Zootaxa 3821 (2): 222–238
www.mapress.com/zootaxa/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

http://dx.doi.org/10.11646/zootaxa.3821.2.3
http://zoobank.org/urn:lsid:zoobank.org:pub:E68F3711-DB8E-4D6D-807A-BEA6275DC1B8

Description, host range and distribution of a new *Macrodiplosis* species (Diptera: Cecidomyiidae) that induces leaf-margin fold galls on deciduous *Quercus* (Fagaceae) with comparative notes on Palaearctic congeners

WANGGYU KIM[1], JUNICHI YUKAWA[1], KEITH M HARRIS[2], TSUNEO MINAMI[3], KAZUNORI MATSUO[1] & MAŁGORZATA SKRZYPCZYŃSKA[4]

[1]*Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka, Japan. E-mail: kincho3@gmail.com*
[2]*81 Linden Way, Ripley, Woking, Surrey, UK*
[3]*Asahikawa-shi, Hokkaido, Japan*
[4]*Agricultural University of Cracow, Poland*

Abstract

A gall midge that induces upwardly folded leaf-margin galls on *Quercus serrata*, *Q. mongolica* and *Q. dentata* (Fagaceae) in Japan and South Korea is described as *Macrodiplosis selenis* **sp. n.** (Diptera: Cecidomyiidae). *M. selenis* is distinguished from Palaearctic congeners by a combination of morphological characters. Genetic differences supported the result of morphological comparison and indicated that *M. selenis* is closely related to the European *M. roboris*, whose gall is similar to that of *M. selenis*.

Key words: DNA Barcode, eastern Palaearctic Region, identification

Introduction

Quercus (Linnaeus 1753) is a large genus in the family Fagaceae, consisting of at least 600 species in the Holarctic and Oriental Regions (Mabberley 1997). Various insects induce galls on *Quercus*, and cynipids (Hymenoptera) are the most abundant (e.g., Felt 1965; Yukawa & Masuda 1996; Abe *et al*. 2007). Species of gall midges (Diptera: Cecidomyiidae) that induce galls on *Quercus* are fewer in number than cynipids, 45 and 43 species having been recorded from the Palaearctic and the Nearctic Region, respectively (Gagné & Jaschhof 2014). Among gall midges, the genus *Macrodiplosis* Kieffer, 1895 is one of the main gall inducers on *Quercus*. Four Palaearctic and nine Nearctic species of *Macrodiplosis* have been previously described.

Monzen (1932) recorded an upwardly folded leaf-margin gall on *Quercus serrata* Murray from Mt. Hayachine and Morioka City, Iwate Prefecture, Japan. He thought that the gall was likely induced by *Macrodiplosis volvens* Kieffer, 1895, (now synonymized with *M. roboris* Hardy, 1854), but he did not definitively identify the gall inducer. Later, Shinji (1944) attributed the upwardly folded leaf-margin gall on *Q. serrata* to *Silvestrina quercifoliae* Shinji. However, since species of *Silvestrina* are known to be predators on mites or other minute arthropods (e.g., Gagné & Jaschhof 2014) his assumption was incorrect.

In addition, four other cecidomyiids are known to induce galls on *Quercus* in Japan (Yukawa & Masuda 1996): *Contarinia* sp. produces leaf-fold galls on *Q. acuta* Thunberg and *Q. glauca* Thunberg (Yukawa & Tsuda 1986); *Ametrodiplosis acutissima* (Monzen), makes twig galls on *Q. acutissima* Carruthers, *Q. dentata* Thunberg and *Q. variavilis* Blume (Yukawa & Masuda 1996); an unidentified species produces flattened circular leaf galls on *Q. dentata* and *Q. mongolica* Fischer (Yukawa 1982); a second unidentified species (*Macrodiplosis* sp. 2 in this paper) forms downwardly folded leaf-margin galls on *Q. mongolica* (Yukawa & Sunose 1979).

In 2011, upwardly folded leaf-margin galls were rediscovered on *Q. serrata* (Fig. 1) and *Q. dentata* (Fig. 2) in Fukuoka Prefecture, Japan, and subsequently on *Q. mongolica* (Fig. 3) in Hokkaido, Nagano and Fukuoka Prefectures. In 2012 and 2013, the same sort of gall was also found on *Q. serrata* in Ibaraki, Hyogo, Kagawa and

 Accepted by C. Borkent: 26 May 2014; published: 20 Jun. 2014

Discussion

Identification of the species. The percent divergence in COI sequences between *M. selenis* and other Palaearctic congeners were from 6.5 to 8.7%, which are distinctly higher than the 2% divergence proposed by Hebert *et al*. (2003) as an acceptable distance to consider two closely related entities as distinct species. Thus, the genetic analyses supported the morphological identification of *M. selenis*, indicating its occurrence in Japan and South Korea, and determining its host range (Fig. 34).

The analysis also indicates the existence of another species, *Macrodiplosis* sp. 2, which induces folded leaf-margin galls (downward type) on *Q. dentata* and *Q. mongolica* in Hokkaido and Miyazaki Prefecture, Japan. During the course of this study, we reared only a single male of *Macrodiplosis* sp. 2, terminalia of which are rather similar to those of *M. roboris* and *M. selenis* but distinctly different from those of *M. flexa* in the Russian Far East (cf. Fig. 18 in Kovalev 1972). *Macrodiplosis* sp. 2 will be described as a new species when more adults are obtained.

Various phylogenetic and evolutionary studies have demonstrated that gall shape and structure are 'extended phenotypes' of gall-inducing insects (e.g., Fukatsu *et al*. 1994; Stern 1995; Stone & Cook 1998; Nyman *et al*. 2000). The current genetic analysis also demonstrated that *M. selenis* and *M. roboris,* which share a similar gall shape (Figs 1, 5), are more closely related to each other than to other congeners with different gall shapes (Figs 34–35). Considerable genetic differences indicate that Palaearctic species have diverged widely from Nearctic species, with accompanying diversification of gall shape and structure.

These previously unreported molecular sequences will be helpful in identifying *Macrodiplosis* species, particularly when only larval specimens are available.

Host range and geographical distribution. The current study supports the previously known host range of *Macrodiplosis*, which is associated only with the genus *Quercus* in the Holarctic Region. This suggests possible species diversification of *Macrodiplosis* on a single host plant genus, as has been noted for other cecidomyiid genera (e.g., Skuhravá 1986; Roskam 1992; Yukawa *et al*. 2005; Gagné & Jaschhof 2014; Tokuda 2012; Gagné & Moser 2013). Information on geographical distribution is still limited, but collecting records from Hokkaido, Honshu, Shikoku, and Kyushu, Japan and Gyeongsangbukdo, South Korea indicate that *M. selenis* is widely distributed in Japan and Korea, suggesting possible occurrence in China and the Russian Far East. However, its distribution may not extend to the Oriental Region, as no galls of *Macrodiplosis* species have yet been found on evergreen *Quercus* species in southern Japan and southeastern Asia.

Acknowledgements

We express our sincere gratitude to R.J. Gagné (Systematic Entomology Laboratory, USDA) for reviewing an early draft of this paper and for providing us with specimens of Nearctic *Macrodiplosis*. We also thank C. Borkent, P. Kolesik and one anonymous referee for their valuable comments on the manuscript. We are very grateful to K. Matsunaga (Chikushino City), N. Gyotoku (Kurume City), M. Tokuda (Saga University), J.C. Paik (Sunchon National University, South Korea) and J. Moser (Southern Research Station of USDA Forest Service) for their support in collecting galls and larval specimens. We extend our hearty thanks to T. Hirowatari (Kyushu University) for his valuable comments on the draft and to M. Maruyama (Kyushu University Museum) for his help in genetic analysis. Our thanks are due to the following colleagues for their distributional information on *Macrodiplosis* species: N. Kaiwa, A. Nagai, S. Yamauchi and H. Yoshimura, H. Im, and O. Ji. J.Y. thanks the late E. Möhn for allowing him to examine the cecidomyiid collection of E.H. Rübsaamen in Staatliches Museum für Naturkunde in Stuttgart. W.K. thanks O. Tadauchi, Y. Abe, S. Kamitani and D. Yamaguchi (Kyushu University) for their continuous guidance and encouragement. This is a contribution from the Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka (series 7, No. 6).

References

Abe, Y., Melikab, G. & Stone, G.N. (2007) The diversity and phylogeography of cynipid gallwasps (Hymenoptera: Cynipidae) of the Oriental and eastern Palearctic regions, and their associated communities. *Oriental Insects*, 41, 169–212.

http://dx.doi.org/10.1080/00305316.2007.10417504
Bremi, J.J. (as Brämi, J.) (1847) Mittheilungen über die Insekten der Eichen. *Mittheilungen der Naturforschenden Gesellschaft in Zürich*, 1, 1–16.
David, V.A. (2012) Family Cecidomyiidae (gall midges). *In*: Northcott, J. (Ed.), *Pests of Ornamental Trees, Shrubs and Flowers A Colour Handbook. 2nd Edition.* Manson Publishing Ltd, London, pp. 174–188.
Docters van Leeuwen, W.M. (2009) *Gallenboek*. Herzien en bewerkt door Hans C Roskam, KNNV Uitgeverij, Zeist, The Netherlands, 601 pp.
Efron, B. (1982) *The Jackknife, the Bootstrap, and Other Resampling Plans*. Society for Industrial and Applied Mathematics, Philadelphia, 9 pp.
Felsenstein, J. (1985) Confidence limits on phylogenies - an approach using the bootstrap. *Evolution*, 39, 783–791. http://dx.doi.org/10.2307/2408678
Felt, E.P. (1933) A hibiscus bud midge new to Hawaii. *Proceedings of the Hawaiian Entomological Society*, 8, 247–248.
Felt, E.P. (1965) *Plant Galls and Gall Makers*. Hafner Publishing Company, New York and London, 355 pp.
Folmer, O., Black, M., Hoew, H., Lutz, R. & Vrijenhoek, R. (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. *Molecular Marine Biology and Biotechnology*, 3, 294–299.
Fukatsu, T., Aoki, S., Kurosu, U. & Ishikawa, H. (1994) Phylogeny of Cerataphidini aphids revealed their symbiotic microorganisms and basic structure of their galls: implications for host–symbiont coevolution and evolution of sterile soldier castes. *Zoological Science*, 11, 613–623.
Gagné, R.J. (1989) *The Plant–Feeding Gall Midges of North America*. Cornell University Press, Ithaca, New York, 356 pp.
Gagné, R.J. (1994) *Vaccinidiplosis*, a new genus for *Cecidomyia vaccini* Osten Sacken (Diptera: Cecidomyiidae). *Proceedings of the Entomological Society of Washington*, 96, 599–606.
Gagné, R.J. & Jaschhof, M. (2014) A catalog of the Cecidomyiidae (Diptera) of the world. 3rd Edition. Digital version 2. Available from: http://afrsweb.usda.gov/SP2UserFiles/Place/12454900/Gagne_2014_World_Cecidomyiidae_Catalog_3rd_Edition.pdf (accessed 4 June 2014)
Gagné, R.J. & Moser, J.C. (2013) The North American gall midges (Diptera: Cecidomyiidae) of hackberries (Cannabaceae: *Celtis* spp.). *Memoirs of the American Entomological Society*, 49, 1–103.
Hebert, P.D.N., Cywinska, A., Ball, S.L. & DeWaard, J.R. (2003) Biological identifications through DNA barcodes. *Proceedings of the Royal Society B Biological Science*, 270, 313–321. http://dx.doi.org/10.1098/rspb.2002.2218
Kovalev, O.V. (1972) New species of gall-midges (Diptera, Cecidomyiidae) from the southern Far East of the USSR. *Entomologicheskoe Obozrenie*, 51, 412–428. [in Russian with English summary]
Loew, H. (1850) *Dipterologische Beiträge. IV.* Posen, 40 pp., 1 pl.
Löw, F. (1877) Ueber Gallmücken. *Verhandlungen der kaiserlich-königlichen zoologisch-botanischen Gesellschaft in Wien*, 27, 1–38, pl. I.
Mabberley, D.J. (1997) *The Plant-Book: a portable dictionary of the Vascular Plants.* Cambridge University Press, UK, 858 pp.
McAlpine, J.F. (1981) Morphology and terminology — Adults. *In*: McAlpine, J.F., Peterson, B.V., Shewell, G.E., Teskey, H.J., Vockeroth, J.R. & Wood, D.M. (Coord.), *Manual of Nearctic Diptera. Vol. 1*. Research Branch, Agriculture Canada, Monograph No. 27, pp. 9–63.
Möhn, E. (1955) Beiträge zur systematik der larven der Itonididae (= Cecidomyiidae, Diptera). 1. Teil: Porricondylinae und Itonidinae Mitteleuropas. *Zoologica*, 105, 1–247, 30 pls. http://dx.doi.org/10.1007/bf01988795
Monzen, K. (1932) Studies of arthropod galls (III). *Bulletin of the Scientific Researches of the Alumni Association of the Morioka College of Agriculture and Forestry*, 7, 53–78. [in Japanese]
Nei, M. & Kumar, S. (2000) *Molecular Evolution and Phylogenetics*. Oxford University Press, New York, 333 pp.
Nyman, T., Widmer, A. & Roininen, H. (2000) Evolution of gall morphology and host-plant relationships in willow-feeding sawflies (Hymenoptera: Tenthredinidae). *Evolution*, 54, 526–533. http://dx.doi.org/10.1554/0014-3820(2000)054[0526:eogmah]2.0.co;2
Roskam, J.C. (1992) Evolution of the gall-inducing guild. *In*: Shorthouse, J.D. & Rohfritsch, O. (Eds.), *Biology of insect-induced galls*. Oxford University Press, New York, pp. 34–49.
Shinji, O. (1944) *Galls and Gall-making Insects.* Shunyodo, Tokyo, 580 + 12 + 5 + 5 pp. [in Japanese]
Skuhravá, M. (1986) Family Cecidomyiidae. In: Soós, A. & Papp, L. (Eds.) *Catalogue of Palaearctic Diptera: Sciaridae and Cecidomyiidae. Vol. 4*. Akadémiai Kiadó, Budapest, pp. 72–297.
Skuhravá, M. (1997) Family Cecidomyiidae. *In*: Papp, L. & Darvas, B. (Eds.), *Contributions to a Manual of Palaearctic Diptera* (*with Special Reference to Flies of Economic Importance*)*. Vol. 2. Nematocera and Lower Brachycera,* Science Herald, Budapest, pp. 71–204.
Skuhravá, M., Skuhravý, V. & Jørgensen, J. (2006) Gall midges (Diptera: Cecidomyiidae) of Denmark. *Entomologiske Meddeleser*, 74, 94.
Stern, D.L. (1995) Phylogenetic evidence that aphids, rather than plants, determine gall morphology. *Proceedings of the Royal Society of London,* Series B, 260, 85–89.

Stone, G.N. & Cook, J.M. (1998) The structure of cynipid oak galls: patterns in the evolution of an extended phenotype. *Proceedings of the Royal Society of London,* Series B, 265, 979–988.

Tamura, K., Peterson, D., Peterson, N., Stecher, G., Nei, M. & Kumar, S. (2011) MEGA5: Molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. *Molecular Biology and Evolution*, 28, 2731–2739.
http://dx.doi.org/10.1093/molbev/msr121

Tokuda, M. (2012) Biology of Asphondyliini (Diptera: Cecidomyiidae). *Entomological Science*, 15, 361–383.
http://dx.doi.org/10.1111/j.1479-8298.2012.00539.x

Yukawa, J. (1971) A revision of the Japanese gall midges (Diptera: Cecidomyiidae). *Memoirs of the Faculty of Agriculture, Kagoshima University*, 8, 1–203.

Yukawa, J. (1982) New midge galls from Japan. *Memoirs of the Faculty of Agriculture, Kagoshima University*, 18, 85–96.

Yukawa, J. & Masuda, H. (1996) *Insect and mite galls of Japan in colors*. Zenkoku Nôson Kyôiku Kyôkai, Tokyo, 826 pp. [in Japanese with English explanations for color plates]

Yukawa, J. & Ohsaki, N. (1988) Separation of the aucuba fruit midge, *Asphondylia aucubae* sp. nov. from the ampelopsis fruit midge, *Asphondylia baca* Monzen (Diptera, Cecidomyiidae). *Kontyû*, 56, 365–376.

Yukawa, J., Sato, S., Harris, K.M., Tokuda, M., Sasaki, M., Arakawa, A., Nakada, K. & Sawamura, N. (2009) A new species of *Resseliella* (Diptera: Cecidomyiidae) infesting Japanese pear, *Pyrus pyrifolia* (Rosaceae). *Applied Entomology and Zoology*, 44, 655–666.
http://dx.doi.org/10.1303/aez.2009.655

Yukawa, J. & Sunose, T. (1979) Midge galls of Hokkaido. *Memoirs of the Faculty of Agriculture, Kagoshima University*, 15, 87–97.

Yukawa, J. & Tsuda, K. (1986) Leaf longevity of *Quercus glauca* Thunb., with reference to the influence of gall formation by *Contarinia* sp. (Diptera: Cecidomyiidae) on the early mortality of fresh leaves. *Memoirs of the Faculty of Agriculture, Kagoshima University*, 22, 73–77.

Yukawa, J., Uechi, N., Horikiri, M. & Tuda, M. (2003) Description of the soybean pod gall midge, *Asphondylia yushimai* sp. n. (Diptera: Cecidomyiidae), a major pest of soybean and findings of host alternation. *Bulletin of Entomological Research*, 93, 73–86.
http://dx.doi.org/10.1079/ber2002218

Yukawa, J., Uechi, N., Tokuda, M. & Sato, S. (2005) Radiation of gall midges (Diptera: Cecidomyiidae) in Japan. *Basic and Applied Ecology*, 5, 453–461.
http://dx.doi.org/10.1016/j.baae.2005.07.004