The identity of *Cintractia carpophila* var. *kenaica*: reclassification of a North American smut on *Carex micropoda* as a distinct species of *Anthracoidea*

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Abstract: *Cintractia carpophila* var. *kenaica*, a neglected taxon described from Alaska more than half a century ago, is re-described and illustrated. Its nomenclature and taxonomic status are discussed. This smut species is characterised by small spores with a very finely verruculose surface rarely enclosed by a thin, hyaline, mucilaginous sheath, a wall with 2–5 distinct internal swellings, and parasitism on *Carex micropoda* (*Carex* sect. *Dornera*). It is reallocated to the genus *Anthracoidea* as a distinct species, *Anthracoidea kenaica* comb. nov., and assigned to *Anthracoidea* section *Leiosporae* which includes species having smooth or very finely verruculose spores. Morphological and biological characteristics of the five most similar *Anthracoidea* species are contrasted and discussed.

**Key words:** Anthracoidea, Carex, Cintractia, Historical collections, North America, Smut fungi, Ustilaginales

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**INTRODUCTION**

*A nthracoidea* is the most species-rich genus of smut fungi on *Cyperaceae*. Currently, 106 species are accepted in this genus (Denchev & Denchev 2011a, 2011b, 2012, Vánky & Abbasi 2011, Vánky 2012, Savchenko et al. 2013), but this is certainly not a final number. The magnitude of host plants reported in different publications for some putative species complexes suggests that more species are likely to exist, some of which may be well-delimited morphological species, while others are probably cryptic species that could be uncovered by molecular methods. Some species of *Anthracoidea* were recently included in molecular systematic studies (Hendrichs et al. 2005, Begerow et al. 2007, Bauer et al. 2007, Lutz et al. 2012, Savchenko et al. 2013, Vánky et al. 2013), but sequence data are not available for the vast majority. Distinct species could still be hidden under different generic names, especially under historical names that have not been reassessed in recent years (Piątek 2012). Such historical names should be critically re-examined in addition to any comprehensive molecular studies directed to the description of novel *Anthracoidea* species.

*Cintractia carpophila* var. *kenaica* is such a neglected taxon name and a likely candidate to be a distinct member of *Anthracoidea*. This smut was described from a specimen of *Carex pyrenaica* subsp. *micropoda* collected in the Kenai Peninsula of Alaska. That sedge is now accepted as a distinct species, *Carex micropoda*, belonging to *Carex* sect. *Dornera* (syn. sect. *Callistachys*) (Murray 2002a). Savile (1952) provided the following description of *Cintractia carpophila* var. *kenaica*: “Teliosporae 16.0–23.5 × 11.5–19.5 µm, compressae, ellipsoideae, nunquam angulater. Episporium 0.6–1.3 µm, castaneum, leve; saepius interne gibberibus 2–5 munitum.” Zambettakis (1978) included it in *Anthracoidea*, as “*Anthracoidea heterospora* Kukkonen var. *kenaica* (Savile) nov. comb.”, but without any indication of the basionym or a reference to the place of its valid publication, rendering the combination invalid (Art. 41.5). Likewise, Kukkonen (1963) and Piepenbring (2000) considered this fungus to be a member of *Anthracoidea*, but again without further treatment and any formal nomenclatural and taxonomic decisions. Vánky (2012) included this smut in two places in his monograph: first as a synonym of *Anthracoidea heterospora* and later under excluded or invalidly published taxa, in both cases without detailed observations.

The aim of the present work is to clarify the nomenclatural and taxonomic status of *Cintractia carpophila* var. *kenaica*, and to provide a detailed characterization of this smut fungus as it lacks a detailed description and any iconography.

**MATERIALS AND METHODS**

Sori and spore characteristics were studied using dried herbarium material deposited in DAOM, S, and WRSL. Specimens were examined either by light microscopy (LM) and scanning electron microscopy (SEM) or only by light microscopy (LM).

For light microscopy (LM), hand-cut sections of sori or small pieces of sori were mounted in lactic acid, heated...
Table 1. Spore size range, and mean spore sizes with standard deviation of Anthracoidea kenaica specimens examined in this study.

<table>
<thead>
<tr>
<th>Specimen Description</th>
<th>Spore size range (µm)</th>
<th>Average spore size with standard deviation (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA, Alaska, Kenai Peninsula, Head of Palmer Creek Valley, 26 July 1951, J.A. Calder 6229 (DAOM 28108 – holotype)</td>
<td>(14.5–)15.0–20.5(–21.5) × 12.0–17.5(–18.5)</td>
<td>18.1 ± 1.6 × 15.2 ± 1.7</td>
</tr>
<tr>
<td>Same locality, date and collector (S F-36682 – isotype)</td>
<td>17.0–20.5(–22.0) × 12.0–18.0(–20.5)</td>
<td>19.2 ± 1.3 × 16.1 ± 1.8</td>
</tr>
<tr>
<td>USA, Alaska, St. Paul, Pribilof Island, 22 Aug. 1914, J.M. Macoun (DAOM 66925)</td>
<td>(14.0–)15.0–20.5(–21.0) × (11.5–)12.0–17.5(–18.5)</td>
<td>18.2 ± 1.7 × 15.2 ± 1.8</td>
</tr>
<tr>
<td>Canada, British Columbia, Bella Coola, Mt. Fougner, 23 Aug. 1956, J.A. Calder, J.A. Parmelee &amp; R.L. Taylor (DAOM 70101)</td>
<td>(14.5–)17.0–20.5(–22.0) × 13.5–18.5(–19.0)</td>
<td>18.5 ± 1.2 × 15.9 ± 1.4</td>
</tr>
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</table>

RESULTS

Detailed morphological characteristics of the holotype, isotype, and two non-type specimens of Cintractia carpophila var. kenaica are embraced in the species description and illustrated (Figs 1–2). The internal soral structure in the holotype was typical of species of Anthracoidea in that the spores were produced directly on the outer surface of the achene, and not within U-shaped cavities embedded in sterile stroma, a characteristic of Cintractia (Kukkonen 1963, Kukkonen & Vaissalo 1964, Piepenbring 2000). This indicated this smut fungus was better placed in Anthracoidea, as was suggested in other studies (Kukkonen 1963, Zambettakis 1978, Piepenbring 2000). The spores were uniform in shape and size ranges between collections (Table 1). My examination of specimens of Cintractia carpophila var. kenaica matched well the short description given by Savile (1952), although the spore surface was not smooth as stated in the protologue, but smooth or very finely punctate in LM, and very finely verruculose in SEM. The very fine ornamentation of spores was probably outside the limits of resolution of Savile’s light microscope.

In general, the present examination confirms the decision of Savile (1952) to consider this smut as distinct. However, a specific status seems to be appropriate for this taxon. This is in line with the conclusion of Kukkonen (1963), who, however, did not formally make the transfer. Accordingly, a new combination is necessary.

TAXONOMY

A nthracoidea kenaica (Savile) M. Piątek, comb. nov. MycoBank: MB804512 (Figs 1–2)


Description: Sori in all or single ovaries of the inflorescence, black, globose or ovoid, about 1–1.5 mm diam, at first covered by a silvery membrane and perigynium that later ruptures revealing agglutinated spores, powdery on the surface, the sori are partly hidden by the perigynium and scales. Sori develop around reduced achenes that are consecutively surrounded by a thin dark layer of the remnants of achene epidermis, a hyaline layer of sporogeneous hyphae with young spores, a layer of gradually maturing dark spores, and a thin membrane of host origin. Spores usually more or less flattened, chestnut brown, reddish brown to dark brown, quite regular in shape and size, globose, subglobose or broadly ellipsoidal, small, (14.0–)15.0–20.5(–22.0) × (11.5–)12.0–18.5(–20.5) µm [av. ± SD, 18.5 ± 1.5 × 15.6 ± 1.7 µm, n = 200(4)], rarely enclosed by a thin, hyaline, mucilaginous sheath; wall even, 1.0–1.5 µm thick, somewhat darker than the rest of the spore, without protuberances and light-refractive spots, but with 2–5 distinct internal swellings; surface smooth or very finely punctate in LM, spore profile smooth, surface very finely verruculose in SEM.
Fig. 1. Anthracoidea kenaica on Carex micropoda. A. Sori in the ovaries (S F-36682). B. Transverse section through the sorus showing reduced achene surrounded by spores (DAOM 28108). C–D. Enlarged area close to the achene surface (DAOM 28108). E. The spore formation (DAOM 28108). F. Cells of the soral membrane, indicated by arrows (DAOM 28108). Abbreviations: n – achene, e – dark layer of the remnants of the achene epidermis, s – layer of young hyaline spores, m – layer of gradually maturing dark spores. Bars: A = 1 mm, B = 500 µm, C–D = 20 µm, E–F = 10 µm.


Host and distribution: On Carex micropoda (Carex sect. Dornera); Canada (British Columbia) and USA (Alaska).

Notes: The nomenclature of Cintractia carpophila var. kenaica needs some clarification. The name Uredo carpophila...
Schum. (Schumacher 1903) was introduced as superfluous replacement of *Uredo caricis* Pers. (Nannfeldt & Lindeberg 1965) and is therefore illegitimate and to be rejected (Art. 52.1). Consequently, the name *Cintractia carpophila* (Schum.) Liro (Liro 1938), based on *Uredo carpophila*, is also illegitimate. Also, Liro’s treatment cannot constitute a valid description of a new species to be attributed to him alone due to the absence of a Latin diagnosis (Nannfeldt & Lindeberg 1965), required in the period 1 January 1935 to 31 December 2011 (Art. 39.1). Vánky (2012) considered *Uredo carpophila* as an illegitimate name, which is correct, but also as a *nomen nudum*, which is not correct, since Schumacher (1903) provided a short description of this species: “*U. carpophyla, pulvere nigro capsulas subnude ambiente. Ured. Caricis Pers. Synops. pag. 225. In capsulis Caricis caespitosae. Julio*”. Furthermore, Vánky (2012) considered the name *Cintractia*

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**Fig. 2.** **Anthracoidea kenaica** on *Carex micropoda* (S F-36682). A–C. Spores seen by LM, median and superficial views, note internal swellings indicated by arrows. D–E. Spores seen by SEM. F. Spore wall seen by SEM. Bars: A–E = 10 µm, F = 3 µm.
Anthracoidea kenaica comb. nov. on Carex micropoda

... on Carex micropoda and from Mt Fougner in British Columbia; this last collection represents the first record of this species in Canada. Here the smut is newly reported from Pribilof Island (AK) two other collections from the same region (Savile 1952). Indeed, the verrucose, unlike spores of specimens on C. micropoda and they are distinctly C. deweyana from a specimen on Zambettakis (1978) included two SEM pictures of spores from a specimen on C. deweyana and are they distinctly verrucose, unlike spores of specimens on C. micropoda. Indeed, the Anthracoidea on Carex deweyana represents a distinct species – Anthracoidea deweyanae (Denchev & Denchev 2012). Anthracoidea kenaica was previously reported from the type locality on the Kenai Peninsula and was previously & Denchev 2012).

DISCUSSION

Cintractia carpophila var. kenaica also as illegitimate, but the varietal name Cintractia carpophila var. kenaica is legitimate since an infraspecific name may be legitimate even if its final epithet was originally placed under an illegitimate species name. Similarly, Cintractia carpophila var. verrucosa Savile (Savile 1952), was accepted as a legitimate varietal name that was elevated to the species rank as Anthracoidea verrucosa (Savile) Nannf. (Nannfeldt 1977, Vánky 2012). Therefore, the name Cintractia carpophila var. kenaica is used here to elevate this taxon to species rank.

The type host of A. kenaica is Carex micropoda, but in addition Savile (1952) assigned a single smut collection on Carex deweyana (in Carex sect. Deweyanae; Naczi 2002) to his concept of Cintractia carpophila var. kenaica. Zambettakis (1978) included two SEM pictures of spores from a specimen on C. deweyana and from Mt Fougner in British Columbia; this last collection represents the first record of this species in Canada.

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<table>
<thead>
<tr>
<th>Species</th>
<th>Host plant(s)</th>
<th>Spores (µm)</th>
<th>Wall (µm)</th>
<th>Internal swellings</th>
<th>Spore ornamentation</th>
<th>Mucilaginous sheath</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthracoida elynae</td>
<td><em>Kobresia humilis, K. laxa, K. macrolepis, K. myosuroides, K. schoenoides, K. smirnovii</em></td>
<td>(14–)16–22(–25) × (9–) 10–20(–22)</td>
<td>1–2.5(–3)</td>
<td>frequent 1–2(–3) 1–2(–3) weak internal swellings</td>
<td>smooth, seldom dotted</td>
<td>usually covered by a gelatinous sheath</td>
<td>Kukkonen (1963)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(14–)16–22(–26)</td>
<td>2–3</td>
<td>weak but frequent 2–3 weak internal swellings</td>
<td>almost smooth, only dotted</td>
<td>no data</td>
<td>Nannfeldt (1979)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17–22(–25) × (14–)15–18.5</td>
<td>1–2.5(–3)</td>
<td>often with 1–3 weak internal swellings</td>
<td>smooth to finely punctate on the flat sides</td>
<td>more or less evident hyaline sheath</td>
<td>Vánky (1994, 2012)</td>
</tr>
<tr>
<td>Anthracoida externa</td>
<td><em>Carex filifolia</em> (Carex sect. Filifoliae)</td>
<td>15–22(–23) × 11–20</td>
<td>0.7–2.5</td>
<td>absent</td>
<td>absolutely smooth</td>
<td>always covered by a gelatinous sheath</td>
<td>Kukkonen (1963)</td>
</tr>
<tr>
<td>Anthracoida kenaica</td>
<td><em>Carex micropoda</em> (Carex sect. Domera)</td>
<td>(14–)15–20(–22) × (11.5–)12–18.5(–20.5)</td>
<td>1–1.5</td>
<td>2–5 distinct internal swellings</td>
<td>smooth to very finely punctate in LM, verruculose in SEM</td>
<td>rarely enclosed by a thin mucilaginous sheath</td>
<td>Vánky (2012)</td>
</tr>
<tr>
<td>Anthracoida macrantha</td>
<td><em>Kobresia macrantha</em></td>
<td>15–18(–19.5) × 13–17.5</td>
<td>0.5–1</td>
<td>absent</td>
<td>smooth</td>
<td>hyaline caps common on the flattened side</td>
<td>Guo &amp; Wang (2005)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15–18.5(–20.5) × 13.5–16</td>
<td>1</td>
<td>absent</td>
<td>smooth</td>
<td>present on the flattened sides and often around the entire spore</td>
<td>Vánky (2012)</td>
</tr>
<tr>
<td>Anthracoida nardinae</td>
<td><em>Carex nardina</em> (Carex sect. Nardinae), <em>Carex elynoides</em> (Carex sect. Filifoliae)</td>
<td>(15–)16–22(–23) × (10–) 11–20(–21)</td>
<td>1–3</td>
<td>always 1–3 more or less clear internal swellings</td>
<td>smooth, sometimes obscurely dotted</td>
<td>absent, or at most, rare</td>
<td>Kukkonen (1963)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(15–)16–23 × 13–20(–21)</td>
<td>ca. 2</td>
<td>1–3 clearly seen 1–3 clearly seen</td>
<td>almost smooth, only dotted by hardly discernible dots</td>
<td>no data</td>
<td>Nannfeldt (1979)</td>
</tr>
<tr>
<td>Anthracoida scirpi</td>
<td><em>Trichophorum cespitosum, T. pumilum</em></td>
<td>(16–)17–24(–25) × 12–20(–23)</td>
<td>1–2.5(–3)</td>
<td>absent</td>
<td>smooth or rarely very slightly verrucose</td>
<td>often covered by a gelatinous sheath on the flattened sides</td>
<td>Kukkonen (1963)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17–23 × 14–21</td>
<td>1.5–2</td>
<td>absent</td>
<td>smooth or very minutely punctate</td>
<td>often covered by gelatinous sheaths on the flattened sides</td>
<td>Vánky (1994, 2012)</td>
</tr>
</tbody>
</table>

1 Host plants taken from Vánky (2012), but at least some of them may harbour different Anthracoida species.
ACKNOWLEDGEMENTS

I thank Andrew M. Minnis (Center for Forest Mycology Research, Madison, USA) for nomenclatural advice, Anna Łatkiewicz (Kraków, Poland) for her assistance with the SEM micrographs, and the curators of DAOM, S, and WRSW for the loan of specimens. This study was supported in part by the Polish Ministry of Science and Higher Education (grant no. 2 P04G 019 28) and through the statutory fund of the W. Szafer Institute of Botany of the Polish Academy of Sciences, Kraków, Poland.

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