

New record of *Folsomia quadrioculata* (Tullberg, 1871) and redescription of *Folsomia octoculata* (Handschin, 1925) from the forest of South Korea

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Abstract: During a recent study to understand an interaction of Collembola community and their environmental factors, two species in the genus *Folsomia*, *F. quadrioculata* Tullberg 1871 and *F. octoculata* Handschin 1925, were found in the forest of South Korea. From 2013 to 2015, these two species were sampled from six mountains and *F. quadrioculata* or *F. octoculata* was the dominant species in 5 sampling sites among 6 sampling sites. *F. quadrioculata* and *F. octoculata* were found in litter of deciduous and pine forest, respectively. Therefore, the major tree species seems to be one of the important factors determining their habitat. *F. quadrioculata* is newly recorded from the Korean Peninsula and *F. octoculata* is redescribed based on new materials from South Korea.

Keywords: *Folsomia octoculata*, *Folsomia quadrioculata*, Korea, taxonomy, bioindicator

INTRODUCTION

The Family Isostomidae belongs to order Entomobryomorpha in class Collembola and approximately 1,472 species in 113 genera have been known to be distributed all over the world (Bellinger *et al.* 1996–2018). From Korea, only 37 species of 14 genera have been recorded (Shon 1963; Yosii and Lee 1963; Yosii 1966; Lee 1973, 1977; Lee *et al.* 1993; Lee and Kim 1994; Thibaud and Kim 1995; Kim and Lee 2000; Park and Lee 2000; Potapow 1997, 2001; Lim and Park 2011, 2013; Dányi and Park 2016; Park 2018; Kim and Park 2018).

The genus *Folsomia* has the following features: 1) three last abdominal segments fused to a single segment, 2) no apical bulb on the antenna, 3) presence of PAO, 4) 4 sublobal hairs on outer maxillary lobe, 5) presence of ven-

troapical setae on manubrium, and 6) no ventral setae on Th I and II (Potapow 2001; Fjellberg 2007). There are 189 species in the genus *Folsomia* over the world, comprising 13% of all described species of the family Isotomidae (Bellinger *et al.* 1996–2018). However, only 8 species in *Folsomia* have been known from Korea (Kwak 2011; Dányi and Park 2016), and there are a limited number of researches on descriptions and ecology of them in Korea.

For ecological study, collembolan species were investigated in six mountains of Korea from 2013 to 2015, to understand an interaction of Collembola community occurred in the forest soil in Korea with their environmental factors. In the study, *Folsomia quadrioculata* or *F. octoculata* was the dominant species in 5 sampling sites among 6 sampling sites (Table 1). *F. quadrioculata* and another species, *F. octoculata*, were found in litter of deciduous and pine forest

Table 1. Geographical coordination of each sampling sites with major tree species.

Name of mountain	Location	Elevation (m)	Found Collembolan species	Major species of tree
Hyeolgusan	126° 26' 22" E, 37° 42' 32" N	135	<i>Folsomia quadrioculata</i> (d)	<i>Quercus dentata</i>
Ansan	126° 56' 48" E, 37° 34' 36" N	264	<i>Folsomia octoculata</i> (d)	<i>Pinus densiflora</i>
Youngmunsan	127° 31' 20" E, 37° 30' 55" N	345	<i>Folsomia octoculata</i> (d)	<i>Pinus densiflora</i>
Gyemyeongsan	127° 58' 58" E, 36° 58' 47" N	528	<i>Folsomia quadrioculata</i> (d)	<i>Quercus mongolia</i>
Gyoryongsan	127° 21' 9" E, 35° 25' 46" N	481	<i>Folsomia octoculata</i>	<i>Pinus densiflora</i>
Jogyesan	127° 19' 14" E, 34° 59' 37" N	372	<i>Folsomia quadrioculata</i> (d)	<i>Morus bombycis</i>

(d) means dominant Collembolan species in the site

of Korea, respectively. According to the result of this study, the major tree species seems to be one of the important factors determining their habitat. *F. quadrioculata* is a newly recorded species from the Korean Peninsula. *F. octoculata* was reported in South Korea by Lee (1973, 1977), with the brief remark about color pattern and the chaetotaxy of tenaculum, manubrium and dens in only second report. Therefore, *F. octoculata* is redescribed using recent important characters with illustrations based on the new materials from South Korea. As a result of this study, Korean faunal list of Isotomidae consists of 38 species in 14 genera. This study will be important information on morphology as well as ecology of the two dominant collembolan species in forest soil in Korea.

MATERIALS AND METHODS

Collecting and imaging

The sampling was conducted at six mountains in Korea and details including their location, elevation, and major species of tree were given in Table 1. Three soil sampling cores (diameter: 5 cm, height: 10 cm) were taken at each sampling site and the collembolan species in the sampled soil and leaf litter were extracted by Tullgren funnels. The dominant species was selected as the most abundant species in three sampled soil by sampling core. Specimens were preserved in 95% ethanol and taken photograph with a 3.1-megapixel digital camera (Toupcam, Zhejiang, China) mounted on a stereo microscope.

Morphology

For microscopic study of entire individuals, specimens were cleared in 5% KOH, then mounted in polyvinyl alcohol to prepare permanent slides (Downs 1943). Slides were dried and hardened in the 60°C oven for 3 days. Specimens were examined with bright-field or differential interference-contrast microscopes.

Morphological abbreviations used in this paper are as follows: [Abd. I–VI] abdominal segments, I–VI, [Ant. I–IV] antennal segments I–IV, [Ant. III O] Third antennal organ, [bms] basal microsensilla, [Cl] Claw, [Man] manubrium, [PAO] post-antennal organ, [Th. I–III] thoracic segments I–III, [Ret] retinaculum, [VT] ventral tube.

Voucher specimens are deposited in the National Institute of Biological Resources (NIBR), Incheon, Korea and the Insect Collection, Department of Biology Education, Chonbuk National University, Jeonju, Korea.

TAXONOMIC ACCOUNT

Family Isotomidae Schäffer
Genus *Folsomia* Willem

Folsomia quadrioculata (Tullberg 1871) (Figs. 1A & 2)
네눈마디톡토기 (국명신칭)

Isotoma quadri-oculata Tullberg, 1871: 152 (type locality: Sweden, "Uppsala")

Redescription. Body length 1.0 to 1.5 mm. Body slender and elongate, abdomen thicker towards tip (Fig. 1A).



Fig. 1. Habitus of *Folsomia quadrioculata* (A) and *Folsomia octoculata* (B).

Ground color pale yellow overlaid with mottled grayish pigment except intersegmental margins; antennae pale; legs grayish on coxae, otherwise pale; furcula pale yellow. Eye patches black, ocelli 2 + 2, arranged far from each other on each side. PAO narrow, elongated, 1.2 times longer than width of Ant I. Antenna about 1.5 times of head diagonal. Ant I with 3 small basal microsensilla (2 dorsal and 1 ventral, bms) and 2 ventroapical sensilla (Fig. 2A, B); Ant II with 3 bms (1 dorsal, 1 ventral, and 1 latero-distal) (Fig. 2C, D), lateroapical setaceous sensillum present; Ant III with 1 bms and 5 sensilla (Fig. 2E), the setaceous sensillum absent; Ant IV without apical bulb, with subapical knob in a pit and 6 slender, curved differentiated setae (Fig. 2F). Maxillary palp bifurcate, outer maxillary lobe with 4 sublobal hairs. Labrum 4/5, 5, 4. Cl without teeth. Tibiotarsi III with many setae (up to 28) (Fig. 2G). Sensillary chaetotaxy of Th. II to Abd. IV–VI as 4, 3 / 2, 2, 2, 8, including 1, 0 / 1, 0, 0, 0 microsensilla (Fig. 2H). VT with 3 + 3 latero-distal setae. Ret quadridentate and 1 seta. Man with 1 + 1 ventroapical setae. Dens normally with 8 anterior and 3 posterior setae. Mucro bidentate.

Material examined. 1 specimen on slide: Hyeolgusan (mountain), 126° 26' 22" E, 37° 42' 32" N, Gocheon-ri, Naega-myeon, Ganghwa-gun, Incheon. 6 specimens on slide: Joggyesan (mountain), 127° 19' 14" E, 35° 25' 46" N, Jukhak-ri, Seungju-eup, Suncheon-si, Jeollanam-do Province. 3 specimens on slide: Gyemyeongsan (mountain), 127° 58' 58" E, 36° 58' 47" N, Jongmin-dong, Chungju-si, Chungcheongbuk-do Province.

Distribution. Widely distributed Holarctic species. Newly recorded from the Korean Peninsula in this study.

Biology. All the specimens in the present study were found in litter of deciduous forests.

Remarks. The present materials agreed well with the previous studies by Deharveng (1982) and Fjellberg (2007), and easily identified by 2 + 2 ocelli which are arranged far from each other on each side, 1 + 1 ventroapical manubrial setae and 8 anterior setae on dens. According to some authors, the color of this species are variable, but the specimens of this study were covered with mottled grayish pigmentation without variation in body color.

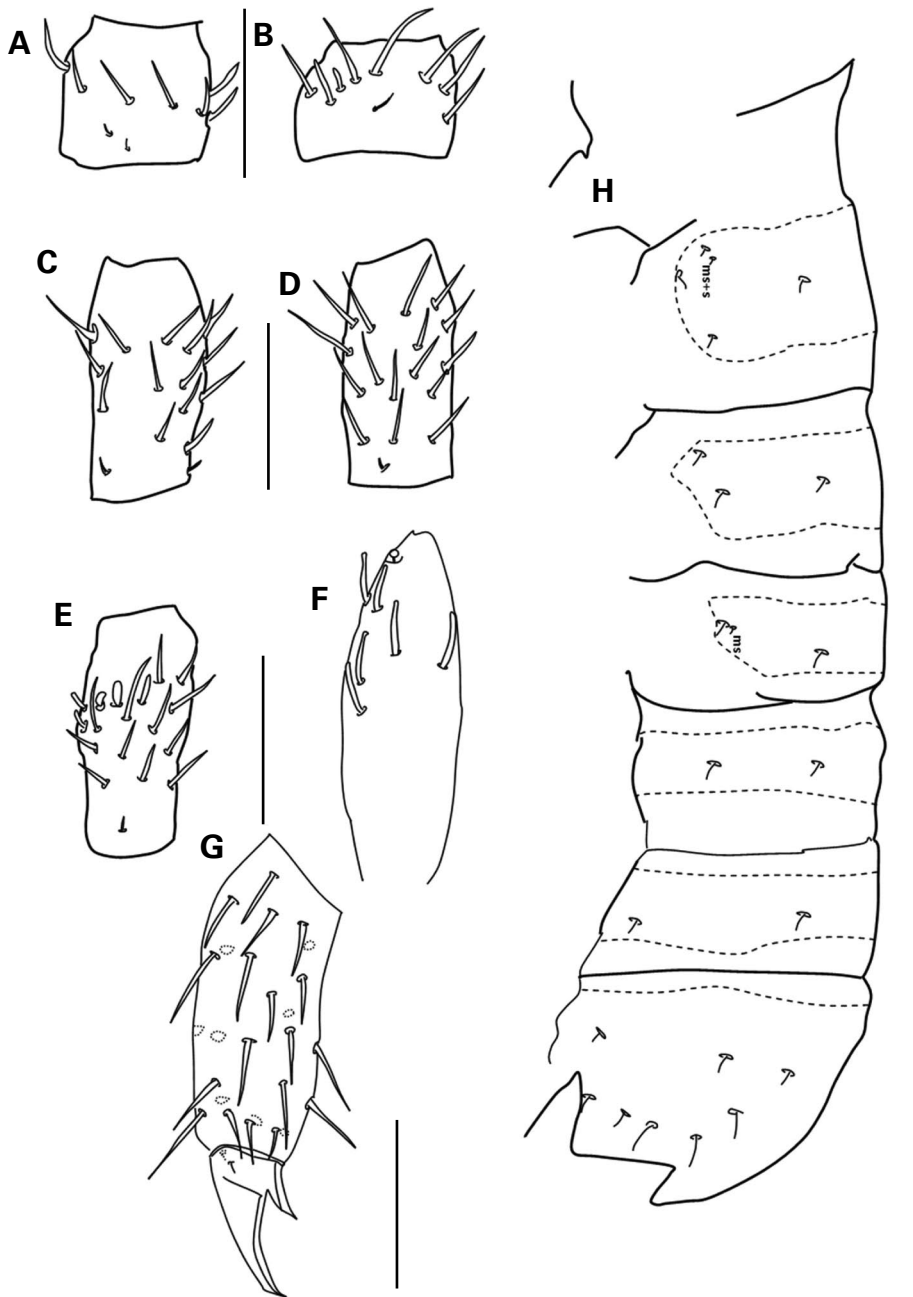


Fig. 2. *Folsomia quadrioculata*; A, dorsal surface, first antennal segment; B, ventral surface, first antennal segment; C, dorsal surface, second antennal segment; D, ventral surface, second antennal segment; E, dorsal surface, third antennal segment; F, fourth antennal segment showing differentiated setae; G, hind leg; H, arrangement of sensilla and microsensilla on Th. II-Abd. VI. Scales: A-G = 25 μ m, H = 100 μ m.

***Folsomia octoculata* (Handschin 1925)**

팔눈마디톡토기 (Figs. 1B & 3)

Folsomia octoculata Handschin, 1925: 226, Figs. 1-5 (Type locality: Java, "Tjibodas")

Folsomia uenoea Uchida, 1943: 5, Pl. 3C-H.

Redescription. Body length 1.0 to 1.4 mm. Body slender and elongate, abdomen slightly expanded towards tip (Fig. 1B). Ground color pale yellow overlaid with scattered deep bluish-gray pigmentation except intersegmental margins; antennae bluish-gray; legs bluish-gray on coxae, otherwise

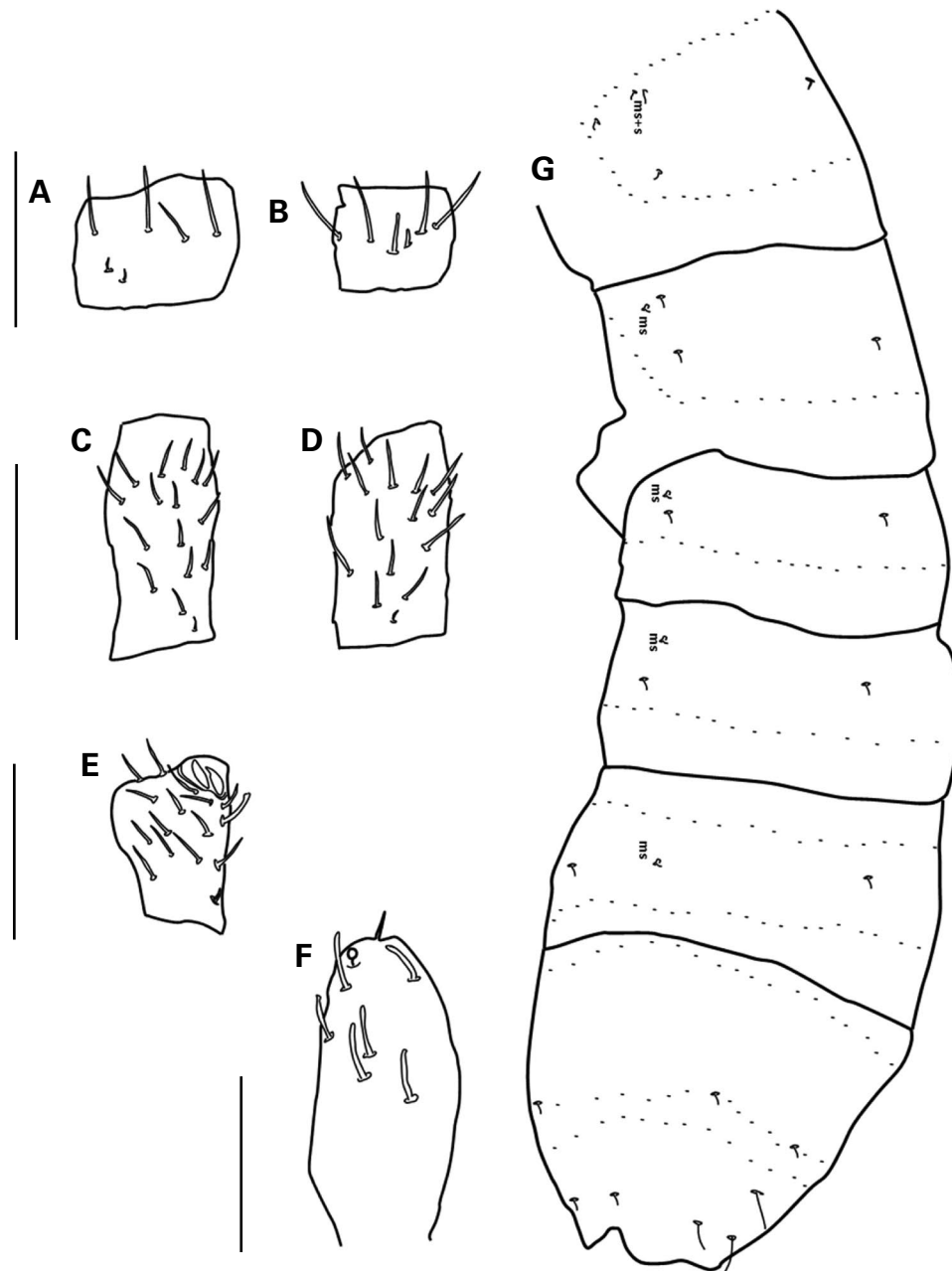


Fig. 3. *Folsomia octoculata*; A, dorsal surface, first antennal segment; B, ventral surface, first antennal segment; C, dorsal surface, second antennal segment; D, ventral surface, second antennal segment; E, dorsal surface, third antennal segment; F, fourth antennal segment showing differentiated setae; G, arrangement of sensilla and microsensilla on Th. II–Abd. VI. Scales: A–F = 25 μ m, G = 100 μ m.

pale; furcula pale yellow. Eye patches black, ocelli 4 + 4, three of the four in the anterior and one in the posterior on each side. PAO narrow, constricted, about 1.5 times longer than the width of Ant I. Labrum 4 / 5, 5, 4. Ant. I with 2 small basal microsensilla (dorsal, bms) and 2 ventral sensil-

la (s) (Fig. 3A, B), Ant II with 2 bms, 1 dorsal and 1 ventral (Fig. 3C, D), Ant III with 1 bms, Ant III O with two inner sens (Fig. 3E), Ant IV without apical bulb, with subapical knob in a pit and 6 slender, curved differentiated setae (Fig. 3F). Sensillary chaetotaxy of Th. II to Abd. IV–VI as 4, 3 /

2, 2, 2, 8, including 1, 1 / 1, 1, 1, 0 microsensilla (Fig. 3G). Ret with 4 + 4 teeth and 1 seta. Man with 2 + 2 ventroapical setae. Dens with 9 anterior and 5 posterior setae. Mucro bidentate. Mucro : dens : Man = 7 : 28 : 30.

Material examined. 4 specimens on slide: Youngmunsan (mountain), 127° 31' 20" E, 37° 30' 55" N, Yongmun-myeon, Yangpyeong-gun, Gyeonggi-do Province. 3 specimens on slide: Gyoryongsan (mountain), 127° 21' 9" E, 36° 22' 8" N, Sangok-dong, Namwon-si, Jeollabuk-do Province. 2 specimens on slide: Ansan (mountain), 126° 56' 48" E, 37° 34' 36" N, Bongwon-dong, Seodaemun-gu, Seoul.

Distribution. East Asia (Indonesia, Malaya, India, Pakistan, Nepal), Far East Asia (China, Japan, Korea), Russia (Far East), Hawaii

Biology. All the specimens in the present study were found in litter of pine forest.

Remarks. The present materials agree well with the previous studies by Handchin (1925) and Yosii (1956) from Indonesia. The ratio of the mucro, dens, and manubrium in the present study is closer to the original description of Handchin (1925; 7 : 25 : 30) than to the record of Yossi (1956; 1 : 4 : 3.5). According to the report by Lee (1977), the specimens from South Korea show variation from 1 to 3 in the number of setae on tenaculum. However, all the specimens under our study had 1 seta.

DISCUSSION

Folsomia quadrioculata and *Folsomia octoculata* were dominant species in this study, but they have been very few studies in Korea. *F. quadrioculata*, the specimens examined showed a considerable correspondence with that reported by Deharveng (1982) and Fjellberg (2007). *F. octoculata* which found in this study have 2 bms on each of Ant. I and II. This is a new morphological feature that has not been reported in previous literature on *F. octoculata*. The appearance of these two species looks very similar, but they can be easily distinguished by showing the difference in body color (*F. octoculata* is darker than *F. quadrioculata*), number of ommatidium, number of anterior setae on manubrium, and microsensillar formula on thorax II to abdomen III.

Despite the morphological similarity between *F. quadrioculata* and *F. octoculata*, their habitats seem to be very different. The major tree species and two *Folsomia* species were closely related. *F. quadrioculata* and *F. octoculata* were found at the sites where deciduous and pine forests are presence, respectively (Table 1). In the previous studies, *F. octoculata*

was mostly found in a pine forests (Potapow 2001), and *F. quadrioculata* was reported as indicator species of the deciduous forests (Slawska *et al.* 2017). Although this relationship cannot be concluded in this study because of the small number of sampling sites, the major tree species seem to be one of the important factors determining their habitat.

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