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http://hdl.handle.net/2324/2658
Distribution of Asteralobia Gall Midges (Diptera: Cecidomyiidae) Causing Axillary Bud Galls on Ilex Species (Aquifoliaceae) in Japan*

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Abstract. We revised and analyzed distributional information on two nominal and some unidentified Japanese Asteralobia species that produce axillary bud galls on Ilex species (Aquifoliaceae). Galls on I. maximowicziana are newly recorded from the Southwest Islands. Galls produced by respective Asteralobia species were collected from most of the distribution range of their host plants, whilst those on I. integra and on I. goshiensis were not found in some localities within the distribution range of the host plants. A wide and common distribution range of Asteralobia sasakii on I. crenata, I. crenata var. paludosa, and I. maximowicziana suggested a high dispersal ability of the species. Distribution patterns of Asteralobia soyogo on I. chinensis, I. integra, and I. pedunculosa indicated a possible host plant preference by the gall midge. An unidentified gall midge associated with I. warburgi is widely distributed in the Southwest Islands and gall dissection data as to age structure indicated that the gall midge might be different from A. sasakii.

Key words: Asteralobia, axillary bud gall, Cecidomyiidae, distribution, gall midge, Ilex.

* Contribution from the Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka (Ser. 5, No. 77)
Introduction

In gall-making cecidomyiids, some of closely related species are known to produce, respectively, a similar sort of gall on different plant species within a single or related plant genera. In Japan, examples have been shown in Asteralobia gall midges on Ilex species (Aquifoliaceae) (Yukawa & Masuda, 1996) and Lasioptera gall midges on wild gourds (Miyatake et al., 2000). In this paper, we refer to the Asteralobia gall midges on Ilex. They are suitable materials to study a possible process of speciation or host race formation in herbivores.

The genus Asteralobia consists of 10 species in the world, five of them being distributed in Japan and the remainders in Russian Far East (Kovalev, 1964; Yukawa, 1971; Yukawa, 1983). Among them, two Japanese species are associated with Ilex species (Yukawa, 1971; Yukawa & Masuda, 1996). Asteralobia sasakii (Monzen) makes axillary bud galls on Ilex crenata Thunb. (Monzen, 1937) and Asteralobia soyogo (Kikuti) on Ilex pedunculosa Miq. (Kikuti, 1939). Thereafter, a similar sort of axillary bud gall caused by congeneric cecidomyiids was successively found on I. chinensis Sims., I. crenata var. paludosa (Nakai) Hara, I. goshtiensis Hayata, I. integra Thunb., I. leucoclada (Maxim.) Makino, I. liukiuensis Loes., and I. warburgi Loes. (Shinji, 1944; Yukawa, 1976; Yamauchi et al., 1982; Yukawa, 1982; Yukawa & Sunose, 1988; Yukawa & Masuda, 1996). These cecidomyiids were tentatively included in A. sasakii in Yukawa & Masuda (1996), but their morphological features have never been compared among gall midges on different host species and the distributional information of respective gall midges has been fragmentary.

In order to identify these gall midges at the species level and to approach the process of speciation or host race formation, we have to synthesize various information such as their distribution range, morphological characters, DNA sequences, and other ecological data.

In this paper, we refer to the distribution range of respective Japanese Asteralobia gall midges on different Ilex species, as the first step toward a future evolutionary study. Distributional information, when combined with phylogenetic relations, will serve to analyze the shift of distribution range.

Materials and Methods

We collected axillary bud galls on Ilex spp. at various localities in Japan. Our colleagues also gave us many galls and their distributional information. Some of the collected galls were dissected under a binocular microscope to obtain larval and pupal specimens. Remaining galls were maintained in plastic containers (15 cm in diameter, 25 cm in depth) to rear adult midges. Mature larvae, pupae, and emerged adults were put into 75% ethanol
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for morphological observation and 99.5% acetone for DNA analysis.

In the present paper, we arranged the collecting records of Asteralobia midge galls according to the alphabetical order of plant species. Each collecting record consists of host plant, locality, collecting date, collector, developmental stages of the gall midge, and some other biological information. The names of Japanese main islands are abbreviated in brackets as HK (Hokkaido), HS (Honshu), SH (Shikoku), KY (Kyushu), and SW (the Southwest Islands south of Yakushima Is.), and followed by the names of prefectures. The names of locality with an asterisk mean that the galls have previously been recorded in the same place. The collecting dates with a plus mark mean that the galls were collected there more than one time.

Some collector’s names are abbreviated as follows: IM (=I. Matoba), HN (=H. Nishio), JY (=J. Yukawa), MT (=M. Tokuda), MY (=M. Yukinari), NU (=N. Uechi), and TS (= T. Sunose).

Localities where Ilex galls were found in the previous and present field surveys were plotted on maps to indicate the distribution range of respective gall midges. Upon the maps, we illustrated the distribution range of respective host plants based on Hatusima (1971), Horikawa (1972), and Yamazaki (1989).

The gall midges associated with I. goshiensis and I. liukiensis have never been identified due to the lack of their adult specimens (Yukawa & Masuda, 1996). Because the structure and size of their galls are somewhat different from those on other Ilex spp. (Yamauchi et al., 1982; Yukawa & Masuda, 1996), they may not belong to the genus Asteralobia. However, we included their distributional information in this paper.

Results

Ilex chinensis (Fig. 1A) [see also Yukawa, 1988]


*Ilex crenata* (Fig. 1B) [see also Ijichi, 1937; Yano, 1964; Sunose, 1981; Tamura, 1966; Usuba, 1979; Yukawa, 1971; Yukawa, 1988; Yukawa & Sunose 1988]


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Fig. 1. A-D: Collection records of axillary bud galls on *Ilex* spp. caused by *Asteralobia* gall midges; host plant — ●: *I. chinensis*, ★: *I. crenata*, ☆: *I. crenata var. paludosa*, ▲: *I. leucoclada*, ■: *I. integra*, ◆: *I. pedunculosa*. The shaded area in Fig. 1A, 1B, 1C, and 1D indicates the distribution range of *I. chinensis*, *I. crenata*, *I. integra*, and *I. pedunculosa*, respectively. The area surrounded by a broken line in Fig. 1B and 1C indicates the distribution range of *I. crenata var. paludosa* and *I. leucoclada*, respectively.

*The Southwest Islands.
The distribution of *Asteralobia* gall midges on *Ilex* is shown on these maps, with points indicating their occurrence on various islands in Japan including Hokkaido, Honshu, Shikoku, Kyushu, Sadogashima Is., Chushima Is., Miyakejima Is., Nijima Is., Hachijojima Is., and The Izu Isls.
Ilex crenata var. paludosa (= Ilex crenata subsp. radicans) (Fig. 1B) [see also Yukawa, 1976; Yukawa & Sunose, 1979; Sunose, 1982; Yukawa & Sunose, 1988; Yukawa, 1994]


Ilex goshiensis (Fig. 2A) [see also Yamauchi et al., 1982]


Ilex integra (Fig. 1C) [see also Usuba, 1979; Yukawa, 1988; Yukawa et al., 2000]


Ilex leucoclada (Fig. 1C) [see also Yukawa, 1982]

Fig. 2. A-C: Collection records of axillary bud galls on Ilex spp. caused by Asteralobia gall midges; host plant — ●: I. goshiensis, ▲: I. liukiuensis, ■: I. warburgii, ★: I. maximowicziana, ☆: I. maximowicziana var. kanehirae.

The shaded area in Fig. 2A, 2B, and 2C indicates the distribution range of I. goshiensis, I. liukiuensis, and I. maximowicziana, respectively. The area surrounded by a broken line in Fig. 2B and 2C indicates the distribution range of I. warburgii and I. maximowicziana var. kanehirae, respectively.
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Ilex liukiuensis (Fig. 2B) [see also Yamauchi et al., 1982]

Ilex maximowicziana Loes. (New gall record) (Figs. 2C & 3)

Ilex pedunculosa (Fig. 1D) [see also Yano, 1964; Yukawa, 1971; Yukawa, 1988]
Fig. 3. An axillary bud gall caused by Asteralobia sp. on Ilex maximowicziana. Arrows point toward the exit holes of the gall midge.

Discussion

The distribution range of Asteralobia gall midges is summarized in Table 1. The gall midges were collected from most of the distribution range of respective host plants. Although axillary bud galls have never been found on I. leucoclada in Hokkaido, and on I. liukiuensis on Tanegashima Is. and Yakushima Is., more frequent field surveys will provide us with further information in these areas.

Galls on I. integra have never been recorded from the Southwest Islands and those on I. goshiensis in Honshu, Shikoku, and Kyushu, even though frequent surveys have been performed (e.g. Yamauchi et al., 1982; Yukawa, 1976; Yukawa, 1988; present data). The main difficulty in talking about the distribution range of a species is the reliance to be placed on absences. A species may be erroneously recorded as absent when collecting has been insufficient or at the wrong season, or when a species is rare (Yukawa, 1984). In the
Table 1. Distribution range of gall midges producing axillary bud galls on Ilex in Japan.

<table>
<thead>
<tr>
<th>Host plant</th>
<th>HK</th>
<th>HS</th>
<th>SH</th>
<th>KY</th>
<th>SW</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>I. chinensis</em></td>
<td>−</td>
<td>⬤</td>
<td>⬤</td>
<td>⬤</td>
<td>−</td>
</tr>
<tr>
<td><em>I. crenata</em></td>
<td>−</td>
<td>⬤</td>
<td>⬤</td>
<td>⬤</td>
<td>−</td>
</tr>
<tr>
<td><em>I. c. var. paludosa</em></td>
<td>⬤</td>
<td>⬤</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td><em>I. goshiensis</em></td>
<td>−</td>
<td>⬤</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td><em>I. integra</em></td>
<td>−</td>
<td>⬤</td>
<td>⬤</td>
<td>⬤</td>
<td>−</td>
</tr>
<tr>
<td><em>I. leucoclada</em></td>
<td>⬤</td>
<td>⬤</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td><em>I. liukiensis</em></td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>⬤</td>
<td>⬤</td>
</tr>
<tr>
<td><em>I. maximowicziana</em></td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td><em>I. m. var. kanehirae</em></td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td><em>I. pedunculosa</em></td>
<td>−</td>
<td>⬤</td>
<td>⬤</td>
<td>⬤</td>
<td>−</td>
</tr>
<tr>
<td><em>I. warburgi</em></td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>⬤</td>
</tr>
</tbody>
</table>

Abbreviations and symbols indicated in Table 1 are as follows: HK: Hokkaido; HS: Honshu; SH: Shikoku; KY: Kyushu; SW: The Southwest Islands; −: Host plant is not distributed; ⬤: Host plant is distributed but gall midge has never been recorded; ⬤: Both host plant and gall midge are distributed.

* Host plant is distributed only on Tanegashima Is. and Yakushima Is.

case of gall midges associated with Ilex spp., we can easily find galls at any seasons because galls remain on the host trees long after the event of galling (Yukawa & Masuda, 1996). In addition, galls on other Ilex spp. than *I. integra* and *I. goshiensis* were frequently found in the Southwest Islands and in Honshu, Shikoku, and Kyushu, respectively (Figs. 1 & 2). Therefore, these gall midges may well be absent from aforementioned areas. If so, these distribution patterns, when combined with phylogenetic data, will contribute to discussing host plant and distribution range shift by the respective cecidomyiid species.

Our preliminary data of DNA analysis (Tokuda & Yukawa, unpublished data) indicate that gall midges associated with *I. crenata* var. *paludosa*, and *I. maximowicziana* are possibly identical with *A. sasakii* on *I. crenata*. This gall midge is distributed most widely and commonly in Japan including Sadogashima Is. (Yukawa & Sunose 1988) and the Izu Isls. (Sunose, 1981) (Figs. 1B & 2C). Such a wide and common distribution pattern seems to suggest that the gall midge has a high dispersal ability compared to others.

Gall midges associated with *I. chinensis* and *I. integra* are mainly distributed in Shikoku, Kyushu, and western parts of Honshu (Figs. 1A & 1C). Based on adult morphology and DNA analysis (Tokuda & Yukawa, unpublished data), we suspect that these two gall midges are identical with *A. soyogo* that produces axillary bud galls on *I. pedunculosa* in the same areas (Fig. 1D).

*Ilex integra* is distributed widely in Japan except Hokkaido and northern parts of Honshu (Fig. 1C; Horikawa, 1972), but the galls on this plant have been collected from some
restricted parts of eastern Honshu (Chiba and Kanagawa Prefectures) and Tanegashima Is. (Kagoshima Prefecture) (Fig. 1C), where I. chinensis and I. pedunculosa are not distributed (Figs. 1A & 1D). Similarly in Kyushu, we collected galls from I. integra at several localities where both I. chinensis and I. pedunculosa were not found. In addition, many galls were found on I. pedunculosa trees but not on I. integra trees, even though they (a total of 130 trees) grow sympatrically at Kamiyama Forest Park (Kamiyama Town, Tokushima Prefecture) (Masaaki Yukinari, 2001, personal communication). At Ino (Hisayama Town, Fukuoka Prefecture), we observed a similar phenomenon between co-existing I. chinensis and I. integra trees. The former bears galls but the latter does not. These results suggest a possibility that A. soyogo prefers I. pedunculosa and I. chinensis to I. integra for galling.

An unidentified gall midge associated with I. warburgi is widely distributed in the Southwest Islands (Fig. 2B). This species was still 3rd instar in early March when A. sasakii already pupated in the galls on I. maximowicziana in Ishigakijima Is. and Iriomotejima Is. Therefore, this gall midge seems to emerge later in the season than A. sasakii, suggesting that they are temporally isolated and not identical.

Acknowledgements

We wish to express our thanks to Dr. S. Kobayashi (Faculty of Science, Kyushu Univ.) for identifying Ilex species collected from Ishigakijima Is. and Iriomotejima Is. and to Mr. M. Yukinari (Tokushima City) for giving us useful host information and galls on Ilex at Kamiyama Forest Park, Tokushima Prefecture. Our thanks are also due to the following persons for offering materials: Dr. Y. Abe (Kyoto Pref. Univ.), Mr. S. Fukuda (Hachinohe City), Mr. S. Gotoh (Tanabe City), Dr. S. Hatusima (Prof. Emeritus at Kagoshima Univ.), Mr. I. Honda (Ishikawa Pref.), Mr. H. Ikenaga (Nat. Food Res. Inst.), Ms. E. Kimura (Aomori City), Dr. K. Kiritani (Ito City), Ms. N. Kuroiwa (Fukuoka Pref.), Mr. I. Matoba (Wakayama Pref. Mus. of Nat. Hist.), Prof. Y. Miyatake (Osaka Aoyama Junior College), Dr. A. Mori (Univ. of Notre Dame, USA), Prof. A. Nakanishi (Mus. of Nature & Human Activities, Hyogo), Ms. H. Nishio (Fukuoka Pref.), Mr. K. Ogata (Nishino-omote City), Dr. H. Sato (Forestry & Forest Reproduct Res. & Ext. Cen.), Mr. T. Sanui (Forest Exp. Stn. Miyazaki Pref.), Dr. H. Sato (Forestry & Forest Reproduct Res. Inst.), Mr. Y. Sato (Kagoshima Pref. Forest Exp. Stn.), Miss M. Shoubu (Entomological Laboratory, Kyushu Univ.), Dr. M. Sueyoshi (Japanese Science and Technology Corporation: Domestic fellow at Forestry & Forest Reproduct Res. Inst.), Dr. T. Sunose (Shirasagi Memorial Mus. of Nat. Hist.), Mr. K. Tabuchi (Chiba Univ.), Mr. K. Takahashi (Fukuoka Plant Protection Office, Chikugo Branch), Mr. S. Takasugi (Kanagawa Pref.), Mr. I. Togashi (Ishikawa Pref.), Mr. Y. Tohsaka (Kyoto Univ.), Dr. K. Yamagishi (Meijo Univ.), Mr. A. Yamamoto (Wakayama Pref.), and
Mr. Y. Yamashita (Kanagawa Pref.). Makoto Tokuda and Nami Uechi thank Dr. O. Tadauchi, Dr. S. Kamitani, and Mr. D. Yamaguchi (Entomological Laboratory, Kyushu Univ.) for their support.

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