Absence Record of Fagus Gall Midges (Diptera: Cecidomyiidae) on Ulleung Island, Korea and in North America

Sato, Shinsuke

Yukawa, Jun-ichi

https://doi.org/10.5109/2650

出版情報：ESAKIA. 41, pp.17-25, 2001-03-31. Entomological Laboratory, Faculty of Agriculture, Kyushu University
バージョン：

ESAKIA, (41): 17 - 25. March 31, 2001

Absence Record of *Fagus* Gall Midges (Diptera: Cecidomyiidae) on Ulleung Island, Korea and in North America*

Shinsuke SATO

Entomological Laboratory, Graduate School of Bioresource and Bioenvironmental Science,
Kyushu University, Fukuoka, 812-8581 Japan

and

Junichi YUKAWA

Entomological Laboratory, Faculty of Agriculture,
Kyushu University, Fukuoka, 812-8581 Japan

Abstract. Among 11 *Fagus* species (Fagaceae) recorded in the world, only 4 species, *Fagus sylvatica*, *Fagus hayatae*, *Fagus crenata*, and *Fagus japonica* are known to be galled by Cecidomyiidae (Diptera). In 2000 we attempted to find midge galls on *Fagus multinervis* on Ulleung Island, Korea, and to reconfirm the absence of midge galls on *Fagus grandifolia* in USA and on *Fagus mexicana* in Mexico. No *Fagus* midge gall was found on the island and in North America and we placed reliance on the absence of midge galls in these areas based on the total number of *Fagus* leaves examined. We discussed possible explanations for the distribution pattern of *Fagus* gall midges in relation to the distributional sift of *Fagus* under global climatic changes in the past.

Key words: *Fagus*, gall, Cecidomyiidae, Ulleung Island, North America, absence record.

Introduction

Coevolution between galling insects and host plants were well documented in Roskam (1981) for the gall midges of the genus *Semudobia* inhabiting birch catkins. Interrelations between *Fagus* gall midges and *Fagus* species also provide us with an interesting study subject of the coevolution.

The genus *Fagus* (Fagaceae) is divided into 2 subgenera, *Fagus* and *Engleriana* (Kato *et al.*, 2000). The former contains at least 7 species and the latter 4 species in the world (Table 1), but future taxonomic studies will possibly add a few more species to the genus (Hara, 1992). All known species are deciduous and distributed only in the temperate zone of the Northern Hemisphere between latitude 20° N and 60° N (Hara, 1992; Minaki, 1996). The distribution range of each species is restricted to a relatively small area, except that *Fagus grandifolia* Ehrhart and *Fagus sylvatica* Linnaeus are widely distributed in North America and Europe, respectively.

Among the 11 *Fagus* species in the world, the following 4 species, *Fagus*

---

* Contribution from the Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka (Ser. 5, No. 57).

Table 1. List of *Fagus* species in the world (modified from Hara, 1992 and Minaki, 1996).

Subgenus & Species	Distribution range
Subgenus *Fagus*	
Fagus crenata Blume	Japan (southern Hokkaido to Kyushu)
Fagus hayatae Palibin ex Hayata	Taiwan (northern part), China (Yangtze valley)
Fagus lucida Rehder et Wilson	China (Yangtze valley and south of the Yangtze River)
Fagus orientalis Lipsky	Europe (around the Caspian Sea and the Black Sea)
Fagus sylvatica Linnaeus	Europe (central to northern part)
Fagus grandifolia Ehrhart	USA (eastern part), Canada (south eastern part)
Fagus mexicana Martinez	Mexico (central)
Subgenus *Engleriana*	
Fagus japonica Maximowicz	Japan (northern Tohoku District to Kyushu)
Fagus multinervis Nakai	Korea (Ulleung Island)
Fagus engleriana Seemen	China (Yangtze valley)
Fagus longipetiola Seemen	China (south of the Yangtze River), Vietnam (northern part)

sylvatica, *Fagus hayatae* Palibin ex Hayata, *Fagus crenata* Blume, and *Fagus japonica* Maximowicz are known to be galled by Cecidomyiidae (Diptera). In Europe, 3 species of gall midge, *Mikiola fagi* (Hartig), *Hartigiola annulipes* (Hartig), and *Phegomyia fagicola* (Kieffer) are responsible for leaf galls on *F. sylvatica* and *Contarinia fagi* Rübsaamen for bud galls (Skuhravá, 1986). In Taiwan, unidentified gall midges are known to produce at least 4 sorts of leaf galls on *F. hayatae* that is a relic species with a very limited distribution (Yang *et al.*, 2000).

In Japan, there are 2 *Fagus* species, *F. crenata* and *F. japonica*. The former is common in the cool temperate zone, being distributed discontinuously from the lowland of Kuromatunai, Hokkaido to Mt. Takakuma, Kagoshima Prefecture. The latter is distributed from Iwate Prefecture to Miyazaki Prefecture and confined to mountainous regions near the Pacific Ocean. At least 28 sorts of midge gall have been known to occur on the leaves of these 2 species taken together (Yukawa, 1991; Yukawa & Masuda, 1996). Two sorts of them are produced only on *F. japonica*, 6 on both species, and 20 on *F. crenata* alone. These galls are considered to be produced by different gall midge species, respectively, since galls are fundamentally species-specific in shape and structure (Yukawa & Masuda, 1996).

No midge galls have been found on the remaining 7 *Fagus* species. In North America, *F. grandifolia* and *Fagus mexicana* Martinez have been surveyed possibly on many occasions, but *Fagus* midge galls have never been recorded (Felt, 1965; Gagné, 1989), which indicates the possible absence of midge galls on *Fagus* in North America. For 5 other species, no intensive field surveys have been performed to detect midge galls. In order to consider the phylogeny of *Fagus* gall midges, the presence or absence confirmation of midge galls on these *Fagus* species is essential. Therefore, in 2000 we attempted to find midge galls on *Fagus multinervis* Nakai that grows on Ulleung Island, Korea. In addition, we surveyed *F. grandifolia* in the southern part of Appalachian Mountains, USA and *Fagus mexicana* in Tutotepec, Mexico to reconfirm the absence record of midge galls on *Fagus* in North America.

In this paper, we report the results of our field surveys on Ulleung Island and in North America. We also discuss possible explanations for the distribution pattern of *Fagus* gall midges based on the distributional sift of *Fagus* under global climatic changes in the past (Wolfe & Leopold, 1967; Momohara, 1992; Yonebayashi, 1992 ; Kong, 2000).

Materials and Methods

Field surveys were performed at 5 localities (Fig. 1) and the time devoted to and

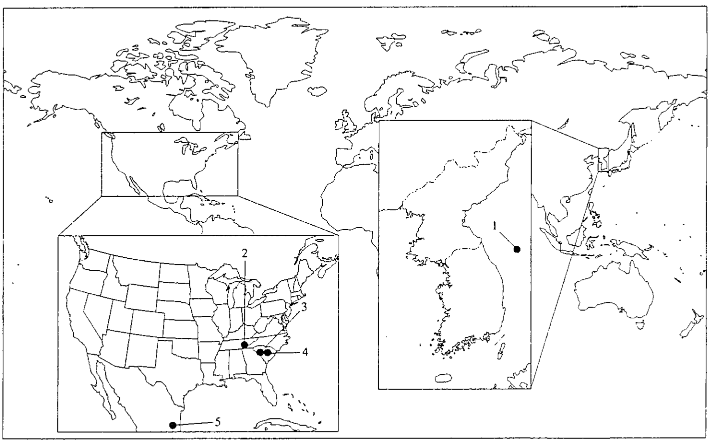

Fig. 1. Localities where *Fagus* midge galls were surveyed. Numbers indicate the localities as follows: 1, Mt. Seongin-bong, Ulleung Island, Korea; 2, Highlands Biological Station, NC, USA; 3, Clemson, SC, USA; 4, Oconee Station Cove, SC, USA; 5, Tutotepec, Mexico.

Table 2. Locality, date and intensity of surveys.

Locality	Date in 2000	Location	Alt. (m)	Time devoted (hr)	Number of examiners
Mt. Seongin-bong, Ulleung Is., Korea (Natural Forest)	May 31	N 37 ° 30′ E 130 ° 51′	600-984	3	1
Highlands Biological Station, NC, USA (Natural Forest)	Oct. 17	N 35 ° 03′ W 83 ° 12′	1250	0.5	2
Clemson, SC, USA (Univ. Botanical Garden)	Oct. 18	N 34 ° 41′ W 82 ° 50′	350	1	3
Oconee Station Cove SC, USA (Natural Forest)	Oct. 18	N 34 ° 50′ W 80 ° 05′	335	2	3
Tutotepec, Mexico (Natural Forest)	Oct. 22	N 20 ° 24′ W 98 ° 12′	1840	-	1

the number of persons engaged in the respective surveys are indicated in Table 2. In each locality except for Tutotepec, we randomly searched living and fallen leaves of *Fagus* species for midge galls. At Tutotepec, a total of 643 living and fallen *Fagus* leaves were collected and brought back to a lodging house to examine the galls.

We estimated the total number of leaves that were examined at the respective localities in order to express collecting intensity instead of searching time and the number of examiners (Table 2). For this estimation, we determined the number of leaves that can be examined by 1 person within 1 hour in the field, using our recent sampling data for *Fagus* midge galls in Japan. Then we referred to the gall densities of several Japanese *Fagus* gall midges to estimate the minimum number of leaves that should be examined to detect at least 1 midge gall in the field. The mean gall density per leaf was calculated based on the data for galled and ungalled *Fagus* leaves in various localities of Japan.

Results and Discussion

Results of field surveys

We could not find any midge gall on Mt. Seongin-bong, Ulleung Island, Korea, where we devoted at least 3 hrs to examining *F. multinervis* leaves. Similarly at 3 localities in USA, midge galls could not be found on *F. grandifolia* leaves during a total of 3.5 hr field survey. At Tutotepec, we collected and examined 263 living and 380 fallen leaves of *F. mexicana*, but no midge galls or their scars were detected on any of these leaves.

Estimation of the number of leaves examined at respective localities

Our sampling data for *Fagus* midge galls in Japan indicated that 1 person can

Table 3. Number of leaves that can be examined by 1 person within 1 hour in the field, data obtained from our recent samplings of *Fagus* midge galls in Japan.

Date in 1998	Locality	Time devoted (hr)	Total number of leaves examined
June 12	Mt. Shibi, Kagoshima Pref.	1	2005
Oct. 18	Fujisato, Akita Pref.	2	4503

Table 4. Estimated number of leaves that were possibly examined in the respective localities.

Locality	Time devoted (hr)	Number of examiners	Estimated number of leaves examined
Mt. Seongin-bong	3	1	6000
Highlands	0.5	2	2000
Clemson	1	3	6000
Oconee	2	3	12000

examine at least 2000 leaves in the field within 1 hour or at least 4000 leaves within 2 hours (Table 3). Based on this result, we converted the differently expressed collecting intensities (Table 2) into the estimated number of leaves that were possibly examined at respective localities (Table 4). The estimated number varied from 2000 in Highlands to 12000 in Oconee. At Tutotepec, 643 leaves were directly examined as mentioned earlier (Table 2).

Difficulties in assessing the reliability of absence record

The main difficulty in this study 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). Another difficulty is to evaluate the intensity of survey. The intensity is generally determined by such factors as the number of collectors, their skill and experience, the total time devoted to collection, and weather conditions.

In collecting midge galls, however, the skill and experience of collectors and the weather conditions can be neglected since galls are usually conspicuous and easily be recognizable in the field. In addition, we visited the localities in good collecting seasons when galls should be mature either on living leaves or on fallen leaves, and scars of gall, if any, should be recognizable on the leaves even after the fall of galls.

In order to overcome the insufficiency of field survey, we referred to *Fagus* midge gall densities in Japan and estimate the minimum sampling size or effort to detect at least 1 midge gall.

Midge gall densities in Japan tremendously varied with localities (Table 5), and the maximum density (Gifu Prefecture) was about 12000 times as great as the minimum (Akita Prefecture). Based on these data, the minimum sampling size for detecting at least 1 midge gall was calculated for the respective gall densities (Table 5). At the maximum gall density, the first midge gall can be detected by examining only 1 leaf, whilst at the minimum gall density, at least 1429 leaves should be examined to detect 1 midge gall.

Reliance of absent record on Ulleung Island and in North America

At least 6000 *F. multinervis* leaves were estimated to be examined on Ulleung Island, and a total of 20000 *F. grandifolia* leaves were examined in the USA (Table 4). Table 5 indicates that these numbers are far enough for detecting at least 1 midge gall, if any, in the field. Therefore, no findings of *Fagus* midge galls on Ulleung Island and in the USA indicate that their absent records are highly reliable.

In Tutotepec, there was no midge gall or scar on 643 *F. mexicana* leaves examined. The examined leaf number '643' in Tutotepec is situated between the minimum sampling size in Tottori Prefecture and that in Yamagata Prefecture (Table 5). In Japan there were only 2 cases in which an examination of more than 643 leaves was required before the detection of midge gall. In other cases, the first midge gall was detected before examining 527 leaves. In addition, when we tried to find *Fagus* midge galls in Japan, we have succeeded every time to find at least 1 midge gall in the first forest where we visited (Sato & Yukawa, unpublished). These data indicate a high probability that no *Fagus* gall midges are associated with *F. mexicana*.

Thus we reconfirmed by the field surveys the possible absence of midge galls on

Table 5. Minimum number of leaves that should be examined to detect at least 1 midge gall at respective localities in Japan.

Date	Locality	Mean gall density per leaf	Minimum number of leaves to detect at least 1 gall [a]
Dec. 5, 1990	Nonomata, Gifu Pref.	8.3995	1
Sep. 5, 1999	Kamiiso, Hokkaido Pref.	0.1686	6
Oct. 19, 1998	Hikarigahara Heights, Niigata Pref.	0.1218	9
Oct. 23, 1998	Togatani, Ishikawa Pref.	0.1122	9
Sep. 26, 1999	Mt. Takanawa, Ehime Pref.	0.0178	57
June 8, 1999	Mt. Kurodake, Oita Pref.	0.0156	65
Dec. 1, 1989	Mt. Karimata, Kumamoto Pref.	0.0138	73
Oct. 5, 1998	Mt. Kongo, Osaka Pref.	0.0073	137
Nov. 3, 1986	The Shiiya Pass, Miyazaki Pref.	0.0066	152
Oct. 20, 1998	Kamikoike, Fukui Pref.	0.0051	197
Oct. 19, 1998	Kaminodaira Heights, Nagano Pref.	0.0049	205
June 12, 1998	Mt. Shibi, Kagoshima Pref.	0.0022	455
Oct. 24, 1998	Mt. Daisen, Tottori Pref.	0.0019	527
Oct. 22, 2000	**Tutotepec**	-	**643** [b]
Oct. 15, 1998	Mt. Choukai, Yamagata Pref.	0.0009	1112
Oct. 18, 1998	Fujisato, Akita Pref.	0.0007	1429

[a] Minimum number = 1 / mean gall density.
[b] Actual number of leaves examined at Tutotepec, Mexico.

Fagus in North America which has been noted in Felt (1965) and Gagné (1989).

Historical back ground of Fagus *in the Korean Peninsula and on Ulleung Island*

A large area called Paleo-Ulleung Land existed in the area including the Korean Peninsula and Ulleung Island during the period from Miocene to late Pliocene (Yoon, 1997). On Paleo-Ulleung Land, volcanic activities had created a large magma dome, which has been remaining as Ulleung Island after the land has submerged deep in the sea (more than 1000m below the sea level) during Pleistocene (Yoon, 1997). Some fossil species of *Fagus* were collected from the soil layers of Miocene around the eastern coast of the Korean Peninsula (Kong, 2000). This indicates the existence of *Fagus* species in Paleo-Ulleung Land at that time. Thereafter, all *Fagus* species became extinct in the Korean Peninsula owing to cool and dry climate (Kong, 2000), but only *F. multinervis* has been surviving on Ulleung Island.

Explanations for the absence of midge galls on Fagus *on Ulleung Island*

In order to understand the absence of *Fagus* gall midges on Ulleung Island, there are 2 possible explanations: (1) after the isolation of Ulleung Island from the Korean Peninsula, gall midges that were associated with *F. multinervis* and other *Fagus* species on the island has become extinct by climatic changes under glacial periods; (2) gall midges were distributed in Paleo-Ulleung Land during Pliocene, but they were associated with other *Fagus* species than *F. multinervis*. After the isolation of Ulleung Island from the Korean Peninsula, the gall-bearing *Fagus* species have become extinct both in the Korean Peninsula and on Ulleung Island, but only non-gall bearing *F. multinervis* has been surviving on Ulleung Island.

These 2 explanations, however, cannot be examined since there is no fossil record of midge galls on *Fagus* in east Asia. The only data available for examination at the moment is the relative abundance in the sorts of midge gall between the subgenera *Fagus* and *Engleriana*. In Japan, *F. crenata* that belongs to the subgenus *Fagus* has much more sorts of midge gall than *F. japonica* that belongs to *Engleriana* (see introduction for actual figures). Therefore *F. multinervis* that belongs to *Engleriana* is considered to have a relatively small probability to be a gall-bearing species.

We must wait further surveys of *Fagus* and *Engleriana* in China before we refer the absence of midge galls on *F. multinervis* to the second explanation based on the relative abundance.

Historical back ground of Fagus *in Eurasia and North America*

Fagus forest, as well as other broad-leaved deciduous forests, was distributed continuously in northern Pacific across Beringia during early and middle Miocene (Wolfe & Leopold, 1967). At the same time, coniferous forests in the area were restricted to uplands. However, by late Miocene, the broad-leaved deciduous forests retreated from the area to the southward by climatic deterioration, whilst the coniferous forests extended from the uplands to lowland and apparently began to occupy large areas (Wolfe & Leopold, 1967). This indicates that the change of flora in the area during the period from middle to late Miocene resulted in the disjunction of broad-leaved deciduous forests between northwestern North America and northeastern Asia. During late Miocene, the Bering Strait between northwestern North America and northeastern Asia opened, which inhibited floristic interchange (Wolfe & Leopold, 1967).

The aforementioned history indicates that the disjunction of broad-leaved deciduous forests, including *Fagus* forest, already existed during the period from middle to late Miocene before opening of the Bering Strait.

Explanations for the absence of midge galls on Fagus *in North America*

There are 2 possible explanations for the absence of gall midges on *Fagus* in North America: (1) *Fagus* gall midges have become extinct by climatic changes under glacial periods (Gagné, 1989), although their host plants, as well as other deciduous broad-leaved trees, survived around the root of the Florida Peninsula during the most severe glacial period (about 20000-14000 years ago) (Yonebayashi, 1992); (2) *Fagus* gall midges have never been distributed in North America. They have evolved on *Fagus* species in the Eurasian Continent after opening of the Bering Strait, so that they could not expand their distribution range to North America.

As to the first explanation, there are 2 questions. Why have fossil midge galls on *Fagus* never been found in North America whilst those on other deciduous broad-leaved trees have been recorded during Oligocene-Miocene (Larew, 1992)? Why have *Fagus* gall midges become extinct whilst other gallers have been surviving on deciduous broad-leaved trees? The second question is based on the fact that intercontinental biotic combinations are common in gallers on deciduous tree genera except *Fagus*, even though broad-leaved deciduous forests in the northern Pacific were separated during late Miocene by climatic deterioration and opening of the Bering Strait (Wolfe & Leopold, 1967). For example, willow gall midges of the genus *Rabdophaga* and birch gall midges of the genus *Semudobia* are common both in Eurasia and in North America (Roskam, 1977; Roskam & van Uffelen, 1981; Gagné, 1984).

The second explanation may be supported by the fossil records in Eurasia. The oldest fossil of midge gall on *Fagus* was found in Spain from the soil layer of late Miocene after the disjunction of broad-leaved deciduous forests between northwestern North America and northeastern Asia (Diéguez *et al.*, 1996). Thereafter, fossils of *Fagus* midge galls were recorded from the soil layer of Pliocene after opening of the Bering Strait (Larew, 1992). If these fossil records indicate that *Fagus* gall midges have evolved in the Eurasian Continent, the second explanation seems to be more reliable than the first.

However, in order to determine which of the 2 explanations is more reliable, we need to construct the phylogenetic trees of both *Fagus* species and *Fagus* gall midges, particularly because the latter consists of species belonging to several different genera with different historical backgrounds (Skuhravá, 1986; Sato & Yukawa, unpublished). Therefore, further field surveys of midge galls on the remaining 5 *Fagus* species and the classification of unidentified *Fagus* gall midges are required.

Acknowledgements

We wish to express our cordial thanks to Dr. R. J. Gagné, Systematic Entomology Laboratory, Plant Science Institute, USDA, USA for his valuable comments on *Fagus* gall midges in North America, to Prof. R. Wyatt and Mr. B. Wycle, Highlands Biological Station, NC, USA for their kind cooperation in the field surveys, and to Prof. T. Yahara, Department of Biology, Kyushu University for his overall help for the field survey in Mexico. One of us, SS also thanks Assoc. Prof. O. Tadauchi and Assist. Prof. S. Kamitani, Entomological Laboratory, Kyushu University for their continuous guidance and support.

References

Diéguez, C., J. L. Nievesaldy & E. Barron, 1996. Fossil galls (Zoocecids) from the upper Miocene of La Cerdana (Lerida, Spain). *Rev. Palaeobot. Palynol.*, **94**: 329-343.

Felt, E. P., 1965. *Plant Galls and Gall Makers.* 364pp. Hafner, New York.

Gagné, R. J., 1984. The geography of gall insects. pp. 305-322, In Ananthakrishnan, T. N. (ed.) *Biology of Gall Insects*. Edward Arnold Ltd., London.

Gagné, R. J., 1989. *The Plant-feeding Gall Midges of North America*. xi+356pp, pls. Cornell Univ. Press, Ithaca, New York.

Hara, M., 1992. [The genus *Fagus* and *Fagus* stands in the world]. pp.43-48, In Endo, Y., M. Hara & T. Ohba (eds.) *Natural History of Beech Forests*. Natural History Museum and Institute, Chiba. (In Japanese.)

Kato, S., T. Koike, T. L. Thomas, F. H. Chang, K. Ueda & T. Mikami, 2000. Analysis of mitochondrial DNA of an endangered beech species, *Fagus hayatae* Palibin ex Hayata. *New Forests*, **19**: 109-114.

Kong, W. S., 2000. Vegetational history of the Korean Peninsula. *Global Ecology and Biogeography*, **9**: 391-402.

Larew, H. G., 1992. Fossil galls. pp.50-59, In Shorthouse, J. D. & O. Rohfritsch (eds.) *Biology of Insect-induced Galls*. Oxford Univ. Press, New York.

Minaki, M., 1996. [Beech forest and its relationship with people]. *The Iden*, **50**: 53-59. (In Japanese.)

Momohara, A., 1992. [Origin and evolution of the genus *Fagus*]. pp.56-60, In Endo, Y., M. Hara & T. Ohba (eds.) *Natural History of Beech Forests*. Natural History Museum and Institute, Chiba. (In Japanese.)

Roskam, J. C., 1977. Biosystematics of insects living in female birch catkins. I. Gall midges of the genus *Semudobia* Kieffer (Diptera, Cecidomyiidae). *Tijdschr. v. Ent.*, **120**: 153-197.

Roskam, J. C., & G. A. van Uffelen, 1981. Biosystematics of insects living in female birch catkins. III. Plant-insect relation between white birches, *Betula* L., section Excelsae (Koch) and gall midges of the genus *Semudobia* Kieffer (Diptera, Cecidomyiidae). *Neth. J. Zool.*, **31**: 533-553.

Skuhravá, M., 1986. Family Cecidomyiidae. pp.72-297, In Soós, A. & L. Papp (eds.) *Catalogue of Palaearctic Diptera Vol. 4, Sciaridae-Anisopodidae*. Elsevier, Amsterdam.

Wolfe, J. A. & E. B. Leopold, 1967. Neogene and early Quaternary vegetation of northwestern North America and northeastern Asia. pp.193-206, In Hopkins, D. M. (ed.) *The Bering Land Bridge*. Stanford Univ. Press, Stanford.

Yang, S. Y., M. Y. Chen & J. T. Yang, 2000. *Plant Galls in Taiwan*. 127pp. Taiwan Council of Agriculture, Taipei. (In Chinese.)

Yonebayashi, C., 1992. [Process of geohistorical establishment on *Fagus* forest]. pp. 61-66, In Endo, Y., M. Hara & T. Ohba (eds.) *Natural History of Beech Forests*. Natural History Museum and Institute, Chiba. (In Japanese.)

Yoon, S., 1997. Miocene-Pleistocene volcanism and tectonics in southern Korea and their relationship to the opening of the Japan Sea. *Tectonophysics*, **281**: 53-70.

Yukawa, J., 1984. Geographical ecology of the butterfly fauna of the Krakatau Islands, Indonesia. *Tyô to Ga*, **35**: 47-74.

Yukawa, J., 1991. [Gall midges producing galls on *Fagus crenata* and *Fagus japonica*]. *Forest Pests*, **40**: 198-205. (In Japanese.)

Yukawa, J. & H. Masuda, 1996. *Insect and Mite Galls of Japan in Colors*. 826pp. Zenkoku Nôson Kyôiku Kyôkai, Tokyo. (In Japanese.)