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ORIGINAL RESEARCH PAPER

The revision of specimens of the *Cladonia pyxidata-chlorophaea* group (lichenized Ascomycota) from northeastern Poland deposited in the herbarium collections of University in Bialystok

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Abstract

In northeastern Poland, the chemical variation of the *Cladonia chlorophaea-pyxidata* group was much neglected, as TLC has not been used in delimitation of species differing in the chemistry. As a great part of herbal material of University in Bialystok from NE Poland was misidentified, I found my studies to be necessary. Based on the collection of 123 specimens deposited in Herbarium of University in Bialystok, nine species of the *C. pyxidata-chlorophaea* group are reported from NE Poland. The morphology, secondary chemistry, and ecology of examined lichens are presented and the list of localities is provided. The results revealed that *C. fimbriata* is the most common species in the northeastern Poland, comprising around 33% of the studied specimens. *Cladonia conista*, *C. cryptochlorophaea*, and *C. merochlorophaea* are known only from very few locations. This study shed light on the role of the lichens substances to diagnosis of the species of *C. pyxidata-chlorophaea* group.

Keywords

Cladoniaceae; chemotaxonomy; distribution; ecology

Introduction

Lichens of the *Cladonia pyxidata-chlorophaea* group are characterized by primary thallus squamulose and scyphose podetia. The podetia are covered with farinose to granular soredia, corticated granules, and/or more or less areolate cortex. Apothecia are brown and rare [1,2].

The species of this group have a diverse secondary chemistry. Fourteen chemotypes and 35 lichen secondary metabolites have been identified within the group from the world [3]. However, the species status of chemically different entities has been frequently questioned.

Some authors recognize chemical variability only at the chemotypes of species, varieties and subspecies level [4–6], others support chemically defined taxa at the species level [2,7–9]. Many authors accept the later viewpoint about chemically species [2,9–12]. The *C. pyxidata-chlorophaea* group requires molecular investigation with a larger number of samples and more variable gene regions [10,11]. The recent molecular studies have indicated that at least all the chemically different taxa of the *C. chlorophaea* group do not form a separate subclade and their morphological similarity is rather a result of convergent evolution [10].

The aim of the present study is the revision of specimens of the *C. pyxidata-chlorophaea* group (lichenized Ascomycota) from the area of NE Poland deposited in Herbarium of University in Bialystok. For each specimen examined, the occurrence of the lichens of the *C. pyxidata-chlorophaea* group from tested area along with their morphology, chemistry, ecology, and distribution of each species is described. The chemical variation of the *C. pyxidata-chlorophaea* group from NE Poland was not sufficiently recognized because thin layer chromatography (TLC) has not been used during species identification. The area of study includes protected areas (e.g., Wigry National Park, Biebrza National Park, Narew National Park, Podlaski Przełom Bugu Landscape Park, Puszcza Knyszyńska Landscape Park) and areas not protected in the vicinity of the villages or small towns (e.g., Suchowola, Kaniuki, Ciechanowiec, Boćki) and surrounding the Siemianówka Reservoir in the Upper Narew Valley and forests (e.g., Romincka Forest).

Material and methods

The revised lichen material was collected in NE Poland by Abramowicz A., Bystrek J., Czubała A., Gosk A., Gutowska M., Jabłońska K., Karpowicz A., Kolanko K., Kulikowska K., Matwiejuk A., Pietryszek M., Śliwowoska J., Świderska M., Zabuska S., in the years 1991–2015. The morphology of each specimen was examined using a stereomicroscope (Leica EZ4) at magnification 0.8(–3.5) × 10. Lichen substances were investigated by TLC in solvent A and C following the methods of Orange et al. [13]. In total, 123 specimens were examined.

Results

Nine species of the *C. pyxidata-chlorophaea* group were found in the examined material. *Cladonia fimbriata* appeared to be the most common species of the investigated lichen group in NE Poland. Three taxa, *C. conista*, *C. cryptochlorophaea*, *C. merochlorophaea* are known only from very few locations.

Fig. 1 Location of investigation sites of *Cladonia chlorophaea*.

Cladonia chlorophaea (Flörke ex Sommerf.) Spreng., Syst. Veg. 4: 273(1827)

A characteristic species with regular podetia covered soredia. Podetia are up to ca. 3.0 cm tall. Scyphi are up to 7 mm wide, with irregular or dentate margins, usually gradually expanded. Scyphi and surface of podetia covered by granular soredia and corticated granules. Apothecia are brown and stalked, on cup margin. Pycnidia occur on scyphal margins. For a detailed description see [5,14–16]. The species is characterized by the production of fumarprotocetraric acid complex only. The specimens of *C. chlorophaea* are often morphologically similar to *C. grayi* and *C. merochlorophaea*.

The species is common and inhabits a many substrata, namely soil (12 specimens), bark (six specimens) and wood (four specimens). Corticolous specimens were collected from *Betula* spp. (two specimens), *Pinus sylvestris* (one specimen), *Salix* spp. (one specimen), *Fraxinus excelsior* (one specimen), and *Robinia pseudoacacia* (one specimen). *Robinia pseudoacacia* is a new phorophyte of *C. chlorophaea* in NE Poland [2]. A similar habitat requirement was also discovered from Poland by Kowalewska et al. [2] and Belarus by Tsurykau and Golubkov [9]. Location of investigation sites of *C. chlorophaea* in NE Poland from the herbarium collections of University of Bialystok has been presented in Fig. 1.

Cladonia chlorophaea is widely distributed in Poland [2]. Many localities of this species were reported in NE Poland by Kowalewska et al. [2]. It is known from all continents including the Antarctic region [2,8,17,18].

Specimens examined. NE Poland, Podlaski Przełom Bugu Landscape Park, Forest District Sarnaki, Forestry Mierzwice, pine forest, soil, leg. M. Murawska, B. Bystrek, 2002-05-05, det. A. Matwiejuk, 2014-11-16; surrounding of the Siemianówka Lagoon, village Bondary, soil, leg. B. Marszalik, 1993-06-17, det. A. Matwiejuk, 2014-11-16; Romincka Forest, spruce-pine forest, soil, leg. M. Gutowska, 1991-07-26, det. A. Matwiejuk, 2014-11-16; Romincka Forest, spruce-pine forest, soil, 1991-07-28, leg. M. Gutowska, det. A. Matwiejuk, 2014-11-16; Romincka Forest, spruce-pine forest, soil, 1992-09-19, leg. M. Gutowska, det. A. Matwiejuk, 2014-11-16; Romincka Forest, spruce-pine forest, soil, leg. M. Gutowska, 1992-09-12, det. A. Matwiejuk, 2014-11-16; Klejniki, logging, soil, leg. M. Pietryszek, 1999-05-26, det. A. Matwiejuk, 2014-11-16; Klejniki, logging, the botttom, soil, leg. M. Pietryszek, 1999-05-26, det. A. Matwiejuk, 2014-11-16; Klejniki, logging, western slope, soil, leg. M. Pietryszek, 1999-05-4, det. A. Matwiejuk, 2014-11-16; Narew National Park, bark of *Robinia pseudoacacia*, leg. A. Mrozowska, 2001-10-24, det. A. Matwiejuk, 2014-11-16; Narew National Park, bark of *Fraxinus excelsior*, leg. A. Mrozowska, 2001-01-16, det. A. Matwiejuk, 2014-11-16; surroundings of Suraż village, Doktorce, soil, leg. K. Jabłońska, 2001-01-16, det. A. Matwiejuk, 2014-11-16; surroundings of Suraż village, Doktorce, wood, leg. K. Jabłońska, 2002-05-14, det. A. Matwiejuk, 2014-11-16; surroundings of Suraż village, Doktorce, approx. 0.5 km to the NW, pine forest, soil, leg. K. Jabłońska, 2002-05-14, det. A. Matwiejuk, 2014-11-16; surroundings of Suraż village, Doktorce, wood, building a farm, leg. K. Jabłońska, 2001-09-20, det. A. Matwiejuk, 2014-11-16; surroundings of Suraż village, Doktorce, bark of *Betula pendula*, leg. K. Jabłońska, 2002-08-13, det. A. Matwiejuk, 2014-11-16; surroundings of Ciechanowiec, forest by the Nurzec River, village Zadobrze, soil, leg. S. Zabuska, 2004-11-7, det. A. Matwiejuk, 2014-11-16; surroundings of Laskowiec village, wood, leg. S. Zabuska, 2014-11-16. det. A. Matwiejuk, 2014-11-16; surroundings of Laskowiec village, soil, leg. A. Gosk, 1999-11-01, det. A. Matwiejuk, 2014-11-16; surroundings of Laskowiec village, soil, leg. A. Gosk, 1999-11-01, det. A. Matwiejuk, 2014-11-16; surroundings of Laskowiec village, soil, leg. A. Gosk, 1999-11-01, det. A. Matwiejuk, 2014-11-16; Laskowiec Stary (near Zambrów), bark of *Salix* sp. wood, leg. A. Gosk, 2000-11-11, det. A. Matwiejuk, 2014-11-16; Zamczysk, bark of *Betula pendula*, leg. A. Gosk, 2001-06-6, det. A. Matwiejuk, 2014-11-16; Ciechanowiec, soil, leg. S. Zabuska, 2004-05-26, det. A. Matwiejuk, 2014-11-16; Boćki, soil, leg. A. Matwiejuk, 2001-03-30, det. A. Matwiejuk, 2014-11-16; forest near Rykaczew, soil, leg. A. Gosk, 2000-07-11, det. A. Matwiejuk, 2014-11-16; surrounding of Laskowiec village, forest, bark of *Pinus sylvestris*, leg. A. Gosk, 1999-11-01, det. A. Matwiejuk, 2014-11-16; Puszcza Knyszyńska Landscape Park, Góry Leńce, young forest pine, soil, leg. K. Kulikowska, 1992-08-25, det. A. Matwiejuk, 2014-11-16.

Number of specimens examined: 29.

Cladonia conista Robbins ex A. Evans, Trans. Connecticut Acad. Arts 30: 472 (1930)

Cladonia conista is distinguished by the podetia tall, up to ca. 2.5 cm high, with regular, ± goblet-shaped cups. The upper part of the stalk and the cups with soredia. The lower part of the stalk is corticated. Soredia are farinose rather than granular. The detailed description of the species is presented elsewhere [2,7]. Secondary metabolites of *C. conista* include bourgeanic and fumarprotocetraric acids. *Cladonia conista* is morphologically very similar to *C. humilis*. In contrast to this species, *C. conista* produces bourgeanic acid (K−). *Cladonia humilis* produces fumarprotocetraric acid and atranorin (K+ yellow). Pino-Bodas et al. [12] have stated that the species are morphologically indistinguishable, but the taxa differ in their geographical distribution and *C. conista* and *C. humilis* are recognized as distinct species.

The species was found on soil in pine woodland (one specimen). The observed habitat requirements agreed with those reported for the species by Kowalewska et al. [2]. All the Polish specimens were found on soil. Distribution of stands of *C. conista*

Fig. 2 Location of investigation site of *Cladonia conista*.

Fig. 3 Location of investigation site of *Cladonia cryptochlorophaea*.

in NE Poland from the herbarium collections of University of Bialystok has been presented in Fig. 2.

Cladonia conista is rare species in Poland and NE Poland [2]. It is predominant on the Atlantic coast of America and in northern regions of Europe [2,9,12].

Specimens examined. NE Poland, surrounding of the Siemianówka Reservoir in the Upper Narew Valley, pine forest, soil, det. A. Matwiejuk, 2014-05-12, leg. A. Matwiejuk, 2015-05-23.

Number of specimens examined: 1.

Cladonia cryptochlorophaea Asahina, J. Jap. Bot. 16: 711 (1940)

This species is characterized by the podetia goblet- to trumpet-shaped cups. Soredia usually present. The surface of the podetia is mostly roughly corticated. For the description of the species see [2,7,15]. Substances detected by TLC include cryptochlorophaeic, paludosic, and fumarprotocetraric acids. *Cladonia cryptochlorophaea* is morphologically very similar to few species (*C. merochlorophaea*, *C. novochlorophaea*, *C. grayi*) [1,2,7], but the latter differs chemically by producing cryptochlorophaeic and paludosic acids. Morphologically, *C. cryptochlorophaea* resembles *C. grayi*, but the podetia of *Cladonia grayi* are usually abundantly granular-sorediate [2].

Substrate of the specimen includes soil. The species prefers pine forests. Almost three-quarters of the records of *C. cryptochlorophaea* in Poland [2] are represented by epigeic specimens. The similar ecology notes are given by Holien and Tønsberg [7], Ahti [15]. Distribution of investigation site of this species in NE Poland from the herbarium collections of University of Bialystok has been presented in Fig. 3.

In Poland, it is rare species [2], but its known localities are scattered, mostly in northeastern and southern part of Poland [2,19]. The species is known from all continents, except Antarctica. Many specimens have been recorded mostly in boreal zone [9].

Specimens examined. NE Poland, surrounding of the Siemianówka Reservoir in the Upper Narew Valley, pine forest, soil, det. A. Matwiejuk, 2014-05-12, leg. A. Matwiejuk, 2015-05-23.

Number of specimens examined: 1.

Cladonia fimbriata (L.) Fr., Lichenogr. Eur. Ref.: 222 (1831)

This species is distinguished by the podetia up to 3.0 cm tall, simple, with scyphi. Scyphi are up to 6 mm wide, regular. Podetia with goblet-shaped. The surface of podetia and scyphi coated with soredia. Soredia are farinose. Apothecia are rare, brown and simple. For the description of the species see [2,5,14–16]. The species produces fumarprotocetraric acid complex only. *Cladonia fimbriata* may resemble *C. chlorophaea*. It has more regular and extended scyphi, granular soredia and smaller stalks. *Cladonia fimbriata* is most similar to *C. conista*, but *C. conista* differs by its usually distinctly corticate podetial stalk [2,20].

The species is ubiquitous and inhabits a wide range of substrata. In NE Poland, *C. fimbriata* prefers well-lit open pine, oak and birch forests and urban areas. The species was found on soil (30 specimens), wood (eight specimens), *Betula* spp. (one specimen), *Pinus sylvestris* (one specimen), rock (one specimens). Location of investigation sites of *C. fimbriata* in NE Poland has been presented in Fig. 4.

Fig. 4 Location of investigation sites of *Cladonia fimbriata*.

Cladonia fimbriata is common species in Poland [2]. Many localities of this species were reported in NE Poland by Kowalewska et al. [2]. Outside Poland, the species has been recorded from many regions. It is known from all continents except for tropic regions [8,18].

Specimens examined. NE Poland, Hołodolina, 0.5 km S, edge of the forest of birch, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, edge of the forest of birch, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, the embankment stones, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, the embankment stones, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, edge of the forest of birch, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, edge of the forest of birch, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, edge of the forest of birch, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, edge of the forest of birch, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, the embankment stones, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, edge of the forest of birch, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, edge of the forest of birch, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, edge of the forest of birch, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, edge of the forest of birch, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, edge of the forest of pine and spruce, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, edge of the forest of pine and spruce, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, edge of the forest of pine and spruce, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Hołodolina, 0.5 km S, edge of the forest of pine and spruce, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 0.5 km NE, wood, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 1 km NE, pine forest, soil, leg. A. Abramowicz, det. 2014-10-12, A. Matwiejuk, 2014-11-16; Suchowola, 1 km NE, pine forest, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 1 km NE, pine forest, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 1 km NE, pine forest, wood, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 1 km NE, pine forest, wood, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 1 km NE, pine forest, wood, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 1 km NE, pine forest, wood, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 1 km NE, pine forest, wood, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Boćki, soil, leg. A. Matwiejuk, 2000-04-17, leg. A. Matwiejuk, 2014-11-16; Puszcza Knyszyńska, Krasne reserve, soil, leg. J. Śliwska, 1992-07-29, det. A. Matwiejuk, 2014-11-16; surrounding of Suraż, soil, leg. K. Jabłońska, 2002-08-16, det. A. Matwiejuk, 2014-11-16; surrounding of Ciechanowiec, wood, leg. S. Zabuska, 2003-07-18, det. A. Matwiejuk, 2014-11-16; surrounding of Ciechanowiec, wall, leg. S. Zabuska, 2004-10-20, det. A. Matwiejuk, 2014-11-16; surrounding of Ciechanowiec, soil, leg. S. Zabuska, 2003-09-2, det. A. Matwiejuk, 2014-11-16; surrounding of Ciechanowiec, soil, leg. S. Zabuska, 2003-07-01, det. A. Matwiejuk, 2014-11-16; surrounding of Ciechanowiec, bark of *Betula pendula*, leg. S. Zabuska, 2004-07-11, det. A. Matwiejuk, 2014-11-16; surrounding of Ciechanowiec, soil, leg. S. Zabuska, 2003-09-02, det. A. Matwiejuk,

2014-11-16; surrounding of Laskowiec village, wood, leg. A. Gosk, 1991-11-01, det. A. Matwiejuk, 2014-11-16; surrounding of Laskowiec village, soil, leg. A. Gosk, 1991-11-01, det. A. Matwiejuk, 2014-11-16; Puszcza Knyszyńska Landscape Park, Biele, soil, leg. K. Kolanko, 1993-07-15, det. A. Matwiejuk, 2014-11-16; Stryki, soil, leg. M. Świderska, 2004-06-25, det. A. Matwiejuk, 2014-11-16.

Number of specimens examined: 41.

Cladonia grayi G. Merr. ex Sandst., Clad. Exs. No. 1847 (1929)

The squamulose of primary thallus are shrub-like. The podetia are up to 4.0 cm tall. In the upper part, the podetia are covered by granular soredia, with goblet or trumpet-shaped scyphi up to ca. 1 cm wide, often with proliferations. Apothecia are brown to dark brown and stalked. For a detailed description see [2,5,7]. One chemotypes is recognized in NE Poland: grayanic acid always and additionally substances of the fumarprotocetraric acid complex (chemotype II). In Poland, Kowalewska et al. [2] noted 81% specimens from chemotype II. In Nordic countries, chemotype I is somewhat more frequent [8]. In Belarus, both chemotype I (grayanic acid always by accompanied 4-*O*-demethylgrayanic acid) and II are similarly frequent [9]. The species is similarly to *C. merochlorophaea* and *C. novochlorophaea*. Differs by producing grayanic acid [16].

Cladonia grayi is mostly found in pine forests. The species inhabits soil (20 specimens) and wood (six specimens). Distribution of stands of *C. grayi* in NE Poland has been presented in Fig. 5.

In Poland, *C. grayi* is common species [2]. Many localities of this species were reported in NE Poland by Kowalewska et al. [2]. World distribution data of *C. grayi* are most widely, it has been reported from many continents: Europe, Asia, North America, Central America, South America, Australia, and New Zealand [2,8].

Specimens examined. NE Poland, Podlaski Przełom Bugu Landscape Park, Forest District Sarnaki, Forestry Mierzwice, pine forest, soil, leg. M. Murawska, B. Bystrek, 2002-05-05, det. A. Matwiejuk, 2014-11-16; Podlaski Przełom Bugu Landscape Park, Forest District Sarnaki, Forestry Mierzwice, pine forest, soil, leg. M. Murawska, B. Bystrek, 2002-05-05, det. A. Matwiejuk, 2014-11-16; Podlaski Przełom Bugu Landscape Park, Forest District Sarnaki, Forestry Mierzwice, pine forest, soil, leg. M. Murawska, B. Bystrek, 2002-05-05, det. A. Matwiejuk, 2014-11-16; Podlaski Przełom Bugu Landscape Park, Forest District Sarnaki, Forestry Mierzwice, pine forest, soil, leg. M. Murawska, B. Bystrek, 2002-05-05, det. A. Matwiejuk, 2014-11-16; Podlaski Przełom Bugu Landscape Park, Forest District Sarnaki, Forestry Mierzwice, pine forest, soil, leg. M. Murawska, B. Bystrek, 2002-05-05, det. A. Matwiejuk, 2014-11-16; Podlaski Przełom Bugu Landscape Park, Forest District Sarnaki, Forestry Mierzwice, pine forest, soil, leg. M. Murawska, B. Bystrek, 2002-05-05, det. A. Matwiejuk, 2014-11-16; Podlaski Przełom Bugu Landscape Park, Forest District Sarnaki, Forestry Mierzwice, pine forest, soil, leg. M. Murawska, B. Bystrek, 2002-04-23, det. A. Matwiejuk, 2014-11-16; Podlaski Przełom Bugu Landscape Park, Forest District Sarnaki, Forestry Mierzwice, pine forest, soil, leg. M. Murawska, B. Bystrek, 2002-04-23, det. A. Matwiejuk, 2014-11-16; Podlaski Przełom Bugu Landscape Park, Forest District Sarnaki, Forestry Mierzwice, pine forest, soil, leg. M. Murawska, B. Bystrek, 2002-05-05, det. A. Matwiejuk, 2014-11-16; Puszcza Knyszyńska Landscape Park, Góry Leńce, young forest pine, soil, leg. K. Kulikowska, 1992-08-25, det. A. Matwiejuk, 2014-11-16; Puszcza Knyszyńska Landscape Park, sandy slope, soil, leg. K. Kulikowska, 1991-08-27,

Fig. 5 Location of investigation sites of *Cladonia grayi*.

det. A. Matwiejuk, 2014-11-16; Puszcza Knyszyńska Landscape Park, sandy slope, soil, leg. K. Kulikowska, 1991-08-27, det. A. Matwiejuk, 2014-11-16; Biebrza National Park. Gugny, swampy forest, leg. K. Kolanko, 1993-06-22, det. A. Matwiejuk, 2014-11-16; Biebrza National Park. Gugny, swampy forest, leg. K. Kolanko, 1993-06-22, det. A. Matwiejuk, 2014-11-16; Biebrza National Park. Gugny, swampy forest, leg. K. Kolanko, 1993-06-22, det. A. Matwiejuk, 2014-11-16; Biebrza National Park. Gugny, swampy forest, leg. K. Kolanko, 1990-05-10, det. A. Matwiejuk, 2014-11-16; Wigry National Park, Studziany Las reserve, soil, leg. J. Bystrek, A. Matwiejuk, 1993-08-06, det. A. Matwiejuk, 2014-11-16; surroundings of Ciechanowiec, wood, leg. S. Zabuska, 2003-07-10, det. A. Matwiejuk, 2014-11-16; Boćki, soil, leg. A. Matwiejuk, 2000-04-17, det. A. Matwiejuk, 2014-11-16; Suchowola, 0.5 km NE, pine forest, wood, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 0.5 km NE, pine forest, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 0.5 km NE, pine forest, wood, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 0.5 km NE, pine forest, wood, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 0.5 km NE, pine forest, wood, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 1 km NE, pine forest, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16.

Number of specimens examined: 26.

Cladonia merochlorophaea Asahina, J. Jap. Bot. 16: 713 (1940)

Podetia are up to ca. 3 cm tall, simple, with gradually flaring scyphi. Scyphi are up to 1.5 cm wide, usually areolate-corticate, verrucolose, covered by coarse granules. The granules may change into phyllidia, microsquamules or macrosquamules. Surface of podetia are areolate-corticate. Apothecia are brown and stalked. Revised specimens from the detailed description by Holien and Tønsberg [7], Ahti [14], and Kowalewska et al. [2]. Substances detected by TLC are merochlorophaeic and 4-*O*-methylcryptochlorophaeic acids and fumarprotocetraric acid complex (chemotype II). In Poland, 90% of specimens produce fumarprotocetraric acid [2]. In Belarus, 67% specimens contain this acid [9]. Holien and Tønsberg [7] reported a similar proportion from Norway. Morphologically, *C. merochlorophaea* is similar to the other species, e.g., *C. cryptochlorophaea*, *C. novochlorophaea*, but the latter differs chemically by producing cryptochlorophaeic acid.

Cladonia merochlorophaea is found in pine forests, on soil (two specimens). The similar ecology notes are given by Holien and Tønsberg [7] and Kowalewska et al. [2]. Location of investigation site of *C. merochlorophaea* in NE Poland from the herbarium collections of University of Bialystok has been presented in Fig. 6.

Occurrence of *C. merochlorophaea* has been reported from many localities of Poland including several sites of north-eastern part of the country [2]. The species is known from all continents, except Antarctica [2,18].

Fig. 6 Location of investigation site of *Cladonia merochlorophaea*.

Specimens examined. NE Poland, Suchowola, 1 km NE, pine forest, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16; Suchowola, 1 km NE, pine forest, soil, leg. A. Abramowicz, 2014-10-12, det. A. Matwiejuk, 2014-11-16.

Number of specimens examined: 2.

Cladonia monomorpha Aptroot, Sipman & van Herk, Lichenologist 33: 273 (2001)

Squamules of primary thallus are greenish-grey, large and thick. Podetia are up to 1.5 cm tall, with regular cups. Scyphi are gradually flaring, inside covered with bullate corticate plates inside. Apothecia are brown, simple or occur in glomerulose accumulations. For detailed descriptions see Tsurykau and Golubkov [9], Aptroot et al. [21], and Kowalewska and Kukwa [22]. The species is characterized by the production only fumarprotocetraric acid complex. *Cladonia monomorpha* is similar to *C. pyxidata* and *C. pocillum*. All those taxa are esorediate and contain fumarprotocetraric acid as the mayor secondary metabolite, while they differ morphologically. For a detailed description see Kowalewska et al. [2] and Aproot et al. [21].

In NE Poland, the species was found on soil (one specimen). In Poland, the frequency on different substrata is as follows: soil, rocks, and tree bark [2]. This agrees with the habitat spectrum published by Aproot et al. [21]. Location of investigation site of *C. monomorpha* from the herbarium collections of University of Bialystok has been presented in Fig. 7.

Most of the records come from the northern and southern part of the country [2]. Several localities of *C. monomorpha* were reported in NE Poland by Kowalewska et al. [2]. The species is known from Europe, Asia, and North America [2,21].

Fig. 7 Location of investigation site of *Cladonia monomorpha*.

Specimens examined. NE Poland, Kaniuki, 1 km SE, pine forest, soil, leg. A. Matwiejuk, 2015-10-10, det. A. Matwiejuk, 2015-11-23.

Number of specimens examined: 1.

Cladonia novochlorophaea (Sipman) Brodo & Ahti, Canad. J. Bot. 74: 1167 (1996)

Squamules are brown-grey. Podetia are brownish or blackish, up to 1.4 cm tall. Scyphi are up to 0.8 cm wide, simple to proliferating from margins. Surface of podetia are corticate, verruculose, squamulose, inner part of the scyphi eroded, covered with cortical plates. Apothecia are stalked, brown. For detailed descriptions see Brodo and Ahti [5], Tsurykau and Golubkov [9], and Ahti [14]. The species is characterized by the production homosekikaic, sekikaic, and fumarprotocetraric acids. *Cladonia novochlorophaea* is morphologically similar to *C. merochlorophaea*, but it is never clearly sorediate. It has a similar chemistry to *C. homosekikaica*.

In NE Poland, *C. novochlorophaea* has been found on soil (six specimens), wood (three specimens) and bark of *Picea abies* (one specimen) in open habitats and forests. Distribution of stands of this species in NE Poland has been presented in Fig. 8.

It is known from northern and central part of the Poland. It is rare species. Three localities of *C. novochlorophaea* were reported in NE Poland by Kowalewska et al. [2]. The species has been reported from Europe, North and South America, New Zealand, and the Antarctic region [8,23].

Fig. 8 Location of investigation sites of *Cladonia novochlorophaea*.

Specimens examined. NE Poland, Podlaski Przełom Bugu Landscape Park, Forest District Sarnaki, Forestry Mierzwice, pine forest, soil, leg. M. Murawska, B. Bystrek, 2001-05-05, det. A. Matwiejuk, 2014-12-10; Puszcza Knyszyńska Landscape Park, Kopisk, bark of *Picea abies*, leg. K. Kulikowska, 1992-05-12, det. A. Matwiejuk, 2014-12-10; Puszcza Knyszyńska Landscape Park,

surroundings of Waliły village, young forest birch, soil, leg. A. Karpowicz, 1991-08-27, det. A. Matwiejuk, 2014-12-10; Biebrza National Park, Gugny, pine forest, soil, leg. K. Kondej, 1990-10-27, det. A. Matwiejuk, 2014-12-10; Puszcza Knyszyńska Landscape Park, Zalesie, soil, leg. K. Kulikowska, 1991-10-26, det. A. Matwiejuk, 2014-12-10; Rybniki, wood, leg. M. Świderska, 2004-06-25, det. A. Matwiejuk, 2014-12-10; Rybniki, wood, leg. B. Marszalik, 1992-05-19, det. A. Matwiejuk, 2014-12-10; surroundings of Ciechanowiec, forest by the Nurzec River, village Zadobrze, soil, leg. S. Zabuska, 2003-10-10, det. A. Matwiejuk, 2014-12-10; Laskowiec Stary (near Zambrów), wooden house, leg. A. Gosk, 1999-11-11, det. A. Matwiejuk, 2014-12-10; Biebrzańska Kotlina, Grzędy, leg. A. Czubała, 1999-10-27, det. A. Matwiejuk, 2014-12-10.

Number of specimens examined: 10.

Cladonia pyxidata (L.) Hoffm., Deutschl. Fl. 2: 121 (1796)

This species is distinguished by the corticate and regular scyphose podetia cover with peltate and flat squamules in upper part. Podetia are to 2.5 cm high, trumpet-shaped. Scyphi are up to 0.6 cm wide. Surface of podetia and scyphi covered with an irregular areolate cortex. Apothecia are brown, rare, on scyphi margins. For a detailed description of the *C. pyxidata* see Aptroot et al. [21], Kowalewska et al. [2]. Substances detected by TLC are only fumarprotocetraric acid complex. *Cladonia pyxidata* is morphologically similar to *C. monomorpha* and *C. pocillum*, which differs from the podetial surface, rink-like or globose apothecia [2,6,21].

In NE Poland, the species was recorded on soil, mainly in well-lit pine forests (12 specimens). One specimen was collected from wood. Location of stands of *C. pyxidata* in NE Poland from the herbarium collections of University of Bialystok has been presented in Fig. 9.

This species is rare in north part of Poland, but it is common in southern Poland [2]. The species is known worldwide [8,18]. It is common in the arctic and temperate zones [15].

Fig. 9 Location of investigation sites of *Cladonia pyxidata*.

Specimens examined. NE Poland, Puszcza Knyszyńska Landscape Park, young forest pine, soil, leg. K. Kulikowska, 25.08.992, det. A. Matwiejuk, 2014-12-10; Wigry National Park, Studziany Las Reserve, soil, leg. J. Bystrek, A. Matwiejuk, 1993-08-06, det. A. Matwiejuk, 2014-12-10; Biebrzańska Kotlina, Grzędy, soil, leg. A. Czubała, 1999-10-27, det. A. Matwiejuk, 2014-12-10; Biebrzańska Kotlina, Grzędy, soil, leg. A. Czubała, 1999-10-27, det. A. Matwiejuk, 2014-12-10; Biebrzańska Kotlina, Grzędy, soil, leg. A. Czubała, 2001-03-26, det. A. Matwiejuk, 2014-12-10; Biebrzańska Kotlina, Grzędy, soil, leg. A. Czubała, 1999-10-27, et. A. Matwiejuk, 2014-12-10; Biebrzańska Kotlina, Grzędy, soil, leg. A. Czubała, 1999-10-27, det. A. Matwiejuk, 2014-12-10; Biebrzańska Kotlina, Grzędy, soil, leg. A. Czubała, 1999-10-27, det. A. Matwiejuk, 2014-12-10; Klejniki, logging, soil, leg. M. Pietryszek, 1999-05-04, det. A. Matwiejuk, 2014-12-10; Klejniki, logging, soil, leg. M. Pietryszek, 1998-07-13, det. A. Matwiejuk, 2014-12-10; Tyniewicze, slope logging, soil, leg. M. Pietryszek, 1999-04-18, det. A. Matwiejuk, 2014-12-10; surroundings of Ciechanowiec, forest, wood, leg. S. Zabuska, 2002-07-17, det. A. Matwiejuk, 2014-12-10; Forest near Rykaczew, soil, leg. A. Gosk, 2000-07-11, det. A. Matwiejuk, 2014-12-10.

Number of specimens examined: 13.

Discussion and conclusion

The taxa from *C. pyxidata-chlorophaea* group are probably the earliest designated group of chemical taxa [9]. The importance of secondary lichen metabolites to the taxonomy and species discrimination within the *C. pyxidata-chlorophaea* group has been confirmed based upon simultaneous analyses of DNA sequences and morphological and chemical data by Stenroos et al. [10].

In NE Poland, the chemical variation of the *C. pyxidata-chlorophaea* group was much neglected, as TLC has not been used in delimitation of species differing in the chemistry. As a great part of herbarium collections of University of Bialystok from NE Poland was misidentified, I found my research highly needed. Except for the samples of *C. fimbriata*, many studied specimens were misidentified.

So far, the lichens from the group *C. pyxidata-chlorophaea* and allied species has been reported from different regions of Poland mostly based on the identification using methods of classical taxonomy [19]. The information about the species recognizable only by secondary substances is rather sparse. In northeastern part of Poland, only a few studies have used these laboratory techniques for the identification of *C. pyxidata-chlorophaea* group so far [2]. Altogether, nine species of the *C. pyxidata-chlorophaea* group have been recognized in the examined materials. Three taxa (*C. asahinae*, *C. humulis*, and *C. pocillum*) have not been reported up to now from NE Poland [2]. *Cladonia asahinae* was found in the mountains. *Cladonia humilis* was known from a few localities along the Baltic coast, and *C. pocillum* from southern Poland [2].

Cladonia fimbriata is the most common species in Poland [2] and NE Poland. For comparison, *C. grayi* is the commonest species in Belarus (ca. 40% of the studied specimens) and *C. pyxidata* is uncommon in Belarus, known only from 10 localities [9]. In Poland, *C. homosekikaica* Nuno has not reported from *C. pyxidata-chlorophaea* group. This species was reported in the neighboring countries of Poland, in Belarus [9] and Lithuania [24].

The lichens from the group *C. pyxidata-chlorophaea* were found in NE Poland on soil, in open and sun-exposed sites, and in pine forest. Three species (*C. chlorophaea*, *C. fimbriata*, *C. novochlorophaea*) have been reported on bark of trees. *Cladonia chlorophaea*, *C. fimbriata*, *C. grayi*, and *C. novochlorophaea* inhabit wood. Only one specimens of *C. fimbriata* has been reported on rock. Similar habitat requirements for many species were reported by Kowalewska et al. [2].

The paper presents a number of new localities of species of *C. pyxidata-chlorophaea* group for NE Poland [2]. Additionally, a bark of *Robinia pseudoacacia* as a new substrate to *C. chlorophaea* has been found.

The use of TLC method for the identification of lichens collected in this region of Poland showed several specimens of rare species: *C. conista*, *C. cryptochlorophaea*, *C. monomorpha*, and *C. novochlorophaea*.

The studies have shown that species *C. pyxidata-chlorophaea* group differ in their chemical characteristics. In four species of this group, the only chemical component is fumarprotocetraric acid complex (*C. chlorophaea*, *C. fimbriata*, *C. monomorpha*, *C. pyxidata*). In other species occur fumarprotocetraric acid and other acids. Bourgeanic acid is detected in one species (*C. conista*). Gyrophoric acid has been found only in *C. grayi*. Cryptochlorophaeic and paludosic acids have been detected in *C. cryptochlorophaea*. In *C. merochlorophaea*, substances detected by TLC include merochlorophaeic and 4-*O*-methylcryptochlorophaeic acids. Homosekikaic and sekikaic acids have been detected in *C. merochlorophaea*. Similar chemical content for many species were reported by Kowalewska et al. [2]. Presented study confirmed utility of chemical methods in the diagnosis of the species of *C. pyxidata-chlorophaea* group.

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