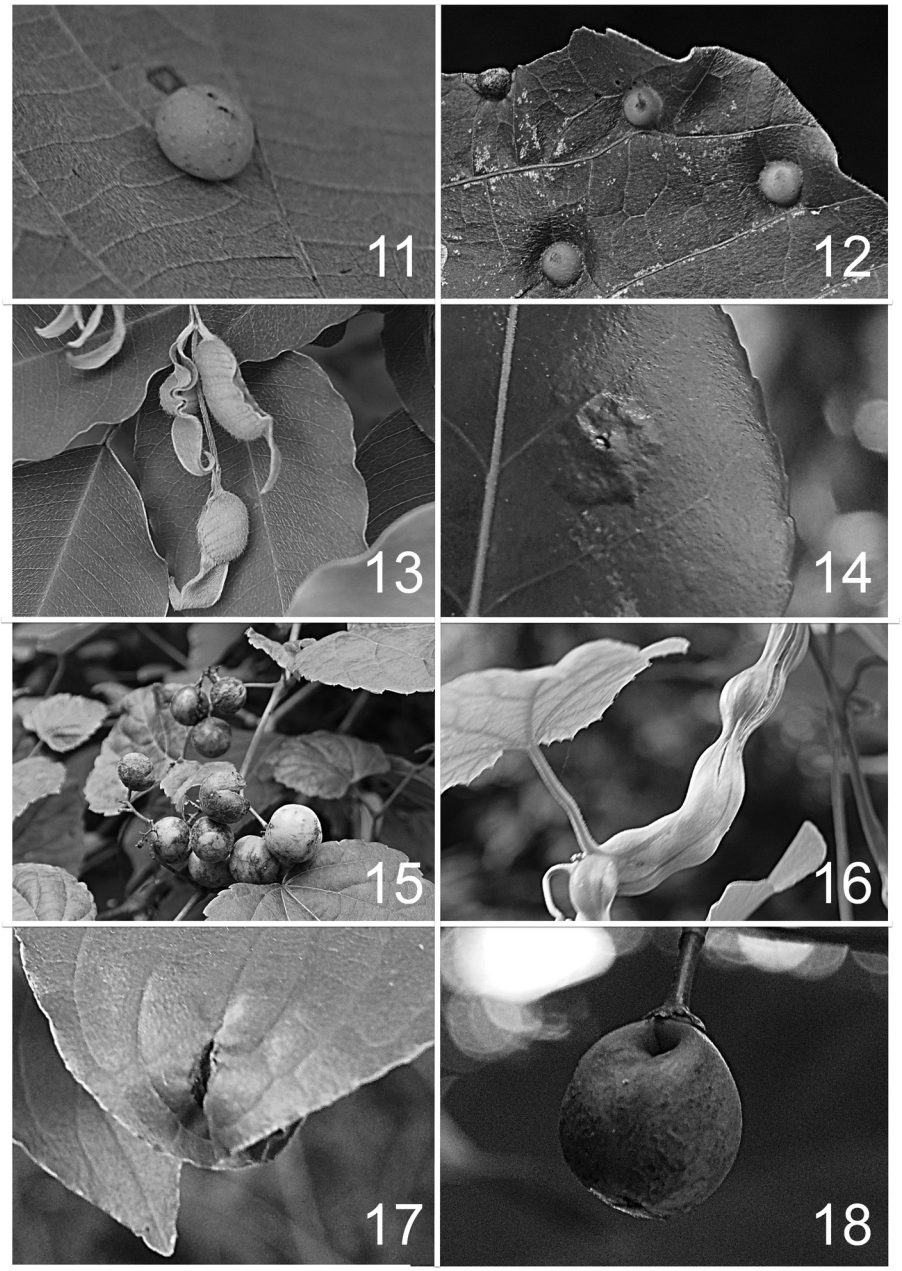
9. Leaf subglobular gall induced by an unidentified cecidomyiid on *Pueraria lobata* (Willd.) Ohwi (Fig. 11).
   Japanese name: Kuzu-ha-ura-tama-fushi (C-3380).
   Collecting data: 19.
   Remarks: This gall occurs commonly in Hokkaido, Honshu, Shikoku and Kyushu (Yukawa & Masuda 1996; Yukawa *et al*. 2012a).
10. Leaf lenticular gall induced by *Pitydiplosis puerariae* Yukawa, Ikenaga & Sato on *Pueraria lobata* (Willd.) Ohwi (Fig. 12).
    Japanese name: Kuzu-ha-togari-tama-fushi (C-3390a).
    Collecting data: 05, 08.
    Remarks: This gall midge is recorded from Hokkaido, Honshu, the Izu Islands, Sado Island, Shikoku, Kyushu, the Nansei Islands, Taiwan, China and the Korean Peninsula (Paik *et al*. 2004; Yukawa *et al*. 2012b; Yukawa 2014). The galls are frequently inhabited by larvae of an inquiline wasp, *Protanaostigma kyushuana* Masi (Hymenoptera: Tanaostigmatidae) (Yukawa *et al*. 2011).
11. Leaf fold gall induced by an unidentified cecidomyiid on *Lespedeza bicolor* Turcz. (Fig. 13).
    Japanese name: Yamahagi-ha-toji-tamago-fushi (C-3490a).
    Collecting data: 10.
    Remarks: This gall has been found in Honshu, Shikoku, Kyushu, the Korean Peninsula and the Russian Far East and is induced also on *L. cyrtobotrya* Miq. (Paik *et al*. 2004; Yukawa & Masuda 1996; Yukawa *et al*. 2012b).

CELASTRACEAE

12. Leaf gall induced by *Masakimyia pustulae* Yukawa & Sunose on *Euonymus japonicus* Thunb. (Fig. 14).
    Japanese name: Masaki-ha-fukure-fushi (C-3810a).
    Collecting data: 12.
    Remarks: This gall midge is recorded from Hokkaido, Honshu, Shikoku, Kyushu, the Nansei Islands, Jeju Island and the Korean Peninsula (Paik *et al*. 2004; Yukawa *et al*. 2012b; Yukawa 2014). There are variations in gall thickness and larval body color in *M. pustulae* (Sunose 1979, 1985). We found thin type galls inhabited by yellow type



Figures 3–10. Cecidomyiid galls found on Tsushima. 3. Downwardly rolled leaf-margin galls induced by an unidentified cecidomyiid on *Quercus serrata*; 4. A downwardly rolled leaf-margin gall induced by an unidentified cecidomyiid on *Quercus* sp; 5. Leaf galls induced by *Asteralobia humuli* on *Humulus japonicas*; 6. Leaf galls induced by *Celticecis japonica* on *Celtis sinensis*; 7. Leaf vein galls induced by an unidentified cecidomyiid on *Morus australis*; 8. A stem gall induced by *Lasioptera achyranthii* on *Achyranthes bidentata*; 9. A leaf gall induced by an unidentified cecidomyiid on *Lindera glauca*; 10. A stem gall induced by an unidentified cecidomyiid on *Eurya japonica*.



Figures 11–18. Cecidomyiid galls found on Tsushima (continued). 11. A leaf subglobular gall induced by an unidentified cecidomyiid on *Pueraria lobata*; 12. Leaf lenticular galls induced by *Pitydiplosis puerariae* on *Pueraria lobata*; 13. Leaf folded galls induced by an identified cecidomyiid on *Lespedeza bicolor*; 14. A leaf gall (thin type) induced by *Masakimyia pustulae* on *Euonymus japonicas*; 15. Fruit galls induced by *Asphondylia baca* on *Ampelopsis glandulosa* var. *heterophylla*; 16. Stem galls induced by *Lasioptera* sp. on *Trichosanthes cucumeroides*; 17. A leaf-vein gall induced by an unidentified cecidomyiid on *Swida macrophylla*; 18. A fruit gall induced by *Asteralobia* sp. on *Trachelospermum asiaticum*.

larvae as has been noted in Sunose (1981).

VITACEAE

13. Fruit gall induced by *Asphondylia baca* Monzen on *Ampelopsis glandulosa* (Wall.) Momiy. var. *heterophylla* (Maxim.) Momiy. (Fig. 15).
Japanese name: Nobudou-mi-fukure-fushi (C-3860a).
Collecting data: 09b.
Remarks: *Asphondylia baca* occurs in Hokkaido, Honshu, the Izu Islands, Sado Island, Shikoku, Kyushu and the Korean Peninsula (Paik *et al*. 2004; Yukawa 2014). This gall midg is known to exhibit host alternation between plants of Vitaceae in summer-autumn and *Weigela* spp. of Caprifoliaceae in winter-spring (Uechi *et al*. 2004).

CUCURBITACEAE

14. Stem gall induced by *Lasioptera* sp. on *Trichosanthes cucumeroides* Max. (Fig. 16).
Japanese name: Karasuuri-kuki-fukure-fushi (C-4100a).
Collecting data: 09b.
Remarks: This gall has been found in Hokkaido, Honshu, Shikoku, Kyushu, Iki Island, Tanegashima Island and the Nansei Islands, and similar galls are induced on various species of Cucurbitaceae in Japan (Yukawa *et al*. 2014).

CORNACEAE

15. Leaf vein gall induced by an unidentified cecidomyiid on *Swida macrophylla* (Wall.) Soják (Fig. 17) and *Swida controversa* (Hemsl. ex Prain) Soják.
Japanese name: Kumanomizuki-ha-myaku-fukure-fushi (C-4140a), Mizuki-ha-myaku-fukure-fushi (C-4140b).
Collecting data: 09a for the galls on *S. macrophylla* and 11 for those on *S. controversa*.
Remarks: The galls on *S. macrophylla* have been found in Kyushu and those on *S. controversa* in Hokkaido and Honshu (Yukawa & Masuda 1996). Recently we found the galls on the latter in Fukuoka Prefecture, Kyushu (unpublished data).

ARALIACEAE

16. Flower bud gall induced by *Asphondylia* sp. on *Hedera rhombea* (Miq.) Bean (see p. 75 in Yukawa & Masuda 1996 for a photograph of the flower bud galls).
Japanese name: Kiduta-tsubomi-fukure-fushi (C-4170).
Collecting data: 22.
Remarks: This gall has been found in Honshu, Toshima Island and Kyushu (Yukawa & Masuda 1996; Tokuda & Kawauchi 2013a).

OLEACEAE

17. Fruit gall induced by *Asphondylia sphaera* Monzen on *Ligustrum japonicum* Thunb. (see p. 79 in Yukawa & Masuda 1996 for a photograph of the fruit galls).
Japanese name: Nezumimochi-mi-midori-fushi (D-0270a).
Collecting data: 15, 16.
Remarks: This gall midge is recorded from Honshu, the Izu Islands, Shikoku,

Kyushu, Tsushima Island, the Nansei Islands and the Korean Peninsula (Yukawa *et al*. 2012b; Yukawa 2014). *Rhus succedanea* L. and *R. sylvestris* Sieb. & Zucc. (Anacardiaceae) are known as short-term alternative host plants of *A. sphaera* (Uechi & Yukawa 2006).

APOCYNACEAE

18. Fruit gall induced by *Asteralobia* sp. on *Trachelospermum asiaticum* (Sieb. & Zucc.) Nakai (Fig. 18).
Japanese name: Teikakazura-misaki-fukure-fushi (D-0330a).
Collecting data: 20.
Remarks: This gall has been found in Honshu, the Izu Islands and Kyushu (Yukawa & Masuda 1996; Tokuda *et al*. 2012).

LAMIACEAE

19. Bud gall induced by an unidentified cecidomyiid on *Isodon inflexus* (Thunb.) Kudô (Fig. 19).
Japanese name: Yamahakka-me-fukure-fushi (D-0520).
Collecting data: 21.
Remarks: This gall has been found in Honshu and Kyushu (Yukawa & Masuda 1996).

ASTERACEAE

20. Leaf gall induced by *Rhopalomyia* sp. on *Chrysanthemum* sp. (Fig. 20).
Japanese name: Tentatively referred as Nojigiku-siro-ke-tama-fushi (D-0880a).
Collecting data: 13.
Remarks: Similar galls are induced on *Chrysanthemum japonense* (Makino) Nakai and *C. indicum* L. in Kyushu and Tanegashima Island (Yukawa & Masuda 1996; Nagai 2010; Yukawa *et al*. 2013).

21. Stem gall induced by *Rhopalomyia giraldii* Kieffer & Trotter on *Artemisia princeps* Pampan. (Fig. 21).
Japanese name: Yomogi-kuki-wata-fushi (D-1070a).
Collecting data: 01, 02a, 02b, 06, 07, 19.
Remarks: This gall midge is recorded from Hokkaido, Honshu, the Izu Islands, Sado Island, Shikoku, Kyushu, the Nansei Islands and the Korean Peninsula (Paik *et al*. 2004; Yukawa 2014).

22. Leaf gall induced by *Rhopalomyia cinerarius* Monzen on *Artemisia princeps* Pampan. (Fig. 22).
Japanese name: Yomogi-ha-siro-ke-tama-fushi (D-1130a).
Collecting data: 19.
Remarks: This gall midge is recorded from Hokkaido, Honshu, the Izu Islands, Sado Island, Shikoku, Kyushu, the Nansei Islands, Jeju Island, the Korean Peninsula and the Russian Far East (Yukawa *et al*. 2012b; Yukawa 2014).

23. Leaf gall induced by *Rhopalomyia yomogicola* (Matsumura) on *Artemisia princeps* Pampan. (Fig. 23).
Japanese name: Yomogi-ha-ebosi-fushi (D-1120a).

Collecting data: 01, 06, 09a.
Remarks: This gall midge is recorded from Hokkaido, Honshu, the Izu Islands, Sado Island, Shikoku, Kyushu, the Nansei Islands and the Korean Peninsula (Paik *et al*. 2004; Yukawa *et al*. 2012b; Yukawa 2014).

Cecidomyiid galls that were not found throughout the current surveys

During the field surveys, Mr. T. Satonaka and we, the authors, searched for cecidomyiid galls on 10 plant species that are known to host gall midges in Japan or the Korean Peninsula. However, we failed to find cecidomyiid galls on these plants. They are listed below together with information on searching sites.

1. Leaf galls induced by *Lasioptera* sp. on *Ficus nipponica* Fr. et Sav. (MORACEAE).
   Searching sites: 09a, 09b, 10, 11, 13, 14, 20, 21.
2. Leaf and flower bud galls induced by unidentified cecidomyiid species on *Fallopia japonica* (Houtt.) Ronse Decr. (POLYGONACEAE).
   Searching site: 20.
3. Leaf galls induced by an unidentified cecidomyiid species on *Deutzia scabra* Thunb. (HYDRANGEACEAE).
   Searching sites: 09a, 09b, 14, 21.
4. Stem galls induced by *Lasioptera* sp., leaf fold galls by *Dasineura* sp. and leaf bud galls by an unidentified species on *Rosa multiflora* Thunb. (ROSACEAE).
   Searching sites: 24, 25.
5. Several sorts of leaf gall induced by unidentified species on *Wisteria brachybotrys* Sieb. & Zucc. (FABACEAE).
   Searching site: 14.
6. Fruit galls induced by *Asphondylia* sp. on *Toxicodendron succedaneum* (L.) Kuntze (ANACARDIACEAE).
   Searching site: 23.
7. Fruit galls induced by *Asphondylia* sp. on *Celastrus orbiculatus* Thunb. (CELASTRACEAE).
   Searching site: 26.
8. Leaf galls induced by *Pseudasphondylia elaeocarpini* Tokuda & Yukawa on *Elaeocarpus sylvestris* (Lour.) Poir. var. *ellipticus* (Thunb.) Hara (ELAEOCARPACEAE).
   Searching site: 28.
9. Leaf vein galls induced by *Lasioptera camelliae* Ohno & Yukawa on *Camellia japonica* L. (THEACEAE).
   Searching sites: 09a, 09b, 10, 14.
10. Fruit galls induced by *Kiefferia* sp. on unidentified species of *Angelica*, *Torilis* or other genera (APIACEAE).
    Searching site: 27.
    Remarks: *Kiefferia pericarpiicola* Bremi induces fruit galls on various species of Apiaceae in the Palaearctic Region (e.g. Barnes 1946; Kovalev 1964). In recent years, Mr. T. Minami and we, the authors, found similar sorts of fruit gall on several plant species of Apiaceae, respectively in Hokkaido, Japan (personal communication)

and the Korean Peninsula (unpublished data). However, such fruit galls have never been found in Kyushu.

Discussion

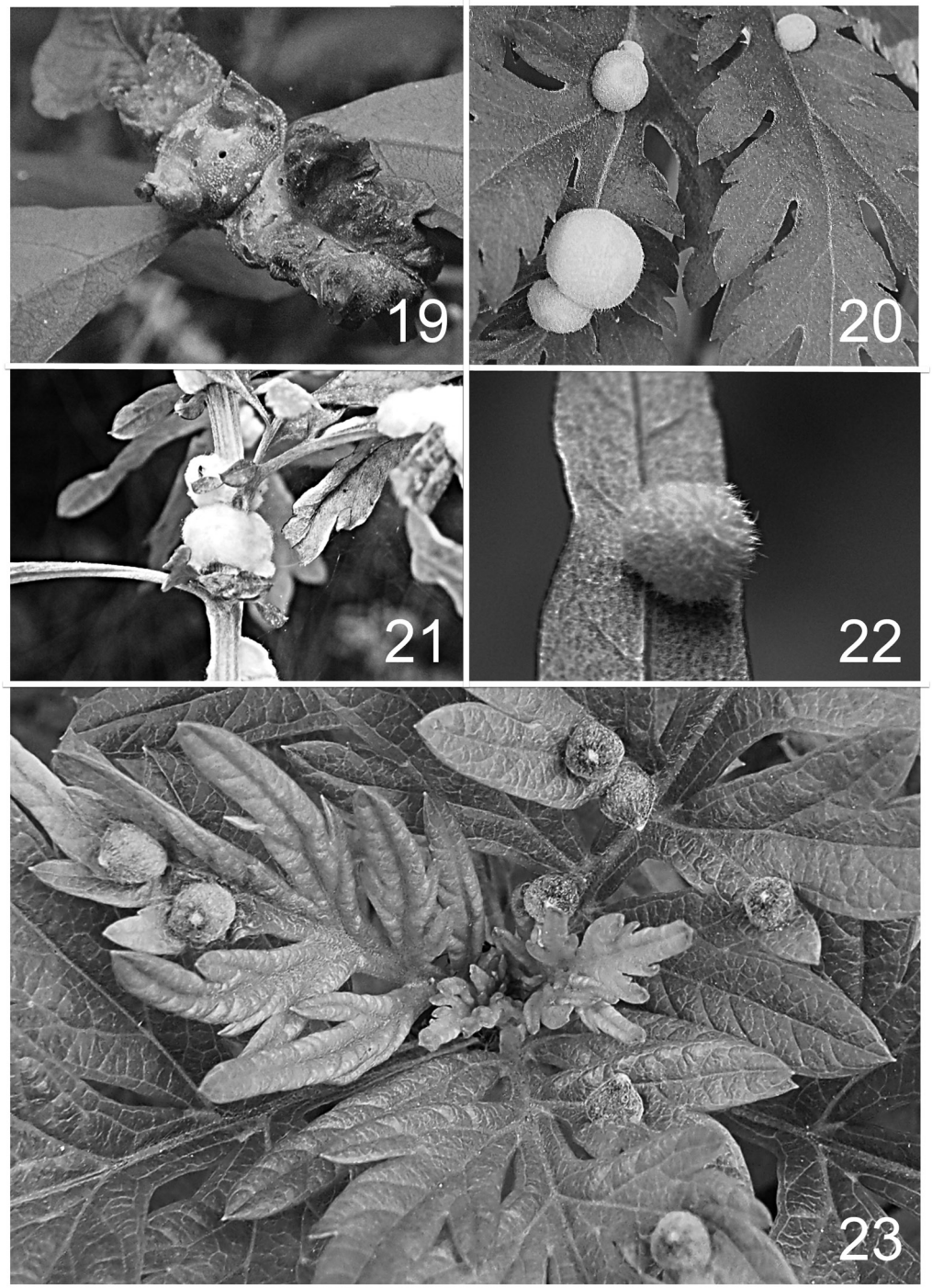
So far, 203 sorts of cecidomyiid gall have been found in Kyushu (e.g. Yukawa 1976, 1978, 1982, 1988; Yukawa & Masuda 1996; Uechi *et al*. 2002; Kodoi *et al*. 2003; Tokuda & Yukawa 2003; Tokuda *et al*. 2004; Ganaha *et al*. 2006; Tokuda & Yukawa 2006; Tokuda *et al*. 2006; Uechi & Yukawa 2006; Uechi *et al*. 2007; Nagai 2010, 2011, 2012; Uechi *et al*. 2012; Yukawa *et al*. 2012a; Tokuda & Kawauchi 2013b; Kim *et al*. 2014; Mishima *et al*. 2014; Nagai 2014; Yukawa *et al*. 2014). In addition, at least 66 sorts of newly found galls are waiting to be recorded from Kyushu (Yukawa *et al*. unpublished). Thus, a total of 269 (203+66) sorts of cecidomyiid gall are now known to occur in Kyushu. Among 23 sorts of cecidomyiid gall that were found on Tsushima, 22 sorts (95.7 %) also occur in Kyushu, which is equivalent to 8.2 % of 269 sorts recorded from Kyushu. The remaining one sort on *Lindera glauca* (Lauraceae) has been known from Honshu.

From the Korean Peninsula (including Jeju Island that is located in the East China Sea: Fig. 1), 67 sorts of cecidomyiid gall have been recorded (Paik *et al*. 2004; Yukawa *et al*. 2012b). Among the 23 sorts found on Tsushima, 11 (47.8 %) of them also occur in the Korean Peninsula, which is equivalent to 16.4 % of the 67 sorts.

It is remarkable that the gall-inducing cecidomyiid fauna of Tsushima is more similar to that of Kyushu (95.7 %) than to that of the Korean Peninsula (47.8 %) even though the island is more distant from Kyushu than from the peninsula (Fig. 1). This may be partially attributed to the fact that the gall-inducing cecidomyiid fauna has been more intensively surveyed in Kyushu (269 sorts) than in the Korean Peninsula (67 sorts). Although further field surveys are needed to confirm this aspect, we consider that the gall-inducing cecidomyiid fauna of Tsushima is actually similar to that of Kyushu rather than the Korean Peninsula. Because Tsushima is more similar to Kyushu than the Korean Peninsula in the vegetation represented by plants of warm temperate forests due to the Tsushima warm current (Nagasaki Biological Society 1976), gall-inducing cecidomyiids that are closely associated with their host plants, naturally result in a higher similarity between the faunas of Tsushima and Kyushu.

During the current field surveys, we failed to find cecidomyiid galls on some plant species than are known to host gall midges in Japan or the Korean Peninsula. We need further intensive field surveys on Tsushima, particularly in seasons from November to the following April because we have not visited the island in these seasons. We know that some cecidomyiid galls can be relatively easily detected during winter and that other galls on deciduous trees can be seen only in early spring. Field surveys in such seasons will lead to increased numbers of cecidomyiid galls that are common to Kyushu and the Korean Peninsula.

Yukawa *et al*. (2000) and Thornton *et al*. (2002) evaluated the role of Sebesi and Sebuku, two stepping stone islands between the Krakatau Islands and Sumatra,



Figures 19–23. Cecidomyiid galls found on Tsushima (continued). 19. Bud galls induced by an unidentified cecidomyiid on *Isodon inflexus*; 20. Leaf galls induced by *Rhopalomyia* sp. possibly on *Chrysanthemum japonense*; 21. Stem galls induced by *Rhopalomyia giraldii* on *Artemisia princeps*; 22. A leaf gall induced by *Rhopalomyia cinerarius* on *Artemisia princeps*; 23. Leaf galls induced by *Rhopalomyia yomogicola* on *Artemisia princeps*.

Indonesia, in the colonization of Krakatau by a wide variety of living organisms 100 years after sterilization of the islands in 1883 by the large volcanic eruption of Krakatau. They concluded that seasonal winds or currents have played a more important role in many cases than the existence of stepping stone islands, even though the islands are located at latitudes similar to those of Java and Sumatra. Partomihardjo *et al*. (2011) demonstrated that 52 sorts of arthropod galls were found on the Krakatau Islands during the period from 1982 to 2000 and many of them have colonized the islands from Java rather than from Sumatra, from which the former is about 40 km away without stepping stone islands.

Because Tsushima is located at latitudes different from those of the Korean Peninsula, insect populations invading from the peninsula seem to encounter more difficulty in establishing on Tsushima than those from Kyushu, probably because of different conditions of latitudinal factors, such as vegetation, temperature and daylength. Prevailing wind direction around Tsushima is northward in summer and southward in winter. Thus, the wind-dispersal of insects to Tsushima from the peninsula cannot be expected in summer. The Tsushima warm current flows from southwest to northeast (e.g. Isoda 2011) and insect dispersal by rafting depends on the direction of currents (e.g. Abe 1984). These conditions indicate that Tsushima may play a more important role as a stepping stone island in the northward expansion of Japanese insects than the southward expansion of Korean insects. Conversely speaking, most insects on Tsushima might have colonized form Japan or have existed there before Tsushima separated from the Japanese Archipelago.

Acknowledgements

We express our thanks to Dr. K.M. Harris (former Director of the International Institute of Entomology, UK) and Prof. T. Hirowatari (Kyushu University) for their critical reading of an early draft. Mr. T. Satonaka (Tsushima Branch, Agriculture and Forestry Department, Nagasaki Prefecture) found flower bud galls on *H. rhombea* and provided us with information on the forestry of the Tsushima Islands, to whom we are indebted. We are grateful to Mr. H. Yoshimura for collecting specimens of an unidentified cecidomyiid from *Lindera glauca*, Mr. T. Minami for collecting fruit galls of *Kiefferia* species on apiaceous plants, Dr. T. Sunose for collecting galls of *Asphondylia sphaera* from *Ligustrum japonicum*, Dr. T. Katsuda, Ms. M. Matsunaga and Mr. A. Nagai for collecting leaf-margin downwardly rolled galls from *Quercus serrata*. This is a contribution from the Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka (Series 7, No.13).

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