

RESEARCH PAPER

***Lycorma delicatula* (Hemiptera: Auchenorrhyncha: Fulgoridae: Aphaeninae) finally, but suddenly arrived in Korea**

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Abstract

A history of name changes in two fulgorid species – *Lycorma delicatula* and *Limois emelianovi* – is reviewed. *Lycorma delicatula* was once mistakenly reported to occur in Korea. Now, it has suddenly become common in western Korea, creating the suspicion that it has recently arrived from China and settled in Korea. A brief morphological and biological description of *L. delicatula* is provided, and its original Korean name, “ggot-mae-mi”, is revalidated. *Limois emelianovi*, sometimes considered a synonym of *emeljanovi*, is the correct name for this species, as *emeljanovi* is simply another transliteration of the personal name Emelianov, Emeljanov or Emel’yanov. The name *emelianovi* stands correct based on the International Code of Zoological Nomenclature code 32.5.1, because there is no internal evidence of an inadvertent error, and an incorrect transliteration is not considered an inadvertent error. The cytochrome oxidase I (COI) barcoding regions of both species were sequenced and compared for future reference.

Key words: barcoding sequence, biology, cytochrome oxidase I (COI), distribution, ICZN, *Lycorma delicatula*, *Limois emelianovi*, synonym.

Introduction

There are two species of Fulgoridae (Hemiptera: Auchenorrhyncha) known to occur in Korea: *Lycorma delicatula* (White, 1845) and *Limois emelianovi* Oshanin, 1908. Both species were reported for the first time in Korea in 1932 by a Japanese researcher, Doi (Doi 1932a,b). Interestingly, while *L. emelianovi* has been steadily collected in Korea, *L. delicatula* has never been found until recently. This led Kwon and Huh (2001) to conclude that *L. delicatula* does not occur in Korea. However, the species has become suddenly (since 2006) quite common in western Korea. It seems that it was somehow introduced from China recently and has reproduced successfully in Korea. As its biology and pest status become more interesting, its nomenclature needs to be addressed.

We investigated the taxonomic history and name changes of two Korean fulgorid species, *Lycorma delicatula* and *Limois emelianovi*. We briefly surveyed the occurrence and studied the life cycle of *L. delicatula*. In addition, we sequenced the cytochrome oxidase I (COI) barcoding regions of the two species for future reference.

Materials and methods

Survey on the occurrence of *Lycorma delicatula*

There have been various sources for the occurrence of *L. delicatula*, such as personal blogs on the Internet. Wherever possible, we visited the sites in person to confirm its existence. The 2007 survey result was not much different from the 2006 survey, as the expansion of the population was

within western Korea. The difference was mainly in the size of the population.

DNA extraction and sequencing of the COI barcoding regions

Localities of the samples used for sequencing are as follows.

1. *L. delicatula*: Chungbuk National University, Gaesin-dong, Cheongju, CB, Korea (36°37'39.9"N, 127°27'13.9"E); 2 November 2007; J. M. Han.
2. *L. emelianovi*: Weol-ag-san [Mount], Songgye-li, Hansu, Jecheon, CB, Korea (36°51'15.6"N, 128°04'53.8"E); 16–17 September 2007; S. W. Cho and J. M. Han.

Specimens freshly collected were soaked in absolute ethyl alcohol and stored at –80°C until DNA was extracted from them. Nucleic acid extraction was performed on thoraces. The total genomic DNA was extracted using a DNeasy Extraction Kit (Qiagen, Germany), and 20 µL of the extract was stored at –20°C until it was used for PCR amplification. The PCR conditions and amplification methods of Lee *et al.* (2005) were followed. Primers were either as in Folmer *et al.* (1994) or developed using the CODEHOP program (Rose *et al.* 1998). Both directions were sequenced for greater accuracy.

Results and discussion

Historical problem of the occurrence of *Lycorma delicatula* in Korea

Lycorma delicatula was first recorded by White in 1845 based on the sample collected from Nankin, China in 1844 (White 1845). However, this species has been known in China as a medicinal insect (Choi *et al.* 2002) since the twelfth century, and here we quote from Liu (1939):

... They look like a moth but with the abdomen larger and the head and the legs blackish. There are two pairs of wings, the outer pair (tegmina) is grey while the inner pair (wings) is deep red, decorated with all five colors ... (from Pen Ts'ao Yen Yi by Kio, Chung Pi in 1111–1116).
... smelling Ailanthus trees. The outer wings of the insects (chu ki) are grayish yellow while the inner ones are decorated with all five colors. They generally line up on the tree and by the late fall, deposit their eggs on the bark. The nymph has six legs, with wings (?) doubled and black and the head depressed and truncated in front ... (from Pen Ts'ao Kang Mu by Li, Shih Chen in 1578).

Based on the above, we know that the species was described in detail morphologically and biologically, including its host plant information.

This species is called “chu-ki” or, more recently, “ban-yi-la-chan” in China, often translated as “spot clothing wax

cicada” in English, and is called “ggot-mae-mi” in Korea. Although its occurrence extends south to India and Vietnam, Liu (1939) reported that the species is more common in northern than in southern China.

At this point, we are uncertain whether there is *L. delicatula* in Japan or not. In the Mokuroku database website, based on *A Check List of Japanese Insects* (Tadauchi & Inoue 2000), “HONSHU?, KYUSHU?, OkinawaHonto Is.?” is listed as localities for *L. delicatula*, but each with “?” added. If *L. delicatula* does not occur in Japan yet, then it is likely the species will be introduced in the near future as the range of its distribution has expanded to Korea.

Together with *L. emelianovi* (=kekuchii), this species was first reported as a *Lycorma* species in Korea in early 1932 by Doi (1932a). Although no specific information was given at that time, it was somehow believed to be *L. delicatula* since then, possibly because *L. delicatula* was the most common species in China. Unfortunately, just a few months after Doi's first note, he reported again that it was a misidentification of *L. emelianovi* (Doi 1932b). But Doi's second report was overlooked, and *L. delicatula* has been thought to occur in Korea for a long time (Zoological Society of Korea 1975). Inevitably, as no specimen had been found, Lee (1979) noted that the occurrence of this species needed further investigation while he included *L. delicatula* in his faunistic study of Korean Auchenorrhyncha. In 2001, Kwon and Huh eventually excluded this species from the list of Fulgoridae, leaving *L. emelianovi* as the only fulgorid species occurring in Korea, and changed the Korean name of *L. emelianovi* from “hui-jo-ggot-mae-mi” to “ggot-mae-mi.”

Through the irony of chance, only a few years after its exclusion from the list of Korean species, *L. delicatula* suddenly appeared in Korea, and this time not a few but many. The first report of *L. delicatula* was in 2004, based on a few adults collected at Cheonan in September (Kim & Kim 2005). In 2005, an image of an adult was posted on the Internet by a netizen. Then in 2006, a sudden burst of its population was noticed in many places. We surveyed the occurrence of *L. delicatula* in 2006 and found it occurred at many sites, all in western Korea (Fig. 1), probably indicating that the species was accidentally introduced from China and has settled successfully. In the following year, the abundance of the species was even more noticeable, especially around early autumn, and many people were annoyed by the intrusion of this species, which is unafraid of people, into houses and orchards. Although their host plant is known to be *Ailanthus altissima* (tree of heaven), the adults also feed on many other kinds of plant and become a pest on some trees, including grapevines.

The presence of *L. delicatula* in Korea is now obvious. As a consequence, we need to fix its Korean name to avoid confusion (*L. delicatula* has been temporarily called “ju-hong-nal-gae-ggot-mae-mi” for the past couple of years.).

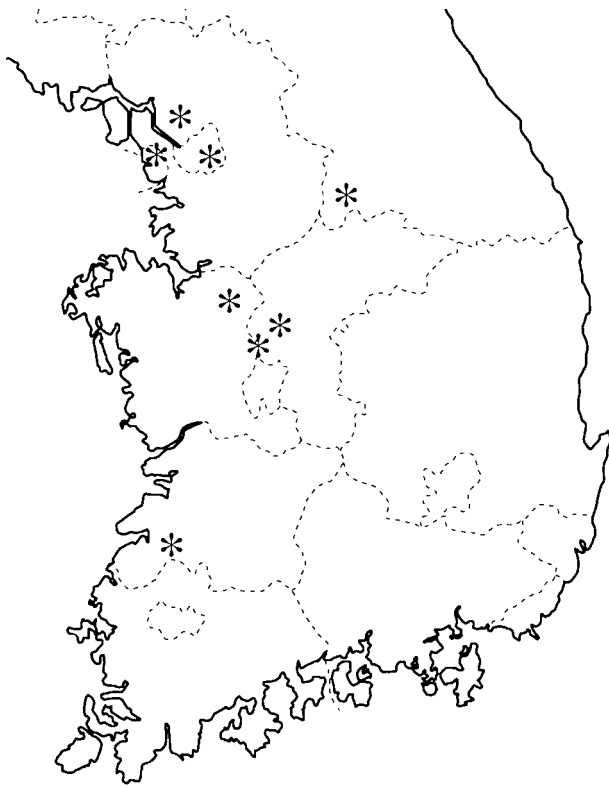


Figure 1 Occurrence of *Lycorma delicatula* in Korea in 2006. The asterisks marked on the map are where the authors visited and confirmed its occurrence.

Here, we propose that “ggot-mae-mi”, the original Korean name of *L. delicatula*, should be revalidated and the name *L. emelianovi* should revert back to its original name, “hui-jo-ggot-mae-mi.”

Overwintering possibility of *Lycorma delicatula* in Korea

Based on our survey in 2006, *L. delicatula* occurs in western areas of Korea, including Seoul, Goyang, Incheon, Wonju, Cheon-an, Cheongju, Jochiwon and Jeong-eup. We have not seen it on Jeju Island or in eastern Korea yet. However, we expect that as time goes by, they will move all over the land, especially to the south-eastern area in the near future. In China, they are found almost all over the nation, including in Beijing (“Ban-yi-la-chan” 2000; Yu 2003; “Chapter 8” 2004), so they can survive the winter of Korea and probably reproduce without any difficulty as Beijing is climatically similar to, if not harsher than, Seoul (the average annual air temperature is approximately 11°C in both cities). In fact, there are several reasons that may support the possibility of their survival in winter in Korea other than climatic similarity: (i) there were images of egg-hatching in Korea in

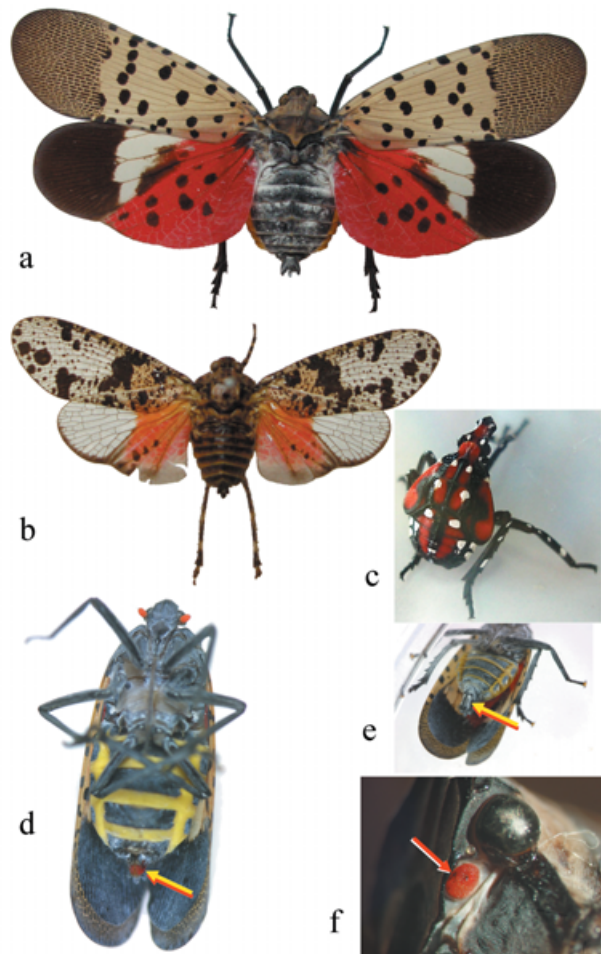


Figure 2 (a) *Lycorma delicatula* adult. (b) *Limois emelianovi* adult. (c) Last instar of *L. delicatula*. First to third instars are similar in color pattern, with white dots on a black body, while the fourth instar has red color added. (d) Female *L. delicatula*: the postero-caudal end of the abdomen is reddish. (e) Male *L. delicatula*. (f) Red antenna of *L. delicatula*.

May 2007 on the Internet, although the authenticity is not confirmed; (ii) for 2 years in a row we found it at the same sites, which strongly indicates it is not randomly arriving from China each year; (iii) the website maintained by the Beijing Association for Science and Technology posted some life cycle images of *L. delicatula* taken in Beijing (Yu 2003); and (iv) we checked some eggs laid in Cheongju in 2007 and found that they were still alive in April 2008.

Morphological and biological peculiarities of *Lycorma delicatula*

Most of the adult characteristics of *L. delicatula* were described by Lee (1979). The difference between *L. delicatula* and *L. emelianovi* is rather obvious (Fig. 2a,b,f). *L. delicatula* is bigger and more colorful than *L. emelianovi*, and its



Figure 3 Twigs wilted (a) and died (b) due to the feeding of *Lycorma delicatula* nymphs.



Figure 4 (a) Grouping tendency of nymphs; (b) grouping tendency of adults; (c) a tree that has become sooty at the bottom and wet around it because of the honeydew produced by a group of *Lycorma delicatula* adults.

antenna is red while it is brownish in *L. emelianovi*. The male and female of *L. delicatula* can be easily distinguished by adult size and by the color of the postero-caudal end of the abdomen (Fig. 2d,e).

The first instar occurs in May. First to third instars have a black body with white dots scattered all over the body and legs, while the last (fourth) instar has a similar color and white-spot patterns except that the body is red with a black edge on each sclerite (Fig. 2c).

When they are young, *L. delicatula* feed on *Ailanthus altissima* Swingle (“ga-juk-na-mu”). Twigs fed on by a group of nymphs often become wilted and die (Fig. 3). The adults begin appearing in July and become locally abundant in August. When they become adults, they usually migrate and, like the nymphs, form a group on bark of various kinds of tree (Fig. 4a,b), such as *A. altissima*, *Platanus orientalis* L. (Oriental plane; “beo-jeum-na-mu”), and *Populus tomentiglandulosa* T. Lee (“eun-su-won-sa-si-na-mu”). In China, they are known to feed on *Actinidia chinensis*, *Malus* sp., *Prunus mume*, *P. persica*, *P. salicina*, *Robinia pseudoacacia* and *Vitis vinifera* (Hua 2000; Qiu 2002). The tree on which many adults are sitting often becomes sooty at the bottom and wet around it because of the honeydew produced by the insects (Fig. 4c).

The adults lay eggs not only on ailanthus but also on other trees, and even on inorganic substances such as bricks. Eggs are laid as a group and are usually covered by light gray form,



Figure 5 *Lycorma delicatula*. (a) Ootheca; (b) eggs after emergence.

which later hardens to form an ootheca (Fig. 5a). The opening lid for emergence is oblong in shape, and the nymph opens the lid from one side while the other side of the lid usually remains attached (Fig. 5b). When the weather gets cold in November, adults begin dying off.

Note on opinion on name change in *Limois emelianovi*

Limois emelianovi Oshanin, 1908 was, according to the original description, named after A. A. Emelianov. However, the specific name *emelianovi* has been considered a typographical error of *emeljanovi* in the *Fulgoromorpha Lists on the Web* (Bourgoin 2006). The name *emeljanovi* was also used in China (Chou *et al.* 1985: p. 30).

The confusion with the name was probably caused by its transliteration to Emelianov, Emeljanov and Emel’yanov, which are in fact all possible alternative transliterations of the same Russian name, in different journals. The International Code of Zoological Nomenclature (1999) states that the original spelling of a name should be maintained unless it is demonstrably incorrect from evidence in the original publication itself. Here we quote the code 32.5.1 regarding incorrect original spellings:

32.5.1. If there is in the original publication itself, without recourse to any external source of information, clear evidence of an inadvertent error, such as a lapsus calami or a copyist’s or printer’s error, it must be corrected. Incorrect transliteration or latinization, or use of an inappropriate connecting vowel, are not be considered inadvertent errors.

What counts is the original spelling and whether there is internal evidence of an inadvertent error. Furthermore, in classical Latin, the letter “j” does not exist at all, so it could

emelianovi delicatulă	----- *****	-----**** *****	***** *****	***** *****TATCG	*AACTCTTTA GAACCCCTTA	TTTTATCTTC TTTTATTTTT
emelianovi delicatulă	GGACTATGAT GGGTTATGAG	CAAGAATACT CTAGACTACT	GGGAACAATG GGGACAATA	AGAAGAATAA AGAAGAATAA	TTATTCCGAT TTATTCCGAT	AGAATTAATA AGAATTAATA
emelianovi delicatulă	CAACCAGGAT CAACCAGGAT	CAATAATTAA CAATAATTAA	AAATGACCAA AAATGACCAA	ATCTATAACA ATYTATAATA	CAATTGTAAC CCATCGTAAC	ATCCCATGCA ATCTCATGCA
emelianovi delicatulă	TTTATTATAA TTCATTATAA	TTTTTTTTAT TTTTCTTTAT	AGTAATGCCA aGTTATACcT	ATTATAATTG ATTATAATTG	GAGGATTTCG GAGGATTTCG	AAATTGACTA AAACTGATTA
emelianovi delicatulă	GTACCAATAA GTTCTATAA	TAATTGGTGC TAATCGGTGC	ACCTGACATA ACCAGACATG	GCATTCCCAC GCATTCCCAC	GAATAAATAA GAATAAATAA	TATGAGATTG TATAGATTG
emelianovi delicatulă	TGATTATTAC TGATTACTAC	CCCATCAAT CACCATCAAT	CATTATATTA TTCACITTTA	ATCTCAAGAT ATTGCAAGAT	CAATAGTAGG CAATcTAGG	TTCAGGATCA GTCAGGATCA
emelianovi delicatulă	GGAACTGGAT GGWACAGGAT	GAACGTGTGA GAACGTGTTA	TCCACCCECTA CCCcCCTCTC	TCAGCACAGA TCAGCCCAAA	TTGCCCATTC TTGCACATTC	AGGACCATCA AGGACCTTCA
emelianovi delicatulă	ATTGATCTAA GTAGAcTAA	CAATCTTCTC CTATTTTTTC	ACTTCATATT WCTTCACATC	GCAGGAATTA GCAGGWTTAA	GATCAATTAT GATCAATCAT	AGGAGCCATT AGGAGCAATc
emelianovi delicatulă	AACTTCATCT AATTTCATTT	CAACAACAAT CAACAACAAT	AAATATACGA AAATATACGG	CCAAAAGGAA CCAAAAGGAA	TAAACAATAGA TAACATATAGA	AAAAATACCC AAAAATACCC
emelianovi delicatulă	CTATTTTGCT CTTTCTGT	GATCAGTCAT GATCAGTCCT	AATTACAGCA AATTACAGCA	GTTCTATTAC GTTTTACTAC	TAGTATCTTT TAGTATCATT	ACCAGTATTA ACCAGTACTA
emelianovi delicatulă	GCTGGAGCAA GCTGGAGCAA	TTACAATACT TTACAATACT	ACTAACAGAT ACTAACAGAT	CGTAATTTTA CGAAACTTTA	ATACATCATT ATACCTCATT	CTTTGACCCA TTTTGACCCC
emelianovi delicatulă	ACTGGAGGAG ACGGGTGGAG	GTGATCCCAT GAGACCCAT	CCTATATCAA TTTA*****	CACTTATTC* *****	***** *****	***** *****----
emelianovi delicatulă	***** -----					

Figure 6 Cytochrome oxidase I (COI) barcoding regions of *Lycorma delicatula* and *Limois emelianovi*. Asterisks show the primer regions used for PCR.

make sense to decide, deliberately, to avoid it when transliterating Cyrillic into English. Even if it is an incorrect transliteration, it is not considered to be an inadvertent error. Therefore, the original spelling of “*emelianovi*” should remain as the correct spelling and any changes should be judged as unjustified emendations.

Barcoding sequences of the two species

While *L. emelianovi* was sequenced easily by the COI primers commonly used for most insects, *L. delicatula* was unsuccessful in PCR with the same primers. We developed three different sets of primers using the CODEHOP program (Rose *et al.* 1998), and one of them worked nicely and could get the sequences (Fig. 6). The two species belong to different genera, and, as we expected, the sequence difference between the two species is approximately 13%. As of 1 April 2008, no fulgorid species has been sequenced in the Barcode of Life Data Systems (BOLD) ("Hemiptera" 2008), and ours will be deposited in the system. The only mtDNA sequences available for *L. delicatula* is from Yeh *et al.* (2005), in which molecular phylogenetic studies using 16S rDNA included three species of *Lycorma* (GenBank accession numbers AF158055, AF158056 and AF158058).

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