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NOTES ON THE DISTRIBUTION AND ECOLOGY OF FUNGI OF THE GENUS *ANTHRACOIDEA* (USTILAGINOMYCETES) IN POLAND

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Abstract. The paper provides confirmation of Nannfeldt's suggestion of the occurrence in Poland of *Anthracoidea angulata* (Syd.) Boidol & Poelt, a new species for Poland, collected on hairy sedge *Carex hirta* L. in the Puszcza Augustowska forest. Another species, *Anthracoidea echinospora* (Lehtola) Kukkonen, is reported on a new host, *Carex nigra* (L.) Reichard, from Wigry National Park. New localities of *Anthracoidea arenaria* (Syd.) Nannf. and *A. caricis* (Pers.) Bref. from the Carpathians are reported. The occurrence of the smut beetle *Phalacrus substriatus* Gyll. and an acarine of the family Eriophyidae in the sori of *Anthracoidea arenaria* is reported.

Key words: *Carex*, smut, beetle, *Phalacrus*, acari, Poland

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INTRODUCTION

Fungi of the genus *Anthracoidea* Bref. are pathogens of plants belonging to the genera *Carex* L., *Carpha* Banks & Sol. *ex* R. Br., *Fuirena* Rottb., *Kobresia* Willd., *Schoenus* L., *Scirpus* L. and *Uncinia* Pers. (Kukkonen 1963; Vánky 1994). According to Piątek *et al.* (2005), 17 species of this genus have been reported from Poland; added to that list and marked with an asterisk were another five species earlier suggested to occur in Poland by Nannfeldt (1977, 1979). Piątek (2005) and Piątek *et al.* (2005) stated that Nannfeldt did not examine voucher specimens of *A. angulata* (Syd.) Boidol & Poelt, *A. bigelowii* Nannf., *A. intercedens* Nannf., *A. irregularis* (Liro) Boidol & Poelt, *A. karii* (Liro) Nannf., *A. vankyi* Nannf. and *A. fischeri* (P. Karst.) Kukkonen. Nannfeldt (1979: 34) had noted that in the case of *A. vankyi* 'it is reported from […] Germany, and Poland to Transylvania (specimens seen)' but in the case of *A. angulata* (Nannfeldt 1979: 14) noted only that 'it is known from Central Europe (Germany), Poland and Hungary'. In both of Nannfeldt's articles (1977, 1979) there is no mention of his having examined Polish specimens of *A. angulata*, nor is the name of any Polish herbarium given. According to T. Majewski, Prof. Nannfeldt did not visit J. Kochman during his visit to Poland. J. Kochman not send any fungi to Nannfeldt. *Mycotheca Polonica*, prepared by J. Kochman, did not include *A. angulata* specimens. It may be that Nannfeldt recognized the occurrence of this species in Poland on the basis of host plants of *Anthracoidea caricis* mentioned by Kochman and Majewski (1973), and their fungus illustration (see their Fig. 15C & D). Other indications of the occurrence in Poland of such species as *A. bigelowii* (Nannfeldt 1979: 16), *A. intercedens* (Nannfeldt 1979: 23), *A. irregularis* (Nannfeldt 1979: 25), *A. karii* (Nannfledt 1979: 26) and *A. fischeri* (Nannfeldt 1979: 19 – 'probably also in East Germany, Poland and Czechoslovakia') are based on host data in the monograph of Kochman and Majewski (1973). Within the genus *Anthracoidea* there are strictly specialized species restricted to a single host plant, such as *Anthracoidea atratae* (Savile) Kukkonen, to a few related host plants, or to plants from different sections of the genus *Carex*, for example *Anthracoidea caryophylleae* Kukkonen. *Anthracoidea caricis* (Pers.) Bref. has been divided into many different taxa by Nannfeldt (1977, 1979) and Vánky (1979). *A. sempervirentis*

Vánky, excluded from it, has a relative in Central Asia (Chlebicki 2002a, c).

Anthracoidea caricis (Pers.) Bref. (Schroeter 1887; Starmachowa 1963; Kućmierz 1968; Kochman & Majewski 1973; Sałata *et al.* 1984; Vánky 1985) and *A. sempervirentis* Vánky (Vánky 1979, 1985; Sałata & Mułenko 1996; Chlebicki 2002a; Piątek *et al.* 2005) are two of the *A. caricis* group confirmed in Poland. Another, *Anthracoidea angulata* (Syd.) Boidol & Poelt, is strictly connected with its host plant *Carex hirta* L. However, Guo (1996, 2000) and Zhuang (2005) reported it also on *Carex melanostachya* Bieb. *ex* Willd. In Poland, the fungus was earlier collected in the environs of Zielona Góra at Węgliniec near Zgorzelec (Schroeter 1887; Kochman & Majewski 1973), Psarskie and Promno near Poznań (Dominik 1935), and the Brzeziczno Reserve in the Pojezierze Łęczyńsko-Włodawaskie lake district (Mułenko 1988) and identified as *Anthracoidea caricis*. Of these voucher specimens only one Schroeter and two Mułenko collections of '*A. caricis*' have been examined. Other collections have not been preserved. *Anthracoidea echinospora* (Lehtola) Kukkonen was noted in Poland by Kochman and Majewski (1973). *Anthracoidea arenaria* (Syd.) Nannf. was noted on *Carex brizoides* L. in Poland by Schroeter (1887), Majewski (1965) and Kochman and Majewski (1973).

It is known that insects can be an important vector for dispersal of fungal spores. Symbiotic flies of the genus *Botanophila* Lioy 1864 (Diptera: Anthomyiidae) transport spermatia of *Epichloë typhina* (Pers.) Tul. & C. Tul. (Bultman *et al.* 1995) and enable adult stromata with perithecia to form. Butterflies can also be vectors of fungal spores (Jennersten 1983). The role of insects in propagation of *Anthracoidea* ustilospores is poorly known. According to Steiner (1984) the spread of *Anthracoidea* basidiospores by phalacrid beetles is much less important than dispersal by wind. Ericson *et al.* (1993), however, stated that the phalacrid beetle *Phalacrus substriatus* Gyll. 1813 is an important contributor to the transmission of smut basidiospores from overwintering sori in the base of tussocks to new flowers. Its larva feeds exclusively ustilospores of *Anthracoidea*.

Material and methods

Specimens collected by the author were examined under a Nikon SMZ 1500 and Olympus BX 51 light microscopes. Thirty spores of each specimen were measured in lactophenol heated to boiling point and then cooled. Dry spores of the species were coated with carbon for SEM. Ornamentation of the spores of *Anthracoidea angulata* was viewed with a Philips scanning electron microscope. Specimens were collected during excursions to the Puszcza Augustowska forest (2001, 2004) and Carpathians (2006), and are deposited in KRAM-F.

For identification of insect inhabitants, fresh specimens of *Anthracoidea arenaria* with beetle larvae and adult acari were placed in paper bags and preserved at room temperature. Part of the material was kept in zip bags in an incubator at 10°C. Imagos of *Phalacrus substriatus* appeared after nine days and were observed under a NIKON SMZ 1500 light microscope. All herbarium specimens of the genus *Anthracoidea* in KRAM-F were screened for the presence of phalacrid beetles and their feces.

Morphology and occurrence

Anthracoidea angulata (Syd.) Boidol & Poelt
Figs 1 & 2

Ber. Bayer. Bot. Ges. **36**: 23. 1963. – *Cintractia angulata* Syd., *Ustilago caricis* (Pers.) Fuckel var. *eructans* J. Kunze – *Cintractia eructans* (J. Kunze) Liro

Sori ovoid, 2–2.4 mm long and 1.2–1.8 mm in diameter. Mature sorus black, powdery on the surface. Ustilospores angular, 13–20 × 17–24 μm (KRAM-F 43554) and 11–19 × 17–24(–25) μm (WRSL, Pilze Schlesiens 427), irregular in shape, slightly flattened and depressed in its central part, with some swellings of irregular shape, surface covered by slightly rounded warts, some of which are distributed in small groups (Figs 1 & 2), wall mostly 2 μm thick, but often thicker up to 4 μm at angles and protuberances. Internal swellings and light-refractive spots distinctly visible.

Material examined. POLAND. Puszcza Augustowska forest, 2 km NW of Rygol, in ovaries of *Carex hirta* L., 17 Aug. 2001, *leg. A. Chlebicki* (KRAM-F 43554); Grünberg (Zielona Góra region):

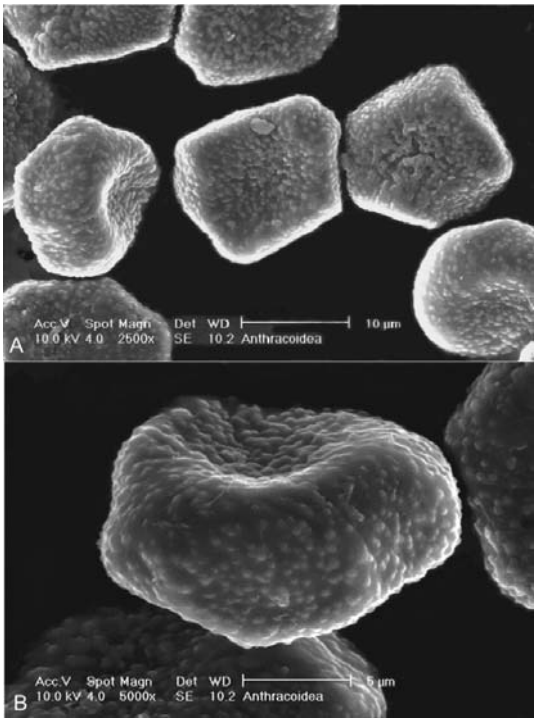

Fig. 1. *Anthracoidea angulata* (Syd.) Boidol & Poelt (KRAM-F 43 554). A – shape of ustilospores; B – structure of ustilospore surface.

Schlossberg (Ostrówek) near Grünberg, on *Carex hirta*, *leg. T. Hellwig* [WRSL, in J. Schroeter, Pilze Schlesiens no. 427, as *Ustilago Caricis* (Pers.) Fuckel]; Pojezierze Łęczyńsko-Włodawskie lake district, on embankment near Jezioro Płotycze lake, in ovaries of *Carex hirta*, 14 Jul. 1978, *leg. W. Mułenko* (LBLM); Pojezierze Łęczyńsko-Włodawskie lake district, Jezioro Brzeziczno Reserve, near dirt road in pine forest, in ovaries of *Carex hirta*, 7 Jun. 1983, *leg. W. Mułenko* (LBLM).

NOTES. The nearest localities of this species were noted in Lithuania (Ignatavičiūtė 2001), western, central and eastern Poland (Schroeter 1887; Dominik 1935; Mułenko 1988) and Germany (Scholz & Scholz 1988). The host plant *Carex hirta* of the section *Carex* can be infected by *A. angulata* as well as by *Anthracoidea subinclusa* (Körn.) Bref., but the latter species possesses echinulate and ovoid ustilospores. Mułenko (1988) noted *A. subinclusa* in the Jezioro Długie Reserve. Specimens of *A. angulata* from WRSL (Pilze Schlesiens 427), the Puszcza Augustowska forest (KRAM-F 43554) and environs of Jezioro Płotycze lake (LBLM) are very similar, with only small differences in the size of ustilospores. The collection from the Jezioro Brzeziczno Reserve is very scarce and consists of only a few sori covered by white membrane. The ustilospores are young, pale brown and mostly globose. It is not a typical collection of *A. angulata* because it is probably not mature.

Guo (1996) reported *Anthracoidea angulata* on *Carex melanostachya* Bieb. *ex* Willd. (sect. *Paludosae*). However, according to Egorova (1999) the sedge belongs to the section *Tumidae*. Guo (1996) noted thinner ustilospore walls in the Chinese specimen than in the specimen of H. Sydow (lectotype, HUV 6) from Sophienstaedt near Berno in Europe. Her SEM picture of ustilospores from China showed warts that were more prominent and slightly diffused in comparison with Vánky's (1994) and my SEM pictures of ustilospores. The Chinese specimen was collected 3 July 1959 at 1340 m a.s.l. in the vicinity of Tacheng in the foothills of the Tarbagatay Mts (Xinjiang province, W China near Kazakhstan border). The collection date suggests that the ustilospores of this specimen are adult.

Anthracoidea arenaria (Syd.) Nannf. Fig. 2A

Bot. Not. **130**: 365. 1977.

Sori in ovaries. Ustilospores mostly medium-sized, 14–18 × 15–20 µm in diameter, in plane view globose to elliptic, oval, subangular or rarely irregular, internal swellings indistinctly visible, wall 1–1.5 µm thick.

MATERIAL EXAMINED. POLAND. Carpathians, Bieszczady Zachodnie Mts., Wołosate, in meadow on NE slope of Kiczera Manzina Mt., in ovaries of *Carex brizoides* L., 11 Aug. 2006, *leg. A. Chlebicki* (KRAM-F 55814).

NOTES. *Anthracoidea arenaria* is a common species in Poland on *Carex arenaria* L., and was rarely noted on *C. brizoides* L. It was noted on *Carex brizoides* in Poland by Schroeter (1887) in the environs of Czerwieńsk, Lwówek Śląski and Głubczyce. Majewski (1965) reported it from the

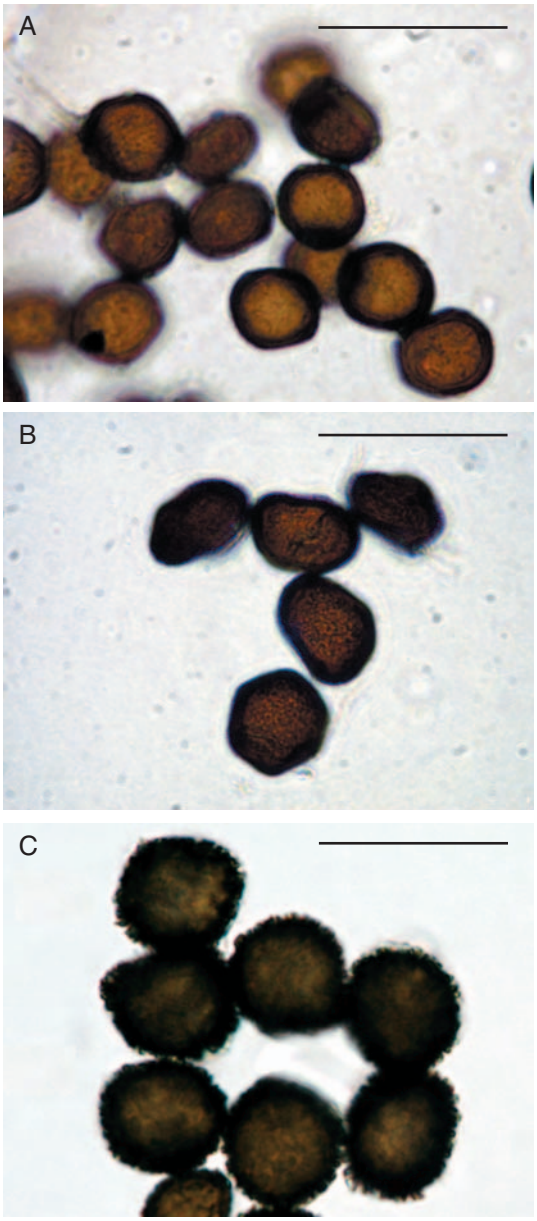

Fig. 2. Ustilospores of *Anthracoidea*. A – *A. arenaria* (Syd.) Nannf. (KRAM-F 55814); B – *A. caricis* (Pers.) Bref. (KRAM-F 55786); C – *A. echinospora* (Lehtola) Kukkonen (KRAM-F 54137). Scale bars = 30 μm.

environs of Sieraków in the Puszcza Kampinoska forest, and Istebna near Cieszyn in the Carpathians. Kochman and Majewski (1973) added a locality from the Puszcza Białowieska forest.

Anthracoidea caricis (Pers.) Bref. Fig. 2B

Untersuch. Gesammtgeb. Mykol. xii: Hemibasidii, Brandpilze iii: 144. 1895, *emend.* Nannf., Symb. Bot. Upsal. **22**: 17. 1979.

Sori in ovaries. Ustilospores in plane view 13–20 × 14–25 μm in diameter, 10–13 μm thick, flattened, angular to irregular, rarely rounded, sometimes with large protuberances, in side view finely serrulate, 1–2(–3) internal swellings distinctly visible, wall 1–1.5 μm thick, thickest at angles, up to 2 μm.

MATERIAL EXAMINED. POLAND. Carpathians, Gorce Mts., Mt. Gorc Troszacki, on meadow near summit, *ca* 1200 m a.s.l., in ovaries of *Carex pilulifera* L., 15 Jul. 2006, *leg. A. Chlebicki* (KRAM-F 55786); Carpathians, Bieszczady Zachodnie Mts., Wołosate, in meadow on NE slope of Kiczera Manzina Mt., in ovaries of *Carex pilulifera*, 11 Aug. 2006, *leg. A. Chlebicki* (KRAM-F 55813).

NOTES. It is a common species in Poland. The fungus was noted at some localities in Lower Silesia on *Carex pilulifera* (Schroeter 1887): Zielona Góra, Czerwieńsk, Głogów, Legnica, Lwówek Śląski, Wrocław, Wałbrzych and Bystrzyca Kłodzka. Kochman and Majewski (1973) reported it on the same host plant from the Góry Świętokrzyskie Mts, Carpathians, environs of Puławy, Gorzów Wielkopolski and environs of Poznań. Starmachowa (1963) noted that it was a very abundant smut in the Tatras in the Dolina Kondratowa valley. Kućmierz (1968) noted it at Przełęcz Iwaniacka pass in the Tatras under the name *Cintractia baccata* (Wallr.) Syd. Sałata *et al.* (1984) also noted this smut in the Tatras in Hala Kalatówki meadow.

Anthracoidea echinospora (Lehtola) Kukkonen Fig. 2C

Ann. Bot. Soc. Zool. Bot. Fennicae 'Vanamo' **34**: 74. 1963. – *Cintractia echinospora* Lehtola

Sori in ovaries, black, ovoid, 1.5–2 mm in diameter. Ustilospores ovoid, 12–14 × 13–18 μm, up to 10 μm thick, densely covered by spines with flattened tips. Internal swelling not visible.

MATERIAL EXAMINED. POLAND. Puszcza Augus-

towska forest, Wigry National Park, Mały Suchar lake, in ovaries of *Carex nigra* (L.) Reichard, 27 Sept. 2004, *leg. A. Chlebicki* (KRAM-F 54137).

NOTES. The fungus has been noted on eight *Carex* species belonging to the section *Phacocystis* (see Vánky 1994; Scholler *et al.* 2003). In Poland the species was collected on *Carex gracilis* Curtis in the environs of Wrocław, Kowary and the Puszcza Kampinoska forest as well as on *Carex elata* All. in Puszcza Białowieska forest (Kochman & Majewski 1973). The fungus possesses very characteristic echinulate ustilospores (Kukkonen 1964, 1969). It is similar to *Anthracoidea subinclusa*, which also possesses echinulate ustilospores, but the spines of the latter are distinctly larger and not so densely distributed as in *A. echinospora*.

Some other *Anthracoidea* species are noted on *C. nigra*, such as *Anthracoidea heterospora* (B. Lindeb.) Kukkonen and *A. liroi* (Lehtola) Nannf. The ustilospores of *A. heterospora* are covered by small warts, and are not echinulate. Kukkonen (1963) pointed out that it can be distinguished from *A. echinospora* even in the field. In Poland *A. heterospora* was noted by Michalski (1986) on the same host plant. Ustilospores of *A. liroi* are finely and densely verrucose (Vánky 1994) with an almost smooth spore profile. Recently, Scholler *et al.* (2003) noted *A. echinospora* on *Carex aquatilis* Wahl., *C. paleacea* Wahl., its hybrid and *C. recta* Boott, all from the section *Phacocystis*, and judged that the fungus is probably a collective species.

Apart from the species mentioned by Kochman and Majewski (1973), Nannfeldt (1977, 1979) and Piątek *et al.* (2005), we should expect other *Anthracoidea* species to occur in Poland, such as *A. scirpi* (J. Kühn) Kukkonen on *Scirpus caespitosus* L. and *A. rupestris* Kukkonen on *Carex rupestris* All. In four years I was not able to find *Anthracoidea rupestris* in the small and vanishing population of *Carex rupestris* in the Bieszczady Zachodnie Mts, nor in other small and vanishing host plant populations in the Hruby Jesenik Mts and Chornohora Mts.

Arthropods play a role in ustilospore propagation. After breaking of the sorus membrane, black-brown ustilospores can be dispersed by wind or insects (Steiner 1984; Ericson *et al.* 1993). The role of the insects in ustilospore propagation is rather poorly known. Ericson *et al.* (1993) noted transmission of spores by adult phalacrid beetles *Phalacrus substriatus* Gyll., whose larvae feed on ustilospores in the sori of *Anthracoidea fischeri* (P. Karst.) Kukkonen. I observed larvae of the same phalacrid beetle (also called the smut beetle) feed on ustilospores in *Anthracoidea arenaria* sori (Fig. 3B & D); another inhabitant of the same sori belongs to the acarine family Eriophyidae (Acari) (Fig. 3C). These acarine specimens abundantly inhabited the sori, but I did not observe them feeding on ustilospores.

Related information in the entomological literature is sometimes scanty. Bullock (1992) noted that the larvae of this smut beetle feed on plants of the genera *Carex* L. and *Narthecium ossifragum* (L.) Huds. The full explanation, however, is that the larvae of these beetles feed on *Anthracoidea* ustilospores in the inflorescences of *Carex*, and the adults feed on pollen, including that of *Narthecium ossifragum*. In his description of *Ph. substriatus*, Cmoluch (1997) mentioned *Carex fusca* Bell., *C. arenaria* L. and *C. digitata* L. as host plants, all infected by fungi (probably by *Anthracoidea echinospora*, *A. arenaria* and *A. irregularis*). He incorrectly suggested that beetles of the genus *Phalacrus* feed on ascospores of Ascomycetes in seeds of Poaceae and *Carex*.

According to Švec and Angelini (1996), *Ph. substriatus* occurs in Europe from Spain in the west to Ukraine in the east. Six species of the genus *Phalacrus* (Cmoluch 1997) have been noted in Poland, among them *Phalacrus substriatus*. This smut beetle probably is not rare, but data on its distribution in Poland are scarce (Burakowski *et al.* 1986; Kubisz, pers. comm.).

Inflorescences infected by the smut were inhabited mostly by phalacrid beetle larvae; almost all such sori were damaged and covered by insect faeces. An obtained imago of the phalacrid beetle belongs to the earlier-mentioned *Phalacrus substriatus* (Fig. 3A). According to Dr. P. Ingvarsson (pers. comm.) the same beetle was also noted in Sweden on *Anthracoidea arenaria*. I also noted faeces and dead phalacrid beetles in herbarium

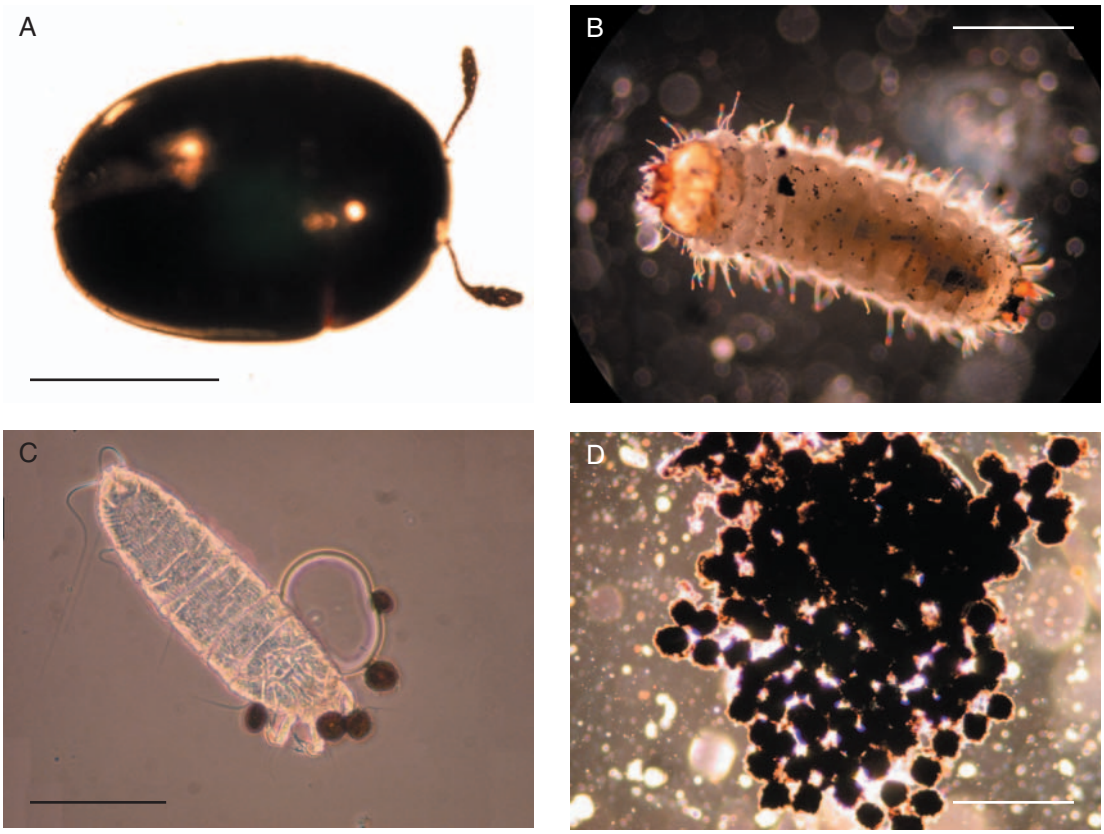

Fig. 3. Inhabitants of sori of *Anthracoidea arenaria* (Syd.) Nannf. A – imago of *Phalacrus substriatus* Gyll.; B – larva of *Ph. substriatus*; C – acari of the family Eriophyidae; D – faeces of *Ph. substriatus*. Scale bars = 1 mm (A), 500 μm (B & D), 60 μm (C).

collections of *Anthracoidea angulata* from Jezioro Płotycze lake (LBLM), *Anthracoidea echinospora* from Wigry National Park (KRAM-F 54137), *Anthracoidea arenaria* and *A. heterospora* from the Šumava Mts in the Czech Republic (KRAM-F 54135 & 55186), and *Anthracoidea vankyi* from Tian Shan in Kazakhstan (KRAM-F 55186). These observations indicate that the role of insects in smut distribution is not accidental.

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