

Reassessment of type specimens of *Cordyceps* and its allies described by Dr. Yosio Kobayasi, preserved in the National Museum of Nature and Science. Part 2: *Cordyceps* (*Elaphocordyceps*) on *Elaphomyces*

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Abstract Four holotype specimens of *Cordyceps* parasitic on *Elaphomyces* that were originally described by Dr. Yosio Kobayasi and Mr. Daisuke Shimizu were relocated, and TNS (National Museum of Nature and Science, Japan) registration numbers (TNS-F-number) were assigned: viz. *Cordyceps minazukiensis* (TNS-F-197989), *C. ophioglossoides* var. *cuboides* (TNS-F-230312), *C. valvatistipitata* (TNS-F-230284), and *Cordyceps* × *jezoensisoides* (TNS-F-230286). Two specimens were selected as lectotypes: *C. delicatistipitata* (TNS-F-230293) and *C. ophioglossoides* f. *alba* (TNS-F-18223). Those taxa, except for *Cordyceps* × *jezoensisoides*, have been treated as members of the genus *Elaphocordyceps* in the latest taxonomy. The new combination *Elaphocordyceps* × *jezoensisoides* (Kobayasi) is proposed. In addition, *Elaphomyces asahimontanus* Kobayasi, the host of *Cordyceps delicatistipitata*, is lectotypified (TNS-F-230293).

Keywords Classification · Clavicipitaceae · Ophiocordycipitaceae · Preservation · Taxonomy

Cordyceps (Fr.) Link sensu lato is the one of the major genera of insect pathogenic fungi. Some members of the group, however, attack hypogeous fungi of the truffle genus *Elaphomyces* Nees. Molecular phylogenetic studies by Sung et al. (2007) demonstrated that *Cordyceps* species that parasitize *Elaphomyces* formed a strongly supported clade along with a few species of *Cordyceps* pathogenic on insects. Based on this work, a new genus, *Elaphocordyceps* G.H. Sung & Spatafora, was established. The genus is characterized by its dominant ecology as being pathogens of *Elaphomyces* and cicadas, and the morphology of darkly pigmented, fibrous stromata with a more or less olivaceous tint (Sung et al. 2007). Twenty-four taxa (21 species and 3 forma) are recognized in this genus, and more than 18 taxa are parasitic on *Elaphomyces* (Sung et al. 2007). Kobayasi and Shimizu studied *Cordyceps* s. l. on *Elaphomyces* and described 8 taxa: 5 new species, *C. delicatistipitata* Kobayasi (Kobayasi and Shimizu 1960), *C. valvatistipitata* Kobayasi (Kobayasi and Shimizu 1960), *C. minazukiensis* Kobayasi & Shimizu (Kobayasi and Shimizu 1982), *C. miomoteana* Kobayasi & Shimizu (Kobayasi and Shimizu 1982), and *C. virens* Kobayasi (Kobayasi 1983); 2 new forma, *C. ophioglossoides* f. *cuboides* Kobayasi (Kobayasi and Shimizu 1960) and *C. intermedia* f. *michinokuensis* Kobayasi & Shimizu (Kobayasi and Shimizu 1982); and 1 new hybrid, *C. × jezoensisoides* Kobayasi (Kobayasi and Shimizu 1960). Kobayasi and Shimizu left an additional forma in nomen nudum status, *C. ophioglossoides* f. *alba* (Kobayasi and Shimizu 1983), validated by Yao et al. (1995), and transferred to *Elaphocordyceps* (Sung et al. 2007). Hence, 9 taxa (5 species, 2 forma, a

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hybrid, and a forma in nomen nudum) on *Elaphomyces* described by Kobayasi and Shimizu are currently recognized. However, Kobayasi and Shimizu did not state the specimen numbers to specify the type specimen. This unfortunate circumstance caused many researchers to assume that the type specimens were lost or at the very least inaccessible. As we carried out the search of type specimens of entomopathogenic fungi at the National Museum of Nature and Science (TNS) (Sato et al. 2010), we located specimens for 6 taxa (3 species, 2 forma, and a hybrid) of those 9 mentioned above. In the present article, we evaluated the condition of the type specimens of *Cordyceps* species on *Elaphomyces* in TNS. Examination and photographic procedures followed those of Sato et al. (2010). In contrast to the previous report (Sato et al. 2010), collection data on all specimen labels agreed with those in the original publication; hence, determination of the holotype was relatively easy. However, Kobayasi and Shimizu did not designate the type for some species, so type designation is provided herein. Most specimens have been kept in formalin except for the specimen TNS-F-230312, which was dried, and all specimens were in relatively good condition. A summary of the taxonomic status, the assigned specimen number (TNS-F-number), and other remarks are listed in Table 1. We use the latest scientific classification of Sung et al. (2007) in the following section.

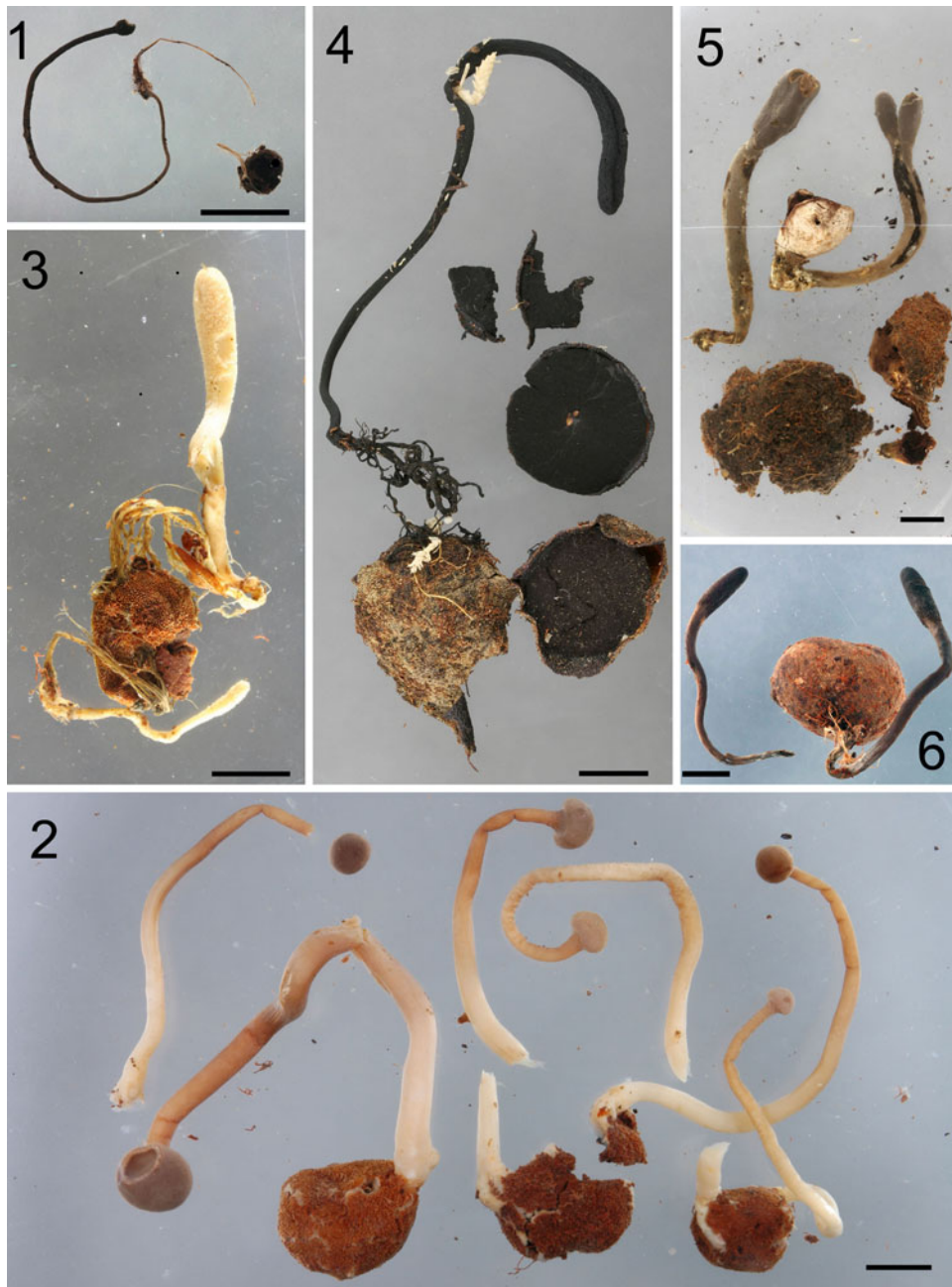
We could not find type specimens of three taxa (*Elaphomyces miomotiana*, *E. virens*, and *E. intermedia* f. *michinokuensis*). Neotypification of those species is necessary for these taxa.

1. *Elaphocordyceps delicatistipitata* (Kobayasi) G.H. Sung, J.M. Sung & Spatafora (2007), Stud. Mycol. 57: 37.
Basionym: *Cordyceps delicatistipitata* Kobayasi (1960), Bull. Natl. Sci. Mus. Tokyo 5: 79. (ut *C. 'delicatistipitata'*) Fig. 1

There were two specimens with label information that agreed with the publication by Kobayasi and Shimizu (1960); one was in formalin liquid (TNS-F-230293) and the other was dried and broken (TNS-F-230309). Because Kobayasi and Shimizu (1960) did not designate the holotype, the specimen preserved in formalin liquid was selected as the lectotype (TNS-F-230293) because it was in better physical condition. The external morphology of the specimen was confirmed to be identical with the color illustration and photograph in Kobayasi and Shimizu (1960, pls. 6, 8-I). Also, the epithet was grammatically correct according to Sung et al. (2007). In the same year that Kobayasi described *C. delicatistipitata* (1960), he also described *Elaphomyces asahimontanus* Kobayasi as the host fungus of *C. delicatistipitata*. The label data on these

Table 1 List of relocated type specimens of *Elaphocordyceps* spp. described by Dr. Kobayasi and Mr. Shimizu in TNS

Name by Kobayasi and Shimizu Japanese name	Name by Sung et al. (2007)	Preserved status	Accession number (TNS-F-)	Determined status	Citation
<i>Cordyceps delicatistipitata</i> Hime-tampotake (proposed in Kobayasi and Shimizu 1960)	<i>Elaphocordyceps delicatistipitata</i>	Formalin	TNS-F-230293	Lectotype	Sung et al. (2007), Kobayasi and Shimizu (1960) Kobayasi and Shimizu 1983; pl. 44-2) Shimizu (1994; pl. 375)
<i>C. minazukiensis</i> Minazuki-tampotake (proposed in Kobayasi and Shimizu 1982)	<i>E. minazukiensis</i>	Formalin	TNS-F-197989	Holotype	Sung et al. (2007); Kobayasi and Shimizu (1982)
<i>C. ophioglossoides</i> f. <i>alba</i> Shiro-hanayasuritake (proposed in Kobayasi 1966)	<i>E. ophioglossoides</i> f. <i>alba</i>	Formalin	TNS-F-18223	Lectotype	Sung et al. (2007), Kobayasi (1966), Kobayasi and Shimizu (1983), Yao et al. (1995)
<i>C. ophioglossoides</i> f. <i>cuboides</i> No Japanese name	<i>E. ophioglossoides</i> f. <i>cuboides</i>	Dried	TNS-F-230312	Holotype	Sung et al. (2007), Kobayasi and Shimizu (1960)
<i>C. valvatostipitata</i> Eriasi-tampotake (proposed in Kobayasi and Shimizu 1960)	<i>E. valvatistipitata</i>	Formalin	TNS- F-230284	Holotype	Sung et al. (2007), Kobayasi and Shimizu (1960), Kobayasi and Shimizu (1983; pl. 46-3), Shimizu (1994; pl. 369)
<i>Cordyceps</i> × <i>jezoenssoides</i> No Japanese name	Not included	Formalin	TNS-F-230286	Holotype	Kobayasi and Shimizu (1960)



Figs. 1–6 *Elaphocordyceps* specimens determined as holotypes or chosen as lectotypes. **1** Lectotype of *Elaphocordyceps delicatistipitata*. TNS-F-230293 (left). Lectotype of *Elaphomyces asahimontanus* (bottom right). **2** Holotype of *Elaphocordyceps minazukiensis*. TNS-F-197989. **3** Lectotype of *Elaphocordyceps ophioglossoides* f. *alba*.

TNS-F-18223. **4** Holotype of *Elaphocordyceps ophioglossoides* f. *cuboides*. TNS-F-230312. **5** Holotype of *Elaphocordyceps valvatistipitata*. TNS-F-230284. **6** Holotype of *Elaphocordyceps* × *jezoënsoides*. TNS-F-230286. Bars 1–6 10 mm

two specimens of *C. delicatistipitata* agreed with the collection data of *E. asahimontanus* in the publication by Kobayasi (Kobayasi 1960). We chose the specimen (TNS-F-230293) again as the lectotype for *E. asahimontanus*.

2. *E. minazukiensis* (Kobayasi & Shimizu) G.H. Sung, J.M. Sung & Spatafora (2007), Stud. Mycol. 57: 37. Basionym: *Cordyceps minazukiensis* Kobayasi &

Shimizu (1982), Bull. Natl. Sci. Mus. Tokyo Ser. B. 8: 117

Fig. 2

Several stromata of this species were found in a single bottle, but they are regarded as a single specimen (ICBN Art. 8.2). External morphology of the photograph in the original paper (Kobayasi and Shimizu 1982, fig. 16A) agreed with that of the specimen.

3. *E. ophioglossoides* f. *alba* (Kobayasi & Shimizu ex Y. J. Yao) G.H. Sung, J.M. Sung & Spatafora (2007), *Stud. Mycol.* 57: 37.

Basionym: *Cordyceps ophioglossoides* f. *alba* Kobayasi & Shimizu ex Y.J. Yao, in Yao, Li, Pegler & Spooner (1995), *Acta Mycol. Sin.* 14: 257 Fig. 3

Although the present specimen was mentioned by Kobayasi (1966) as a white mutant of *C. ophioglossoides*, no description was given. However, Kobayasi and Shimizu (1983) used the scientific name *C. ophioglossoides* f. *alba* Kobayasi & Shimizu, and cited Kobayasi (1966) as if that name were valid. Yao et al. (1995) validated the name, and Sung et al. (2007) transferred the taxon to *Elaphocordyceps*. In spite of these aforementioned taxonomic treatments, a type specimen has not been designated. Here we lectotypify the specimen reported by Kobayasi (1966). Only one of the two stromata is shown in the photograph in the original paper (Kobayasi and Shimizu 1966, figs. A, B)

4. *E. ophioglossoides* f. *cuboides* (Kobayasi) G.H. Sung, J.M. Sung & Spatafora (2007), *Stud. Mycol.* 57: 37.

Basionym: *Cordyceps ophioglossoides* f. *cuboides* Kobayasi (1960) *Bull. Natl. Sci. Mus. Tokyo* 5: 77 Fig. 4

Although the specimen was found in dried condition, it was apparent that it was originally preserved in liquid because residue was present at the bottom of the bottle. The host fungus had been cut into two hemispherical pieces, but they were in good condition. Because the specimen was dried, external morphology has not been maintained as in the photograph (pl. 8-F) in Kobayasi and Shimizu (1960).

5. *E. valvatistipitata* (Kobayasi) G.H. Sung, J.M. Sung & Spatafora (2007), *Stud. Mycol.* 57: 38.

Basionym: *Cordyceps valvatistipitata* Kobayasi (1960) *Bull. Natl. Sci. Mus. Tokyo* 5: 81. (ut *C. 'valvatostipitata'*) Fig. 5

The epithet was grammatically correct (Sung et al. 2007). External morphology of each of two stromata was confirmed to be identical with the color illustration and the photograph in Kobayasi and Shimizu (1960, pls. 6, 9-M).

6. *Elaphocordyceps* × *jezoënsoïdes* (Kobayasi) Hirok. Sato, S. Ban, Masuya & Hosoya comb. nov. MycoBank no.: MB516935.

Basionym: *Cordyceps* × *jezoënsoïdes* Kobayasi (1960) *Bull. Natl. Sci. Mus. Tokyo* 5: 79 MycoBank no.: MB516934 Fig. 6

This taxon was described as a hybrid between *Cordyceps jezoensis* S. Imai and *C. ophioglossoides*. Kobayasi chose one specimen for the holotype from a total of four specimens (Kobayasi and Shimizu 1960). The specimen (TNS-F-230286) was recognized as the holotype because of the congruence of the label data with that in the original paper (Kobayasi and Shimizu 1960). The other three specimens (paratypes) were also found and registered as TNS-F-230291, -230310, and -230317. Sung et al. (2007) placed both *C. jezoensis* and *C. ophioglossoides* in the genus *Elaphocordyceps*. It is most likely that this taxon belongs to *Elaphocordyceps*, and hence a new combination, *Elaphocordyceps* × *jezoënsoïdes*, is proposed here. However, *E.* × *jezoënsoïdes* (\equiv *C.* × *jezoënsoïdes*) was not considered in their manuscript (Sung et al. 2007), and further examination using molecular data is needed to clarify the putative hybrid nature of this species. Photographs of the holotype were not shown in Kobayasi and Shimizu (1960). A photograph in Kobayasi and Shimizu (1960, pl. 8-G) appears to be one of the paratype specimens (TNS-F-230310).

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