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Short communication

Discovery of a naturally occurring individual of *Acanthiophilus helianthi* (Rossi) (Diptera: Tephritidae) in Korea, a managed quarantine pest by the Korean Animal and Plant Quarantine Agency

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ABSTRACT

Acanthiophilus helianthi (Rossi) (safflower fly) is known to host a wide range of plant species belonging to the tribe Cardueae (Asteraceae). It is also known as a serious pest of safflower in the dry regions and marginal areas of the world where safflower is an important oilseed crop. Due to its possible introduction to Korean peninsula, it is listed as a managed quarantine pest by the Korean Animal and Plant Quarantine Agency. We here report a natural occurrence of *A. helianthi* for the first time in Korea, based on a single female specimen collected from northern part of South Korea. Since the discovery of *A. helianthi* is of agricultural and quarantine importance in this part of world, we here provide its detailed morphological redescription, diagnosis, and color photographs including genitalic structures for accurate identification. We also provide a brief account of its biology and pest status summarized from previous literature. In order to make sure the correct identification of the newly discovered Korean specimen of *A. helianthi* as well as to investigate systematic position of the genus *Acanthiophilus*, we conducted a DNA barcoding analysis. Finally, we here suggest that *A. helianthi* should be removed from the Korean quarantine pest list, since its natural occurrence in Korea is confirmed by the present study.

Introduction

The family Tephritidae is a large group of schizophoran flies of over 4700 recognized species worldwide (Norrbom et al., 1999a; Catalogue of Life as of August 15th 2018 – http://www.catalogueoflife.org/). Tephritid larvae are mostly phytophagous including some of the most significant pests of agricultural and quarantine importance (White and Elson–Harris, 1992). As a result of an extensive survey of the family Tephritidae in South Korea, we have recognized 101 species and 55 genera up to date (Han, 2016; Han et al., 2017).

We here report an additional species, *Acanthiophilus helianthi* (Rossi) (safflower fly), to the Korean tephritid fauna. This newly discovered species has been regarded as a serious pest of safflower in the dry regions and marginal areas of the world where safflower is an important oilseed crop (Sabzalian et al., 2008; Saeidi, 2011). It is also listed as a managed quarantine pest by the Korean Animal and Plant Quarantine Agency (https://www.qia.go.kr/listindexWebAction.do as of August 23th, 2018).

Since the discovery of *A. helianthi* is of agricultural and quarantine importance in this part of world, we here provide its detailed morphological redescription, diagnosis, and color photographs including genitalic structures to aid accurate identification. We also provide a brief account of its biology and pest status summarized from previous literature. In order to confirm the identification of the newly discovered Korean specimen of *A. helianthi* as well as to investigate systematic position of the genus *Acanthiophilus*, we conducted a DNA barcoding analysis.

Materials and methods

The terminology and morphological interpretations used in this paper follow the glossary of White et al. (1999). The following 12 ratios are used in the redescription: head ratio (head length excluding antennae in lateral view/head height); frons-head ratio (narrowest width of frons in dorsal view/width of head); eye ratio (shortest eye diameter/longest eye diameter); gena-eye ratio (genal height/longest eye diameter) - genal height is the distance between ventral eye margin and ventral genal margin anterior to genal seta (gena measured with head tilted slightly dorsally so that gena is at its broadest); antenna-head ratio (antenna length measured from scape to flagellomere 1/head height); arista-antenna ratio (arista length/antenna length); wing-thorax ratio (wing length from tegula to apex of vein R_{4+5}/thorax

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length in dorsal view); wing ratio (wing length/wing width); vein M ratio (distance along vein M between crossveins R-M and DM-Cu/distance between crossveins R-M and BM-Cu); subcosta-costa ratio (distance along vein C of subcostal cell/costal cell); cell $r_{1-}r_{2+3}$ ratio (distance along vein C of cell r_1/cell r_{2+3}); cell $r_{4+5-}r_{2+3}$ ratio (distance along vein C of cell r_{4+5}/cell r_{2+3}).

Photographs were taken with a Panasonic (Osaka, Japan) Lumix GMC G5 camera with a Lumix G X Vario 45–175 mm lens and a Raynox (Yoshida Inc., Tokyo, Japan) MSN-202 macro conversion lens. The consecutive digital images in different focal planes (usually 50–100 shots per a single figure) were *Z*-stacked using Helicon Focus software ® (Helicon Soft, Ltd., Ukraine). Photographs of postabdominal structures were taken with a Nikon (Tokyo, Japan) D90 camera mounted on an Olympus (Tokyo, Japan) CX41 compound microscope.

All the specimens examined in the present study are deposited in the Division of Biological Science and Technology, Yonsei University, 1 Yonseidae-gil, Wonju-si, Gangwon-do 26493, Korea (YSUW). Acronyms of other institutions cited in this study are as follows: MNHNP – Museum National d'Histoire Naturelle, National Collection of Insects, 45, rue Buffon, Paris 75,005, France; and ZMHU – Museum für Naturkunde der Humboldt Universität zu Berlin, Bereich Zoologisches Museum, Invalidenstrasse 43, Berlin, D-1040, Germany.

Molecular methods follow Han and Ro (2016). We sequenced the partial mitochondrial cytochrome oxydase 1 gene (DNA barcode region) for three *A. helianthi* specimens. Their GenBank accession numbers are as follows: Korean female – MH780803, Swiss Valais female – MH780804, and Swiss Geneva female – MH780805 (see Material examined section of more detailed collection data). We analyzed these three sequences plus 40 selected sequences downloaded from BOLD Systems (http://www.boldsystems.org/) as of May 1st, 2018. Publically available DNA barcode sequences of *Acanthiophilus*, *Trupanea* (including *Urelliosoma*), *Tephritis, Dectodesis* and *Campiglossa* were selected because they have been known to be closely related (Norrbom et al., 1999a; Merz, 1999; Han et al., 2006).

Neighbor-joining analysis was performed in MEGA 7.0 (Kumar et al., 2015) using the Maximum Composite Likelihood model of nucleotide substitution (Yang, 1994) with different evolutionary rates among sites and lineages. The reliability of clustering patterns in the tree was determined by the bootstrap test (Felsenstein, 1985) (2000 replications).

***Acanthiophilus helianthi* (Rossi)** (Figs. 1–3).

(Common name: safflower fly, capsule fly, safflower capsule fly)

(New Korean name: hong-wha-kkot-kwa-sil-pa-ri)

*Musca helianthi*Rossi, 1794: 73 (type locality: Italy, "Etruria" [Tuscany?]; syntypes ZMHU?; Thompson and Pont, 1993: 82 (type data); Morgulis et al., 2015: 1078 (indicated type unknown).

*Trypeta eluta*Meigen, 1826: 344 (type locality: France – Fontainebleau and Niemes; Portugal; Germany – Stolberg; syntype ♂♀ MNHNP; also possibly syntypes in ZMHU).

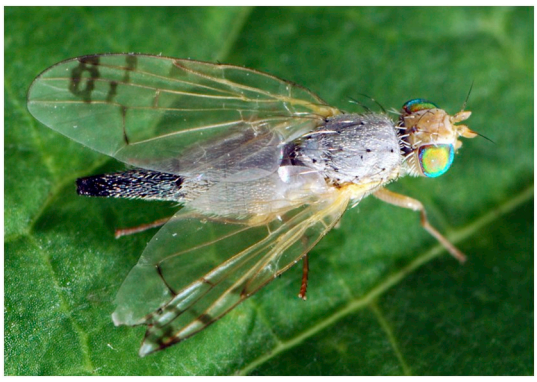

Fig. 1. *Acanthiophilus helianthi*, Korean female.

Acinia helianthi: Macquart, 1849: 497 (redescription)

Urellia helianthi: Becker, 1905: 142 (redescription).

*Acanthiophilus helianthe*Bezzi, 1918: 41 (misspelling of *helianthi* Rossi; distribution).

Acanthiophilus helianthi: Bezzi, 1926: 295 (redescription); Hendel, 1927: 202 (redescription, host records); Stammer, 1929: 489 (list); Niblett, 1939:70 (host record); Phillips, 1946: 104 (host records); Munro, 1957: 1023 (redescription); Swailem, 1973: 165 (description of immature stages); Pemberton and Hoover, 1980: 8 (host records); Neuenschwander and Freidberg, 1983: 90 (host records); Freidberg and Kugler, 1989: 74 (redescription, host records); White and Elson–Harris, 1992: 412 (pest status and distribution); Norrbom et al., 1999b: 65 (in world catalog); Merz, 1999: 639 (cladistics analysis); Morgulis et al., 2015: 1061 (host records), 1069 (in world key), 1078 (redescription, distribution); Saeidi, 2011: 15 (biology); Saeidi and Adam, 2011: 412 (attractant); Saeidi et al., 2015 (biology); Saeidi et al., 2016: 308 (parasitoids).

Diagnosis. This species can be readily distinguished from any other known Korean tephritid species by the combination of the following characteristics (Figs. 1, 2A–E): 1) wing largely translucent with pale yellow pterostigma; 2) with sexually dimorphic pale grey wing pattern confined to area anterior to vein M between apices of pterostigma and R_{2+3}; 3) thorax and abdomen largely dark brown in ground color with heavy whitish pruinosity, generally appearing matte whitish grey; 4) head and legs largely pale yellowish brown; and 5) female with extremely long, shiny dark brown oviscape almost as long as preabdomen. It can be further distinguished from the congeners from other parts of world by: 1) apical 1/3–2/5 of wing cell r_{4+5} translucent; 2) whether merged with other band or not, always with irregular subapical transverse band from apex of cell r_1 and posterior to vein M, and this subapical band with 2–4 hyaline spots; 3) cell br almost completely translucent; and 4) body length excluding oviscape about 3.5–5.0 mm (Morgulis et al., 2015).

Redescription. Body (Figs. 1, 2A–E) predominantly whitish grey with head and legs largely pale yellowish brown; female with extremely long (as long as preabdomen), shiny dark brown oviscape; setae mostly yellowish grey but few yellowish white; setulae mostly yellowish white but some on legs brownish; wing length 4.0–5.0 mm; thorax length 1.4–1.8 mm. Head pale yellowish brown with light whitish pruinosity except for brown ocellar triangle and greyish upper occiput; head ratio 0.94–0.97, frons-head ratio 0.43–0.45, eye ratio 0.79–0.89, gena-eye ratio 0.13–0.16, antenna-head ratio 0.38–0.42, arista-antenna ratio 1.3–1.7; vertex yellow brown; yellowish grey inner vertical seta about 0.6–0.7× as long as longest diameter of eye; outer vertical seta yellowish white, flattened, 0.4–0.5× as long as inner vertical seta; post ocellar seta yellowish white, subequal to posterior orbital seta; 3 yellowish white paravertical setae 0.5–0.8× as long as post ocellar seta, with outer seta shorter than inner seta; ocellar seta yellowish grey, about 3× ocellar triangle length; frons almost bare with frontal angle about 90–95 degree; with 3 yellowish grey frontal setae; yellowish white posterior orbital seta 0.5–0.7× as long as yellowish grey anterior orbital seta; scape yellowish brown with short yellowish brown setulae; pedicel yellowish brown with short dark brown setulae; flagellomere 1 yellowish brown, 1.3–1.5× pedicel length, anterior-apically pointed; arista yellowish brown, extremely short pubescent; face pale yellowish brown without distinct antennal groove; parafacial about 0.2–0.3× as wide as flagellomere 1; facial ridge with fine pale yellow setulae; gena with strong yellowish grey genal seta and relatively long yellowish white setulae; postgena swollen with relatively long yellowish white setulae; postgenal seta indistinguishable from nearby setulae; 6 short and thick yellowish white postocular setae extended about half distance from upper eye margin to lower eye margin; supracervical setulae pale yellow; mouthparts short, palpus apically with yellow brown setulae. Thorax largely dark brown in ground color with heavy whitish pruinosity, generally appearing matte whitish grey; post pronotal lobe

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