The lichens of the *Cladonia pyxidata-chlorophaea* group and allied species in Poland

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Abstract: Kowalewska, A., Kukwa, M., Ostrowska, I., Jabłońska, A., Oset, M. & Szok, J. 2008. The lichens of the *Cladonia pyxidata-chlorophaea* group and allied species in Poland. – Herzogia **21**: 61–78.

The taxonomy, secondary chemistry, morphology, habitat requirements and distribution of *Cladonia pyxidata*, *C. chlorophaea* and the allied species in Poland are treated. The study is based on 2157 examined specimens originating from Poland. Furthermore, types of several taxa as well as additional samples have been studied. Twelve taxa were accepted to occur in Poland. *Cladonia monomorpha* is reported for the first time for North America (Greenland and Vermont) and Asia (Mongolia). *Cladonia pyxidata* var. *baccifera* proved to be a synonym of *C. monomorpha*. *Cladonia pyxidata* var. *neglecta* f. *dilacerata* is tentatively placed in synonymy of *C. cryptochlorophaea*. A key for all taxa known from Poland is provided.

Zusammenfassung: Kowalewska, A., Kukwa, M., Ostrowska, I., Jabłońska, A., Oset, M. & Szok, J. 2008. Die Flechten der *Cladonia pyxidata-chlorophaea*-Gruppe und mit ihr verwandter Arten in Polen. – Herzogia **21**: 61–78.

Die Taxonomie, Sekundärstoffchemie, Morphologie, Habitatansprüche und Verbreitung von *Cladonia pyxidata*, *C. chlorophaea* und verwandten Arten in Polen wird behandelt. Die Untersuchung basiert auf 2157 untersuchten Proben aus Polen. Außerdem wurden Typusaufsammlungen mehrerer Taxa sowie zusätzliche Proben untersucht. Zwölf Taxa wurden als in Polen vorkommend akzeptiert. *C. monomorpha* wird zum ersten Mal aus Nordamerika (Grönland und Vermont) und Asien (Mongolei) angegeben, *C. pyxidata* var. *bacifera* wird mit *C. monomorpha* synonymisiert. *C. pyxidata* var. *neglecta* f. *dilacerata* wird provisorisch in die Synonymie von *C. cryptochlorophaea* gestellt. Ein Bestimmungsschlüssel für alle aus Polen bekannten Taxa wird vorgelegt.

Key words: Cladoniaceae, chemotaxonomy, distribution, Lecanorales, lichenized Ascomycota.

Introduction

The *Cladonia chlorophaea* group and morphologically similar species, *C. fimbriata* (L.) Fr., *C. humilis* (With.) J.R.Laundon s.lat., *C. pocillum* (Ach.) Grognot and *C. pyxidata* (L.) Hoffm. s.lat., are rather conspicuous and commonly collected lichens characterised by scyphose podetia and brown apothecia (Ahti 1966, Orange 1992). The podetia are covered with farinose to granular soredia, corticated granules and/or more or less areolate cortex. The members of the group have a rather diverse secondary chemistry. Since the segregation of several chemically different taxa from *C. chlorophaea* by Asahina (1940) the delimitation of the species within the group became a matter of numerous discussions (see Ahti 1966 and literature cited therein). At the beginning, each segregate was assigned to the rank of species, but later their acceptance varied from one author to another. In many papers they were treated as chemotypes (rarely as varieties or subspecies) (e.g. Motyka 1964, Leuckert et al. 1971, Nowak & Tobolewski

1975, Purvis & James 1992, DePriest 1993, Wirth 1995, Brodo & Ahti 1996, Aptroot et al. 2001) and the species status for chemically different entities was questioned. However, 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 (Stenroos et al. 2002). This finding supports the idea that at least some of the taxa deserve species status. Nevertheless, not all members of the group were included in that phylogenetic study, and certainly more samples are necessary to be included in the future studies. That would make possible to study the status of species showing chemical variation, e.g. *C. grayi* G.Merr. ex Sandst. (Stenroos et al. 2002).

In Poland the chemical variation of the *C. chlorophaea* group was much neglected as TLC has not been used in the delimitation of species differing in the chemistry. Therefore, several years ago, we decided to perform studies on the taxonomy, chemistry, distribution and habitat requirements of that group in Poland. As a great part of the Polish material was misidentified, we found our studies to be necessary and decided to continue our revision. Some results have already been published. Kowalewska & Kukwa (2003a) presented revised records from Northern Poland. Later, *C. conista* Robbins ex A.Evans (as *C. humilis* var. *bourgeanica* A.W.Archer) and *C. asahinae* J.W.Thomson were reported as new to Poland (Kowalewska & Kukwa 2003b, 2007) and new records of *C. monomorpha* Aptroot, Sipman & van Herk (Kowalewska & Kukwa 2004) and *C. conista* (Kowalewska & Szok 2004) were added. Since that, some reliable records have been included in other lichenological papers, e.g. by Jando & Kukwa (2003) and Kubiak (2005), but generally not much has been published so far.

The aim of this paper is to present the results of studies on the chemistry, morphology, habitat requirements and distribution of members of the *Cladonia chlorophaea* group and their allies in Poland. Many foreign other specimens, including type collections of some names, were also studied for comparison. We do not present all specimens examined; here only notes on the distribution, distributional maps and numbers of studied samples are presented.

Material and methods

All the material studied was deposited in the following herbaria: B, GPN, GZU, H, KRA, KRAM, KTC, LOD, OLS, OLTC, POZ, SLTC, UGDA, herb. Kolanko, herb. Kukwa and herb. Leśniański. Chemical analyses were performed with TLC (in solvents A and C) according to the methods of Orange et al. (2001). Morphology was studied under a dissecting microscope. All the localities of examined material are mapped according to the ATPOL grid square system (Zając 1978, modified by Cieśliński & Fałtynowicz 1993, see also Kukwa et al. 2002). We examined 2370 specimens originating from Poland. Sometimes in one envelope more than one taxon was present, and in such case every species was counted as a separate specimen. In case of 69 specimens, we were not able to find an appropriate ATPOL grid square as the data on the labels were insufficient (e.g. only a mountains range reported, or the information was undecipherable). 144 specimens were too small, over-mature or "intermediate" in some respects between two taxa. All those were excluded from the total number of treated samples. Therefore, 2157 specimens are included in this study.

Results

Twelve taxa have been found in the material examined. An additional species, *C. homosekikaica* Nuno, can also occur in Poland, as it was found in Lithuania (Motiejūnaitė 2002). However,

it has not been found in Poland so far. Two taxa, *C. asahinae* and *C. conista*, are known only from very few locations from the country and may be endangered in Poland. *Cladonia fimbriata* appears to be the most widely distributed and commonest species in the country. Except for the samples of *C. fimbriata*, many studied specimens were misidentified, but still members of our group.

The species

Cladonia asahinae J.W.Thomson

J. Jap. Bot. **51**: 361 (1976 [‘1977’]).

Type: U.S.A., Washington, Skagit Co., Mt. Erie on Fidalgo Island S of Anacortes, 1969, J. W. Thomson 16296 (WIS – holotype, not seen). Canada, British Columbia, Strait of Georgia, Mayne Island, Parke Mtn. top, on soil, [04.06.]1962, W. B. Schofield 17539 & F. M. Boas (H – paratype).

Morphology: The species is characterized by podetia with stalk corticated at lower part or up to cups, the cortex is cracked to areolate, areoles are convex to ± flat, outer and inside part of scyphi are covered with farinose to granular soredia or with corticate granules. Very rarely the lower part of scyphi is covered with cortex. For a detailed description see HOLIEN & TØNSBERG (1985), BRODO & AHTI (1996), AHTI & HAMMER (2002) and KOWALEWSKA & KUKWA (2007).

Chemistry: Three chemotypes are recognized, I with rangiformic and fumarprotocetraric acids, II with protolichesterinic and fumarprotocetraric acids, and III with the fumarprotocetraric acid chemosyndrome only (HAMMER 1995, BRODO & AHTI 1996). Only chemotype I has been reported from Europe so far (HOLIEN & TØNSBERG 1985, HUOVINEN et al. 1990). In Polish specimen rangiformic, norrangiformic and fumarprotocetraric acid with related substances were detected (KOWALEWSKA & KUKWA 2007); therefore it belongs to the common chemotype I.

Notes: *Cladonia asahinae* is morphologically similar to *C. chlorophaea* and *C. fimbriata*, but it primarily differs in the production of fatty acids (HOLIEN & TØNSBERG 1985, BRODO & AHTI 1996, KOWALEWSKA & KUKWA 2007). Another fatty-acid producing, morphologically similar species of the *C. chlorophaea* group is *C. conista*, However, it contains rangiformic and norrangiformic acids instead of bourgeanic acid (HOLIEN & TØNSBERG 1985, KOWALEWSKA & KUKWA 2003b).

Ecology: In Poland, the species was found on soil along a path in the mountains.

Distribution: In Poland it is only known from one locality (Fig. 1A). The species has been found in several countries in Europe, including Andorra, the Czech Republic, Finland, Great Britain, Iceland, Lithuania, the Netherlands, Norway, Sweden, and Spain. Additionally it has been reported from Russia (Krasnoyarsk Territory) in Asia, Canada (British Columbia) and the U.S.A. (Alaska, California, Idaho, Montana, Washington) in North America, from Argentina, Chile and South Georgia in South America, and the Antarctic (KOWALEWSKA & KUKWA 2007 and literature cited therein; T. Ahti, pers. comm.).

Number of specimens examined: 1

Cladonia chlorophaea (Flörke ex Sommerf.) Spreng.

Syst. Veg. **4**: 273 (1827). – *Cenomyce chlorophaea* Flörke ex Sommerf., Suppl. Fl. Lapp.: 130 (1826).

Type: Norway, Nordland, Saltdalen, S. Ch. Sommerfelt (O – lectotype, not seen; see photograph in AHTI 2000).

Exsiccates examined: Hansen & Christensen, Lich. Dan. Exs. 96 (UGDA). Krawiec, Lichenoth. Polon. 70 (UGDA-L–14240). Rabenhorst, Clad. Eur. 4 (B). Räsänen, Lich. Fenn. Exs. 789 (H). Rehm, Clad. Exs. 163 (H). Sandstede, Clad. Exs. 834 & 920 (B).

Morphology: The podetia of the species are up to 3.5 cm tall, with short to long and more or less corticate stalk and wide and usually gradually tapering scyphi covered with granular soredia, sometimes mixed with corticated granules. For a detailed description see PURVIS & JAMES (1992), BRODO & AHTI (1996), AHTI (2000) and AHTI & HAMMER (2002).

Chemistry: In all Polish specimens, fumarprotocetraric acid with protocetraric acid and other substances in trace amounts were detected. It agrees with other investigations from temperate to arctic

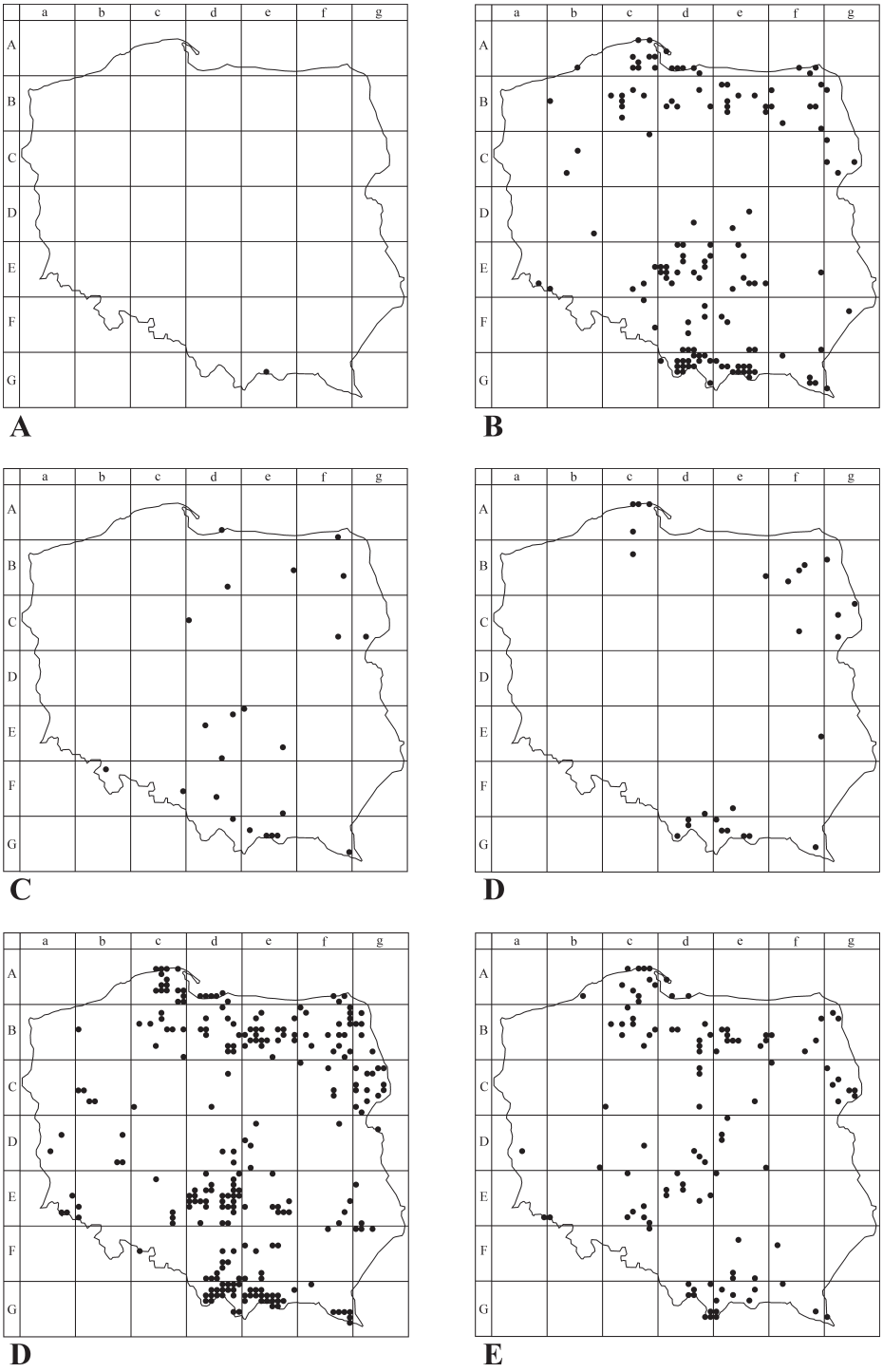

Fig. 1: Known distribution of *Cladonia asahinae* (A), *C. chlorophaea* (B), *C. conista* (C), *C. cryptochlorophaea* (D), *C. fimbriata* (E) and *C. grayi* (F) in Poland given in ATPOL grid square system.

regions (see AHTI 1966, 2000, LEUCKERT et al. 1971, BRODO & AHTI 1996, AHTI & HAMMER 2002). Occasional traces of atranorin were reported by ORANGE (1992) and OSYCZKA & OLECH (2005). AHTI (2000) found unidentified fatty acids in material from the Neotropics. None of such substances were observed in Polish specimens. A physodalic acid chemotype is known from Costa Rica (AHTI 2000).

Notes: *Cladonia chlorophaea* belongs to a group of taxa containing only substances of the fumarprotocetraric acid complex. The main discriminating features of the species are the presence of granular soredia on outer and inner surfaces of scyphi and the non-melanotic base of podetia (AHTI 1966, 2000, ORANGE 1992). Many Polish specimens belong to that species without any doubts. However, there were numerous specimens, which were difficult to be assigned to *C. chlorophaea*. Part of them had rather a typical shape of podetia, but possessed more fine soredia. Those samples were similar to *C. fimbriata*, however, the soredia were not so farinose as in that species (quite good example of such morphology is Hansen & Christensen, Lich. Dan. Exs. 96). Some lichenologists may include such specimens in the variation of *C. chlorophaea*, but some in *C. fimbriata* (T. Ahti, pers. comm.). Additionally, intermediate forms in the shape and size of soredia between such forms and typical specimens of those two taxa were found. However, we suspect that *C. chlorophaea* and *C. fimbriata* include more than two taxa. All those "intermediates" may be a result of different habitat conditions, but one cannot exclude the possibility that there are more species in that group. Molecular data are necessary to solve that problem and a range of several specimens should be included in the data set. For the time being, we have included such atypical specimens in *C. chlorophaea*, but we do not have a definitive opinion on that problem and in the future, when new data will be available, we may have to change some of our identifications.

A second set of specimens, which were difficult to be assigned into *C. chlorophaea*, had corticated granules attached to the surface of podetia, but some of them were loose. Those samples reminded of *C. pyxidata*. Probably the podetia in such material were over-mature, and in consequence most part of soredia became bigger and more distinctly corticated, and thus they resembled areoles. Many of such samples were so difficult to be identified, that we left them undetermined. That problem has already been reported by AHTI (1966). As he has noted, *C. chlorophaea* and *C. pyxidata* are morphologically very closely related, and several specimens may be difficult to identify. WIRTH (1995) went further and united both taxa. Nevertheless, DNA studies should be performed to solve the position of such samples and to establish the boundaries between *C. chlorophaea* and *C. pyxidata*.

Ecology: *Cladonia chlorophaea* grows mainly on soil, but it has also very often been reported from bark of trees. It was also collected from rocks and stumps. It seems that the species, at least in present concept, is an ecologically ubiquitous lichen. Similar habitat requirements were reported also by AHTI (2000) and AHTI & HAMMER (2002). The species was found in Poland on soil (155), stumps (38), rocks (24), *Betula* spp. (19), *Fagus sylvatica* (17), wood (11), *Quercus* spp. (11), *Salix* spp. (8), *Alnus glutinosa* (5), *Abies alba* (4), mosses (4, including 3 over concrete), *Fraxinus excelsior* (3), *Tilia cordata* (3), peat (2), *Picea abies* (2), *Populus* spp. (2), *Acer platanoides* (1), *Pinus sylvestris* (1), *Prunus* sp. (1), bark of twig (1), and thatched roof (1).

Distribution: *Cladonia chlorophaea* is rather widespread in Poland at all altitudes (Fig. 1B). It is almost absent in some regions of western, eastern and central Poland, and there were no specimens in herbaria originating from those parts of the country. Similar tendency is observed in all other common taxa, e.g. *C. fimbriata* and *C. grayi*. *Cladonia chlorophaea* is a cosmopolitan lichen known from all continents. It is commonly reported from Europe, e.g. from Austria (HAFELLNER & TÜRK 2001), the Czech Republic (VĚZDA & LIŠKA 1999), Denmark (SØCHTING & ALSTRUP 2002), Fennoscandia (SANTESSON et al. 2004), Lithuania (MOTIEJŪNAITĖ 2002), and Germany (SCHOLZ 2000). It is also known from Africa (e.g. SWINSCOW & KROG 1988), Antarctica (OSYCZKA & OLECH 2005), Asia (FEUERER 2007 and literature cited therein), Australia (MCCARTHY 2008), North America (ESSLINGER 2007) and South America (AHTI 2000).

Number of specimens examined: 320

Cladonia conista Robbins ex A.Evans

Trans. Connecticut Acad. Arts **30**: 472 (1930).

Type: U.S.A., Connecticut, New Haven Co., North Branford, 1927, A. Evans & F. Musch 1269 (US – lectotype, not seen; see AHTI 2000).

= *Cladonia humilis* var. *bourgeanica* A.W.Archer, Muelleria **7**: 3 (1989).
Type: Australia, New South Wales, Six Foot Track, Binomea Ridge, A. W. Archer 2086 (MEL – holotype, not seen; see Archer 1989); Victoria, Mirimbah, by side of Mt. Stirling Rd., 37°07'S/146°25'E, alt. 700 m, 05.11.1986, A. W. Archer 2005 (H – paratype).
Morphology: Podetia are tall, up to c. 2.5 cm high, with regular, ± goblet-shaped cups. Upper part, or rarely more than half, of the stalk and cups are sorediate. Non-sorediate part of the stalk is covered with more or less even cortex. Soredia are farinose to granular. For a detailed description see Holien & Tønsberg (1985) and Archer (1989).
Chemistry: *Cladonia conista* produces bourgeanic acid and substances of the fumarprotocetraric complex (Holien & Tønsberg 1985, Archer 1989, Kowalewska & Kukwa 2003b).
Notes: *Cladonia conista* is distinguishable from similar European taxa by the usually fine soredia and the presence of bourgeanic acid in the thallus. Sometimes it is regarded only as a chemotype of *C. humilis*, because there are no morphological differences between these taxa in some regions and material with intermediate chemistry is known (Stenroos & Ahti 1990, Ahti 2000). In Norway, *C. conista* has taller podetia and prefers continental sites, whereas *C. humilis* (sub *C. conoidea*) is shorter and grows along the coast (Holien & Tønsberg 1985). We observed the same differences in Poland, therefore we treat both taxa as distinct species; but molecular studies should be performed to evaluate their true status.
Ecology: All the Polish specimens were found on soil. According to the label data the species seems to prefer open habitats, e.g. the edges of forests or roadsides. The observed habitat preferences agreed with those reported for the species by Holien & Tønsberg (1985).
Distribution: The species is rare in Poland, and is preferably found in the continental parts of the country (Fig. 1C). It presumably has a distribution different from *C. humilis* in Poland (see below). *Cladonia conista* has not always been distinguished from *C. humilis* s. str. and therefore the general distribution is not well investigated. So far, we have found information that the taxon is known from Fennoscandia, Netherlands (Holien & Tønsberg 1985, Kowalewska & Kukwa 2003b), Argentina (Stenroos & Ahti 1990), Australia (Archer 1989) and North America (Ahti & Hammer 2002, Esslinger 2007). T. Ahti (pers. comm.) also recorded it from Denmark, Great Britain, Iceland, the Czech Republic, Germany, France, Latvia, Lithuania, Russia, Morocco, South Africa, Turkey, China, Japan, Nepal, India, Brazil and Falkland Islands; in Canada and the United States it is much more widespread than *C. humilis*.
Number of specimens examined: 29

Cladonia cryptochlorophaea Asahina
J. Jap. Bot. **16**: 711 (1940).
Type: Japan, Honshu, Prov. Shinano (Pref. Nagano), Mt. Nyugasa ('Niugasayama'), 1937, I. Yoshioka, Herb. Asahina No. 37031 ('37013') (TNS – holotype, not seen; citation of the type incorrect in Ahti 2000; corrected by T. Ahti, pers. comm. 2008).
= *Cladonia cryptochlorophaea* Asahina f. *inactiva* Asahina, J. Jap. Bot. **16**: 715 (1940).
Type: U.S.A., North Carolina, Carteret Co., Lola, 1939, A. W. Evans & Anderson (UPS – lectotype, not seen; see Ahti 2000).
= ?*Cladonia pyxidata* var. *neglecta* f. *dilacerata* Doppelb., Ber. Naturf. Ges. Augsburg **3**: 62 (1950).
Type: Germany, Bayern, Kr. Augsburg, Haunstetterwald, Wald auf Erica-Bulten, 11.02.1949, H. Doppelbaur (B–20979 – isotypus?).

Exsiccates examined: Britzelmayr, Lich. Exs. 340 (H). Rehm, Clad. Exs. 418 (H). Sandstede, Clad. Exs. 237 (H). Vězda, Lich. Sel. Exs. 1663 (H).

Morphology: The podetia are usually goblet- to trumpet-shaped cups without proliferations from the margin. Though soredia are present, the surface of the podetia is mostly roughly corticated; forms with almost completely sorediate podetia are rare. For a detailed description see Holien & Tønsberg (1985) and Ahti (2000).
Chemistry: The species produces cryptochlorophaeic and paludosic acids with related substances as well as substances of the fumarprotocetraric acid complex (Ahti 1966, 2000, Holien & Tønsberg 1985). We detected cryptochlorophaeic acid and the fumarprotocetraric acid chemosyndrome. A che-

motype without the fumarprotocetraric acid complex, known as f. *inactiva*, has been recorded only in North and South America so far (AHTI 1966, 2000, HOLIEN & TØNSBERG 1985).

Notes: *Cladonia cryptochlorophaea* is morphologically very similar to *C. merochlorophaea*, *C. novochlorophaea* and *C. grayi* (e.g. AHTI 1966, HOLIEN & TØNSBERG 1985). Additionally, both *C. cryptochlorophaea* and *C. merochlorophaea* react KC+ red. There are some visual discriminating characters, e.g. podetia of *C. grayi* are usually abundantly granular-sorediate, whereas most of Polish samples of *C. cryptochlorophaea* are not. However, the only absolutely reliable character is the chemistry. *Cladonia cryptochlorophaea* produces cryptochlorophaeic acid as a major diagnostic substance, whereas grayanic acid is found in *C. grayi*, merochlorophaeic and 4-O-methylcryptochlorophaeic acids in *C. merochlorophaea*, and homosekikaic and sekikaic acids in *C. novochlorophaea* (e.g. AHTI 1966, 2000, HOLIEN & TØNSBERG 1985, BRODO & AHTI 1996). During the examination of the material in B we found an apparent isotype specimen collected by H. Doppelbaur and identified as *C. pyxidata* var. *neglecta* f. *dilacerata* (DOPPELBAUR 1950). It contained cryptochlorophaeic and fumarprotocetraric acids and in our opinion represents an abnormal form of *C. cryptochlorophaea* with strange proliferations.

Ecology: Almost three quarters of the records of *C. cryptochlorophaea* in Poland are represented by epigeic specimens. It was found in rather open and sun-exposed plant communities, e.g. in pine forests or raised peat bogs. Similar ecological notes are given by HOLIEN & TØNSBERG (1985) and AHTI (2000). The species was found on mineral soil (29), decaying peat (8), bark of *Betula pendula* (4), rocks (2), and mosses (1).

Distribution: *Cladonia cryptochlorophaea* has not been reported from Poland until recently (FAŁTYNOWICZ 2003). Most of the older herbarium specimens were named as *C. pyxidata* or *C. chlorophaea*. Based on the material examined, the species seems to be relatively rare lichen in Poland (Fig. 1D). Its known localities are scattered, mostly in southern and north-eastern part of Poland. The species has been reported from almost all continents, except Africa and Antarctica (see AHTI 2000). In Europe it has been reported from e.g. Austria (HAFELLNER & TÜRK 2001), the Czech Republic (VĚZDA & LIŠKA 1999), Denmark (SØCHTING & ALSTRUP 2002), Iceland (FEUERER 2007), Fennoscandia (AHTI 1966, HOLIEN & TØNSBERG 1985, SANTESSON et al. 2004), Lithuania (MOTIEJŪNAITĖ 2002), United Kingdom (AHTI 1966, ORANGE 1992, COPPINS 2002). In Asia it was reported e.g. from China (FEUERER 2007 and literature cited therein), Japan (KUROKAWA 2003) and South Korea (FEUERER 2007 and literature cited therein). In North America it is known from e.g. Canada and U.S.A. (AHTI 1966, THOMSON 1984, ESSLINGER 2007). Known distribution in South America was presented by AHTI (2000). In Australia it was reported by MCCARTHY (2008), but only listed as a synonym of *C. chlorophaea*. T. Ahti (pers. comm.) has also recorded it from Ireland, Belgium, Luxembourg, Germany, Hungary, the Netherlands, Switzerland, Portugal, Spain, Italy, Estonia, South Africa, Russia (Siberia and Far East), New Zealand, Costa Rica, and Chile.

Number of specimens examined: 44

Cladonia fimbriata (L.) Fr.

Lichenogr. Eur. Ref.: 222 (1831). – *Lichen fimbriatus* L., Spec. Pl. **2**: 1152 (1753).

Type: Dillenius, Hist. Musc., tab. 14, Fig. 8, 1742 (lectotype, not seen), Hb. Dillenius, tab. 14, Fig. 8 (OXF – epitype, not seen; see AHTI 2000).

Exsiccates examined: Poelt, Pl. Graec. Lich. 193 (B, H). Hammer, Clad. Exs. 192 (H). Kozioł, Fl. Siles. Exs. 1334 (B–95475, H). Malme, Lich. Suecici Exs. 857 (B–92145). Nowak, Lich. Polon. Merid. Exs. 172 (B, H). Räsänen, Lichenoth. Fenn. 1067 (B, H). Rehm, Clad. Exs. 440 (H). Sandstede, Clad. Exs. 964 (H). Sandstede, Clad. Exs. 279 (B–18569, H). Tuckerman, Lich. Amer. Sept. Exs. 121 (B).

Morphology: The podetia are up to c. 3.5 cm tall, with usually abruptly expanded, regular, goblet-shaped, rarely trumpet-shaped or shallow scyphi, sometimes with proliferations. Soredia are finely pulverulent and cover the scyphi and also often the podetial stalk, at least in upper part. Stalk was distinctly corticate up to the scyphi in few samples; usually compacted soredia frequently formed a rough layer at the base of podetia, giving the impression of a cortex. In some samples soredia inside the scyphi were granular; sometimes some squamules were developed between the soredia. For a detailed

description see Purvis & James (1992), Brodo & Ahti (1996), Ahti (2000) and Ahti & Hammer (2002).

Chemistry: The species produces fumarprotocetraric acid and related compounds (e.g. Brodo & Ahti 1996, Ahti 2000, Azuaga et al. 2001, Ahti & Hammer 2002). The same chemistry was detected in all Polish samples.

Notes: The species, when typically developed, is very characteristic and easily recognizable: the podetia are tall and covered with farinose soredia. It can be confused with *C. chlorophaea*, *C. asahinae*, *C. conista* and *C. humilis*. *Cladonia conista* is morphologically the most similar taxon, but differs by its usually distinctly corticate podetial stalk and the production of bourgeanic acid. *Cladonia humilis* is another species with fine soredia, but differs by having shorter podetia, a corticate stalk and the production of atranorin (Holien & Tønsberg 1985, Archer 1989, Ahti 2000). For the discussion of similarities with *C. chlorophaea* and *C. asahinae* see comments under those taxa. *C. fimbriata* is the only taxon of the treated group, which was earlier correctly identified in almost all cases in the herbaria.

Ecology: *Cladonia fimbriata* is predominantly an epigeic lichen in Poland (57 % of Polish records), but it was also collected on bark of trees (20 %), or wood and stumps (15 %). The frequency on different substrata in Poland is as follows: soil (347), *Betula pendula* and *B. pubescens* (55), stumps (40), wood (50), rocks (21), *Fagus sylvatica* (12), *Salix* sp.(10), *Alnus glutinosa* (8), *Quercus* sp. (7), *Pinus sylvestris* (5), bark of undetermined trees (5), *Populus alba* and *P. nigra* (4), *Fraxinus excelsior* (3), *Picea abies* (3), *Acer platanoides* (2), *A. pseudoplatanus* (2), *Juniperus communis* (2), *Populus tremula* (2), *Tilia cordata* (2), *Abies alba* (1), *Prunus* sp. (1), *Sorbus aucuparia* (1), mosses over rock (10), humus (8), peat (5), concrete (1). *Cladonia fimbriata* occupies similar habitats also in other temperate regions (Purvis & James 1992, Brodo & Ahti 1996). In the Neotropics, however, the species is preferentially found wood and dead bryophytes, while only few records from soils exist (Ahti 2000).

Distribution: The species is very common and widely distributed lichen in Poland (Fig. 1E). Less specimens were available from the western part of the country *C. fimbriata* is a cosmopolitan lichen. In Europe it is very widely distributed and is known e.g. from Austria (Hafellner & Türk 2001), the British Isles (Coppins 2002), the Czech Republic (Vězda & Liška 1999), Denmark (Søchting & Alstrup 2002), Fennoscandia (Santesson et al. 2004), Germany (Scholz 2000), Iceland (Feuerer 2007 and literature cited therein), Lithuania (Motiejūnaitė 2002), Spain (Aragón et al. 2001). Outside Europe, it has been reported from Africa, e.g. in the Cameroons and Morocco (e.g. Feuerer 2007 and literature cited therein), Antarctica (Osyczka & Olech 2005), Asia, e.g. in China (Wei 1991), Japan (Kurokawa 2003), Pakistan and Mongolia (Feuerer 2007 and literature cited therein), Australia (McCarthy 2008), North America (Esslinger 2007) and South America (Ahti 2000). However, it is rare in the inner tropics.

Number of specimens examined: 621

Cladonia grayi G.Merr. ex Sandst.

Clad. Exs. No. 1847 (1929).

Type: U.S.A., "N Virginia" (= North Carolina), Long Creek, Charlotte, 06.1928, F. W. Gray, Sandstede, Clad. Exs. 1847 (FH – lectotype, not seen; see Ahti 2000; B – isolectotype).

= *Cladonia grayi* f. *aberrans* Asahina, J. Jap. Bot. **16**: 714 (1940).

Type: Germany, prov. Brandenburg, Kieferland westlich von Halbe, 04.10.1918, J. Hillmann, Sandstede, Clad. Exs. 338 (TNS – lectotype, not seen; see Ahti 2000; H – isolectotype).

Exsiccates examined: Hammer, Clad. Exs. 199 & 201 (H). Nowak, Lich. Polon. Merid. Exs. 171 (B). Sandstede, Clad. Exs. 338 (H, isolectotype of *C. grayi* f. *aberrans*). Sandstede, Clad. Exs. 1847 (B, isolectotype of *C. grayi*). Tuckerman, Lich. Amer. Sept. Exs. 121 (B, pro parte). Vězda, Lich. Sel. Exs. 1806 (H). Vězda, Lich. Sel. Exs. 2134 (B, H). Zielińska, Pl. Varsav. Exs. 18 (B–20997, H).

Morphology: The podetia are up to c. 3 cm tall, with usually gradually tapering, regular, trumpet- or goblet-shaped scyphi, often with proliferations. Granular soredia are richly produced covering the scyphi and the upper part of the podetial stalk. Lower part of stalk distinctly verruculose corticate, occasionally squamulose. For a detailed description see Holien & Tønsberg (1985), Brodo & Ahti (1996) and Ahti (2000).

Chemistry: *Cladonia grayi* always produces grayanic acid (with 4-O-demethylgrayanic acid) (AHTI 1966, 2000, HOLIEN & TØNSBERG 1985), often with detectable traces of additional unidentified compounds. Several specimens also contain substances of the fumarprotocetraric acid complex and are sometimes named as *C. grayi* f. *aberrans* (AHTI 2000). In Poland, 81 % of specimens produced fumarprotocetraric acid. HOLIEN & TØNSBERG (1985) detected this substance only in 42 % out of 140 specimens from Norway. AHTI (2000) reported also fatty acids from *C. grayi*. Possibly one fatty acid with Rf class C 1–2 occurred in some specimens from the Polish Tatra Mountains, but the spot was faint and might have been an artefact. Some additional substances were reported by CULBERSON et al. (1985), but only in specimens originating from Jamaica or Haiti.

Notes: The species is primarily characterised by the production of grayanic acid and the presence of fine granules (AHTI 2000). These characters separate it from all other morphologically similar taxa, e.g. *C. merochlorophaea* and *C. novochlorophaea*. *Cladonia grayi* shares the chemistry with chemotype I of *C. albonigra* Brodo & Ahti (isotype studied in H) (BRODO & AHTI 1996). The latter differs predominantly in the conspicuously melanotic base, the stereome gradually becoming entirely blackened and the common production of proliferations from centre of the cups. *Cladonia grayi* is never melanotic and only rarely proliferates from the central part of the scyphi (f. *centralis* A.Evans) (BRODO & AHTI 1996). In Europe, *C. albonigra* has only been published from Norway in a chemotype with fumarprotocetraric acid (chemotype III; BRODO & AHTI 1996), but the assignment of this material to *C. albonigra* is uncertain.

In Polish material, two morphotypes of *C. grayi* were observed, one with typically trumpet-shaped or flared scyphi covered with granular soredia, and the other, rarer one, with goblet-shaped podetia and finer, sometimes even almost farinose soredia. This may indicate that *C. grayi* may in fact represent a complex of species, what also has been already suggested by STENROOS et al. (2002). These authors included two samples of *C. grayi* in their study, one with and another one without fumarprotocetraric acid. In their analyses, these samples are not clustered together suggesting the paraphyly of *C. grayi*. However, as only two specimens have been included in phylogenetic analyses so far, at present it is difficult to judge whether the chemistry or the shape of podetia are pivotal for species delimitation

Cladonia grayi was published from Poland in several papers (see FAŁTYNOWICZ 2003 for references), but most records are not based on specimens studied by TLC. As *C. grayi* was thought never to produce fumarprotocetraric acid and, thus, not to react with *para*-phenylenediamine (MOTYKA 1964, NOWAK & TOBOLEWSKI 1975). However, this is incorrect, as specimens of *C. grayi* with fumarprotocetraric acid occur (AHTI 1966, HOLIEN & TØNSBERG 1985). Most of the Polish material earlier assigned to *C. grayi* represented the fumarprotocetraric acid deficient chemotype of *C. novochlorophaea* (KOWALEWSKA & KUKWA 2003a).

Ecology: *Cladonia grayi* inhabits a wide range of substrata, including soil (120), humus (26), peat (21), hummock (13), *Betula* spp. (52), *Pinus sylvestris* (21), *Juniperus communis* (7), bark of undetermined trees (6), *Quercus* sp. (4), *Alnus glutinosa* (1), *Sorbus aucuparia* (1), pine cone (1), plant detritus (9), rocks (8), concrete (1), mosses (3), wood (34), and stumps (17).

Based on the information extracted from the labels, it seems that *C. grayi* is a strictly acidophilous lichen. HOLIEN & TØNSBERG (1985) and AHTI (2000) reported the species from similar habitats, like sandy or humic soil and wood.

Distribution: *Cladonia grayi* is common and quite evenly distributed in the areas studied by lichenologists (Fig. 1F). It is virtually absent from western and some eastern regions of Poland. *Cladonia grayi* has been reported from all continents, except Africa and Antarctica. In Europe it is widely distributed and reported, e.g., from Austria (HAFELLNER & TÜRK 2001), Belgium (DIEDERICH & SÉRUSIAUX 2000), the British Isles (COPPINS 2002), the Czech Republic (VĚZDA & LIŠKA 1999), Denmark (SØCHTING & ALSTRUP 2002), Estonia (RANDLANE & SAAG 1999), Fennoscandia (HOLIEN & TØNSBERG 1985, SANTESSON et al. 2004), Germany (SCHOLZ 2000), Lithuania (MOTIEJŪNAITĖ 2002), and Luxembourg (DIEDERICH & SÉRUSIAUX 2000). The species is known from Canada and the U.S.A. in North America (e.g. ESSLINGER 2007), from Costa Rica in Central America (UMAÑA-TENORIO et al. 2002), and several South American coutries (AHTI 2000). *C. grayi* is also reported from continental Australia, but only as a synonym of *C. merochlorophaea* (MCCARTHY 2008) and New Zealand (AHTI 1966 and literature

cited therein, Feuerer 2007). From Asia, *C. grayi* was reported several times. While some records are old and, thus, doubtful, the occurrence of *C. grayi* in Japan is confirmed by Ahti (1966). T. Ahti (pers. comm.) has recorded it also from the Netherlands, France, Italy, Portugal, Spain, Latvia, Russia (Europe, Siberia, Far East), South Korea, Pakistan and Hawaii.

Number of specimens examined: 346

Cladonia humilis (With.) J.R.Laundon

Lichenologist **16**: 220 (1984). – *Lichen humilis* With., Bot. Arr. Veg. Gr. Brit.: 721 (1776).

Type: Drawing of *Coralloides scyphis humilibus intus fuscis*, Dillenius, Hist. Musc., tab. 14, fig 11 (1742) (holotype; see Ahti 2000); England, London, Greenwich, Charlton and Woolwich, J. J. Dillenius (OXF – epitype, not seen; see Ahti 2000).

= *Cladonia conoidea* Ahti, Lichenologist **12**: 129 (1980).

Type: England, West Cornwall (V.C. 1), Isles of Scilly, St. Mary's, Peninnis Head, 04.05.1979, P. W. James (BM – holotype, not seen; H – isotype).

Morphology: *Cladonia humilis* is very similar to *C. conista*, but the podetia are shorter. For a detailed description see Purvis & James (1992).

Chemistry: Atranorin and fumarprotocetraric acid with related substances were found in all Polish samples in agreement with the findings from other areas (Holien & Tønsberg 1985, Stenroos & Ahti 1990, Purvis & James 1992, Ahti 2000).

Notes: *Cladonia humilis* is the only constantly atranorin-containing member of the group occurring in Poland. It is morphologically or chemically similar to *C. asahinae*, *C. chlorophaea*, *C. conista* and *C. fimbriata*. It differs from all mentioned species at least by shorter podetia with distinct cortex, usually farinose soredia and/or the production of atranorin (Holien & Tønsberg 1985, Archer 1989, Ahti 2000).

Ecology: All Polish specimens were found on soil.

Distribution: The species is known only from four localities in Poland, three of which are situated along the Baltic coast (Fig. 2A). Its distribution differs from that of *C. conista*, which is often regarded as conspecific with *C. humilis*. In Europe, *C. humilis* is known from the British Isles (Purvis & James 1992), Fennoscandia (Santesson et al. 2004), Germany (Scholz 2000), Lithuania (Motiejūnaitė 2002), Luxembourg (Diederich & Sérusiaux 2000). Outside Europe, it has been reported from North America (Ahti & Hammer 2002, Esslinger 2007), South America (Ahti 2000), Asia (Purvis & James 1992, Kurokawa 2003), Australia and New Zealand (Purvis & James 1992, McCarthy 2008). T. Ahti (pers. comm.) has also recorded the species from Iceland, Belgium, the Czech Republic, the Netherlands, France, Portugal, Spain, Italy, Greece, Slovenia, Macaronesia, Ethiopia, and South Africa.

Number of specimens examined: 4

Cladonia merochlorophaea Asahina

J. Jap. Bot. **16**: 713 (1940).

Type: Germany, Oldenburg, Oldenburger Sand, 12.1918, H. Sandstede, Sandstede, Clad. Exs. 389 (TNS – lectotype, not seen; see Ahti 2000; B, H – isolectotypes).

= *Cladonia merochlorophaea* f. *inactiva* Asahina, J. Jap. Bot. **16**: 713 (1940).

Type: Sweden, Uppland, Sandhem, 05.1927, Vrang, Sandstede, Clad. Exs. 1747 (TNS – lectotype, not seen; see Ahti 2000).

Exsiccates examined: Sandstede, Clad. Exs. 236 (sub *C. chlorophaea*, B). Sandstede, Clad. Exs. 389 (B, H, isolectotypes). Sandstede, Clad. Exs. 1874 (sub *C. chlorophaea* f. *costata*, B). Zahlbruckner, Krypt. Exs. 1773 (sub *C. pyxidata* var. *chlorophaea* f. *costata*, B).

Morphology: Podetia are tall, brownish, greenish-grey with gradually flaring scyphi. Surface is areolate-corticate, verruculose or obscurely sorediate with coarse granules. The granules may change into phyllidia, micro- or macrosquamules. For a detailed description see Holien & Tønsberg (1985) and Ahti (2000).

Chemistry: *Cladonia merochlorophaea* always contains merochlorophaeic, 4-O-methylcryptochlorophaeic acids (usually with related substances in traces) and quite often substances of the fumar-

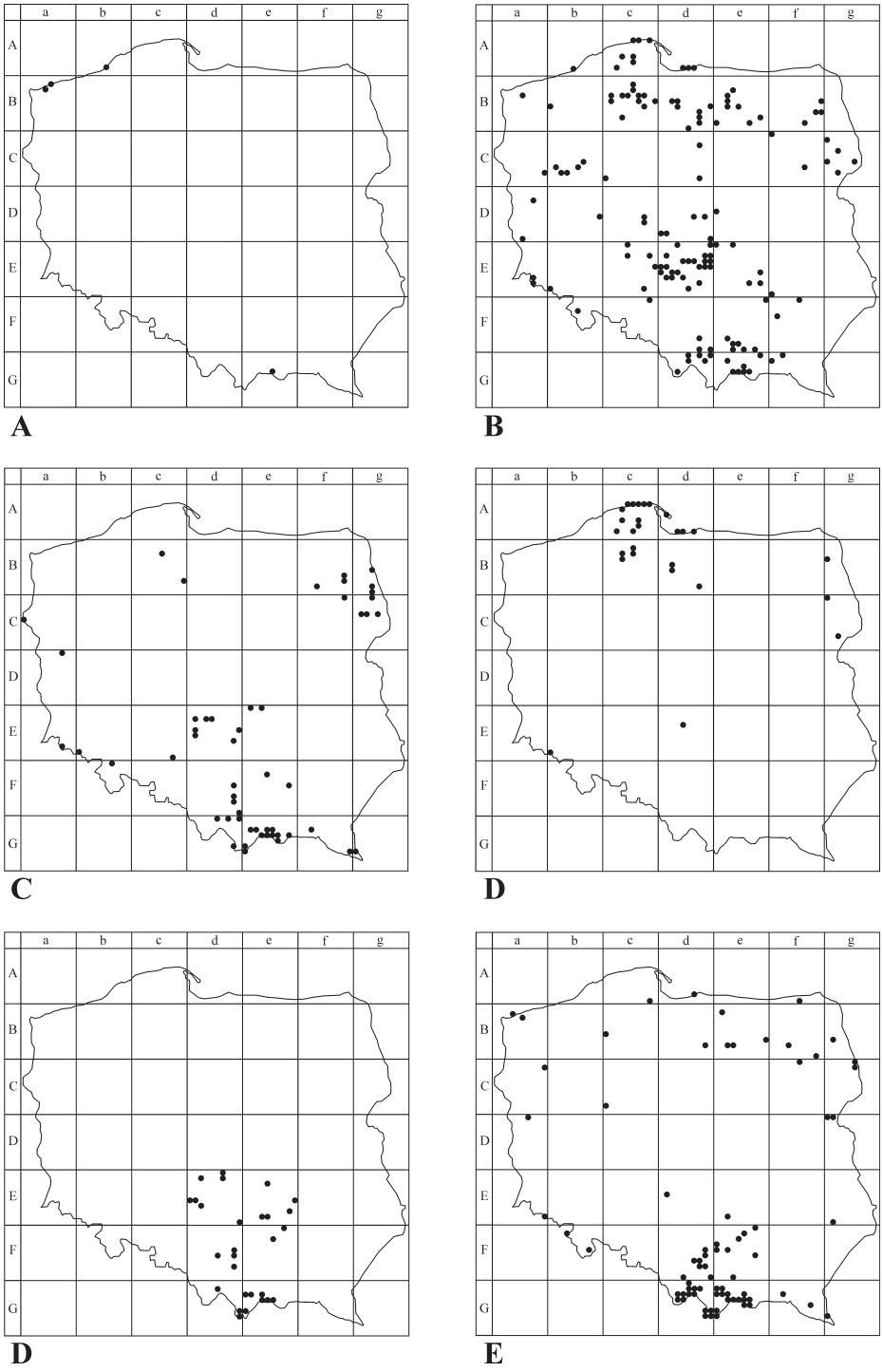

Fig. 2: Known distribution of *Cladonia humilis* (A), *C. merochlorophaea* (B), *C. monomorpha* (C), *C. novochlorophaea* (D), *C. pocillum* (E) and *C. pyxidata* (F) in Poland given in ATPOL grid square system.

protocetraric acid complex (Ahti 2000). In Norway, 67 % specimens contain the fumarprotocetraric acid (Holien & Tønsberg 1985), but in Poland it was detected in almost 90 % of the samples.

Notes: The species is characterised by corticate podetial surface, the production of merochlorophaeic and 4-O-methylcryptochlorophaeic acids and KC+ red reaction of the thallus. *Cladonia cryptochlorophaea* is the only other morphologically and chemically similar taxon occurring in Poland, but it can be differentiated by the presence of cryptochlorophaeic acid (cf. Ahti 1966, 2000). All other species are KC–. In the past *C. novochlorophaea* was treated as synonym of *C. merochlorophaea*, but later it was regarded as distinct species (Ahti 1966, Leuckert et al. 1971, Brodo & Ahti 1996). For a discussion of differences between both taxa confer remarks given under *C. novochlorophaea*.

Ecology: *Cladonia merochlorophaea* is a lichen of soil rich in humus in open habitats (Holien & Tønsberg 1985). In Poland, the species has been found so far on soil (183), decaying peat (15), humus (5), *Betula* spp. (124), *Pinus sylvestris* (16), *Juniperus communis* (4), bark of twigs (3), *Salix* sp. (2), *Alnus glutinosa* (1), bark of undetermined tree (1), *Quercus* sp. (1), *Prunus* sp. (1), wood (18), rock (9), stumps (7), and mossy stone (1). Birch is overrepresented among the specimens, because it was preferentially sampled in the scope of a study by A. Kowalewska (unpublished).

Distribution: The species has been reported from many places of Poland since the 1960s (Fałtynowicz 2003 and literature cited therein), though the density of localities with the species is not uniform (Fig. 2B), as no material was available from some regions of the country. *Cladonia merochlorophaea* is a cosmopolitan lichen and is known from all continents, except the Antarctic (the record from the Antarctic in Ahti 2000 is an error, T. Ahti, pers. comm.). In Europe the species has been reported from Austria (Hafellner & Türk 2001), Belgium (Diederich & Sérusiaux 2000), the Czech Republic (Vězda & Liška 1999), Estonia (Randlane & Saag 1999), Denmark (Søchting & Alstrup 2002), Fennoscandia (Santesson et a. 2004), Germany (Scholz 2000), Iceland (Feuerer 2007), Lithuania (Motiejūnaitė 2002) and Luxembourg (Diederich & Sérusiaux 2000). It is also known from Canada and the U.S.A. in North America (Thomson 1984) and Costa Rica in Central America (Tenorio et al. 2002), Bolivia (Flakus et al. 2008), Brazil, Peru and Venezuela (Ahti 2000) in South America, China (Wei 1991), Japan (Kurokawa 2003) and Russia (Kristinsson et al. 2006) in Asia, Australia (McCarthy 2008) and Africa (Ahti 2000, finding from South Africa erroneously reported as deriving from Antarctica). T. Ahti (pers. comm.) has also records from Hungary, the Netherlands, Portugal, Spain, Italy, the Azores, Russia (Europe, Siberia, Far East), Mongolia, Hawaii, and Argentina.

Number of specimens examined: 393

Cladonia monomorpha Aptroot, Sipman & van Herk

Lichenologist **33**: 273 (2001).

Type: Netherlands, Prov. Gelderland, Garderen, Caitwickerzand, 06.06.2000, A. Aptroot 48216, C. M. van Herk, H. J. M. Sipman, L. B. Sparrius & L. J. Spier (B – holotype; H – isotype).

= *Cladonia pyxidata* var. *baccifera* Räsänen, Ann. Bot. Soc. Zool.-Bot. Fenn. "Vanamo" **20**: 21 (1944).

Type: Finland, Ostrobottnia australis (Oa), Lapua Simpsiö, ad saxum muscosum in silva mixta, 18.09.1920, V. Räsänen (H – holotype).

Exsiccates examined: Hammer, Clad. Amer. Exs. 12, 213 & 214 (sub *C. pyxidata*, GZU). Sandstede, Clad. Exs. 654 (sub *C. pyxidata* var. *neglecta*, B–20945, paratypus). Sandstede, Clad. Exs. 830 (sub *C. pyxidata* var. *neglecta*, B–20944, paratypus). Sandstede, Clad. Exs. 1530 (sub *C. pyxidata* var. *neglecta*, B–20952, paratypus). Vězda, Lich. Rar. Exs. 464 (H).

Morphology: Primary thallus consists of greenish-grey, relatively large and thick squamules, and 1.5 cm tall podetia with ± regular cups. Scyphi are covered with bullate corticate plates inside, but corticate areolate outside, and often usually with bullate plates. Apothecia, if present, are simple or occur in glomerulose accumulations, formed on branched proliferations. For detailed descriptions see Aptroot et al. (2001) and Kowalewska & Kukwa (2004).

Chemistry: Fumarprotocetraric acid was found as the major secondary metabolite in agreement with Aptroot et al. (2001).

Notes: *Cladonia monomorpha* was recently described from several parts of Europe (APTROOT et al. 2001). It is similar to *C. pyxidata* and *C. pocillum*. All those taxa are esorediate and contain fumarprotocetraric acid as the major secondary metabolite, while they differ morphologically. Both *C. pyxidata* and *C. pocillum* have irregularly areolated inner and outer parts of the scyphi, simple, globose or ring-like apothecia, and the latter also larger and mostly coalescent squamules, commonly forming rosettes. The inner and, at least partly, outer part of the scyphi of *C. monomorpha* are covered with bullate plates (plates commonly with whitish margins) and glomerulose apothecia (APTROOT et al. 2001).

C. monomorpha is sometimes regarded as a synonym of *C. pyxidata* (e.g. NIMIS 2003) or as a taxon with uncertain status (SANTESSON et al. 2004). In our opinion, it is very distinct from all other species, and deserves to be recognized. However, molecular data supporting this assumption are not yet available. *Cladonia monomorpha* is also similar to *C. magyarica* Vain. (some specimens in H studied, including an isolectotype), but the latter differs by the production of atranorin (AHTI 1966), the more greyish colour and the more elongated primary squamules.

During the herbarium studies in H we came across a specimen of *C. pyxidata* var. *baccifera* annotated as type collection. The examination of relevant literature proved the specimen to be the holotype (see RÄSÄNEN 1944). Since its morphology matches that of *C. monomorpha* very well, *C. pyxidata* var. *baccifera* is synonymised with *C. monomorpha*.

Ecology: The species was primarily found on soil in open habitats (e.g. pine forests) or rocks, rarely on tree bark. This agrees with the habitat spectrum published by APTROOT et al. (2001). The frequency distribution of the different substrata is as follows: soil (63), rocks (10), gypsum (2), stump (1), *Fagus sylvatica* (1), mosses (1), humus (1).

Distribution: *Cladonia monomorpha* is widely distributed (Fig. 2C), but occurs in small populations in Poland. We assume a decline of the species due to the loss of suitable habitats. The species has been previously reported in Europe from Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Iceland, Luxembourg, the Netherlands, Poland, Rumania, Spain, Sweden, Switzerland, and Ukraine (APTROOT et al. 2001, KOWALEWSKA & KUKWA 2004). Extra-European specimens of *C. monomorpha* studied by us include collections from Greenland, the U.S.A., and Mongolia, representing the first records from North America and Asia.

Number of specimens examined: 79

Additional specimens examined (selected)**: Greenland**. Vicinity of Narsarsuaq, 61°09'53"N/45°24'01"W, on soil, 22.07.2005, M. Kukwa 4330 (UGDA); Narsarsuaq, Blomsterdalen to glacier Kuussuup Sermia, 0–350 m, 61°10–11'N/45°21–24'W, on soil, 24.07.2005, M. Kukwa 4396 (UGDA). **Mongolia**. Bulgan Aimak, Gurvanbulag Somon, Chögnö-Tarna Uul, Dund Bulag, 1750 m, on ground, 18.06.1988, S. Huneck MVR88-66 (H). **U.S.A.** Vermont, Bennington County, Winhall Township, Green Mountain National Forest near Bondville, elev. c. 500 m, c. 43°N/73°W, 31.05.1995, S. Hammer 6025, Hammer, Clad. Amer. Exs. 212 (GZU).

Cladonia novochlorophaea (Sipman) Brodo & Ahti

Canad. J. Bot. **74**: 1167 (1996). – *Cladonia merochlorophaea* Asahina var. *novochlorophaea* Sipman, Acta Bot. Neerl. **22**: 496 (1973).

Type: The Netherlands, Terschelling Island, Boschplaat, 1971, H. J. M. Sipman 4895 (U – holotype, not seen; see AHTI 2000).

Exsiccates examined: Sandstede, Clad. Exs. 389 (B, as mixture in isolectotype of *C. merochlorophaea*). Sandstede, Clad. Exs. 1747 (H, isosyntypus of *C. merochlorophaea* f. *inactiva*).

Morphology: *Cladonia novochlorophaea* is morphological is almost indistinguishable from *C. merochlorophaea*. For a detailed description confer BRODO & AHTI (1996) and AHTI (2000).

Chemistry: *Cladonia novochlorophaea* produces homosekikaic and sekikaic acids with traces of additional related substances and often also substances of the fumarprotocetraric acid complex (BRODO & AHTI 1996, AHTI 2000). In Polish specimens, usually both homosekikaic and sekikaic acids were detected, though sekikaic acid was absent from a few samples. Fumarprotocetraric acid was found in 65 % of Polish samples.

Notes: Though morphologically difficult to separate from *C. merochlorophaea*, *C. novochlorophaea* has often a more brownish tinge than *C. merochlorophaea*. Furthermore, *C. novochlorophaea* is cha-

racterised by its distinct verruculose cortex and the usually complete absence of soredioid granules (Ahti 2000). These tendencies were also observed in Poland, though these morphological characters were not correlated with the content of lichen substances in several cases. Another morphologically similar species is *C. cryptochlorophaea*. In the Polish material, *C. cryptochlorophaea* has usually more distinctly goblet-shaped cups than *C. novochlorophaea*, but observing these difference in the shape of the podetia needs a lot of experience. Thus, the content of lichen substances is the only reliable character in identifying these taxa.

Cladonia homosekikaica has with *C. novochlorophaea* the production of homosekikaic acid in common, but differs from the later by the lack of sekikaic acid and the formation of distinct farinose or granular soredia. Thereby, it resembles more *C. fimbriata* than *C. novochlorophaea* (Brodo & Ahti 1996). *Cladonia homosekikaica* has not yet been found in Poland, but its occurrence is likely, as it is known from Lithuania (Motiejūnaitė 2002).

Ecology: The species prefers open habitats in Poland, e.g., peat bogs or dune vegetation. It is almost equally frequent on soil and tree bark. Substrata of the studied specimens included soil (37), *Betula* spp. (20), *Pinus sylvestris* (4), *Alnus glutinosa* (1), *Juniperus communis* (1), bark of stump (1), pine cone (1), humus (4), peat (2), wood (2), and thatched roof (1). Holien & Tønsberg (1985) treating the species as a chemotype of *C. merochlorophaea*, found *C. novochlorophaea* on soil rich in humus at sun-exposed sites. Brodo & Ahti (1996) reported *C. novochlorophaea* from rock.

Distribution: *Cladonia novochlorophaea* is rare in Poland. Most of the records come from northern part of the country. It seems to be particularly abundant near the coast (Fig. 2D). Outside Poland, the species has been recorded from many regions. It is especially common in Europe (Leuckert et al. 1971, Ahti 2000), but is known also from South America (Argentina, Brazil, Chile, Columbia, Uruguay) and North America, where it is rare, and New Zealand (Ahti 2000). Circumscribing the exact distribution is exacerbated, as *C. novochlorophaea* was often not separated from *C. merochlorophaea*.

Number of specimens examined: 75

Cladonia pocillum (Ach.) Grognot

Pl. Crypt. Sâone-et-Loire: 82 (1863). – *Baeomyces pocillum* Ach., Method. Lich.: 336 (1803).

Type: Sweden (H-ACH 1656A – lectotype; BM – isolectotype; see Ahti 2000; not seen).

= *Cladonia gonggaensis* S.Y.Guo & J.C.Wei, Mycosystema **7**: 31 (1995 [‘1994’]).

Type: China, Sichuan, Mt. Gongga, 30.07.1982, X. Y. Wang et. al. 9189 (HMAS-L – holotype, not seen; H – isotype; see Ahti 2000).

Exsiccates examined: Flagey, Lich. Alger. 6 (sub *C. pyxidata* f. *pocillum*, H). Nowak, Lich. Polon. Merid. Exs. 170 (B–94311, H). Nylander, Herb. Lich. Paris. 19 (B).

Morphology: The species produces a conspicuous primary thallus of large, thick, mostly coalescent squamules forming rosettes. Podetia are covered with an irregularly areolated cortex. Apothecia, if present, are simple and often ring-like. For a description see Ahti (2000) and Ahti & Hammer (2002).

Chemistry: *Cladonia pocillum* contains substances of the fumarprotocetraric acid complex and rarely atranorin (Ahti 2000, Aptroot et al. 2001). A psoromic acid chemotype of *C. pocillum* is known from Europe and Asia (Ahti 2000). In Europe, also specimens containing both psoromic and fumarprotocetraric acids are known (specimens in B and H). Polish specimens always contain only substances of the fumarprotocetraric acid complex.

Notes: *Cladonia pocillum* is characterised by the conspicuous primary thallus, the presence of fumarprotocetraric acid and the preference for calcareous substrata. Ahti & Hammer (2002) doubt its taxonomic status on the species level, and suspect *C. pocillum* to be an ecomorph of *C. pyxidata* growing on basic substrata and accumulating calcium oxalate (see also Gilbert 1977, Wirth 1995). Our observations support the idea that *C pocillum* could be an ecotype of *C. pyxidata*. This is because, we found several morphological intermediate specimens between *C. pyxidata* and *C. pocillum*. However, as the taxonomy of the entire *C. pyxidata-chlorophaea* group is controversially discussed, we prefer to await molecular data before uniting the *C. pyxidata* and *C. pocillum*. For the differences to *C. monomorpha* confer the remarks to this species.

Habitat requirements: In Poland, *C. pocillum* is a calciphilous lichen growing on calcareous soil and rock or on moss cushion covering these substrata. It prefers open and sun-exposed sites, even though some specimens were found in more or less shaded habitats.The frequency distribution of *C. pocillum* on the different substrata in Poland is as follows: soil (25), calcareous rocks (9), mosses over calcareous rock (6), wood (1), gypsum (1), humus (1).

The preferences observed in Poland match with reports of AHTI (2000), AHTI & HAMMER (2002), and SANTESSON et al. (2004).

Distribution: *Cladonia pocillum* is only known from southern Poland from areas with outcrops of calcareous rocks (Fig. 2E). The species has also been reported from northern Poland (FAŁTYNOWICZ 1992, CIEŚLIŃSKI 2003), however no record has been confirmed so far. The species is widespread on all continents, but is primarily found in temperate to arctic and antarctic regions (AHTI 2000, AHTI & HAMMER 2002). However, some records may belong to the recently described *C. monomorpha*.

Number of specimens examined: 47

Cladonia pyxidata (L.) Hoffm.

Deutschl. Fl. 2: 121 (1796). – *Lichen pyxidatus* L., Spec. Pl. **2**: 1151 (1753).

Type: Italy?, Micheli, Nova Pl. Gen., tab. 41, Fig. 1L (1729) (lectotype; not seen; FI – epitype, not seen; see AHTI 2000 and APTROOT et al. 2001).

Exsiccates examined: Nowak, Lich. Polon. Merid. Exs. 169 (B–94312, H).

Morphology: The podetia are gradually flaring from the base to the top and greenish grey to brownish. The surface of the podetial stalk, the outer and inner parts of the scyphi are covered with an irregular areolate cortex. Apothecia are simple, globose or ring-like. A recent description of the *C. pyxidata*, separating it also from the lately described *C. monomorpha*, is published in APTROOT et al. (2001).

Chemistry: *Cladonia pyxidata* always produces fumarprotocetraric acid with related substances. Sometimes fatty acids were also reported. A second chemotype with the additional occurrence of homosekikaic acid and traces of sekikaic acid known from the Neotropics (AHTI 2000) is absent from Poland.

Notes: The species is morphologically similar to *C. monomorpha* and *C. pocillum*. It differs from the former by the podetial surface and the shape of apothecia and from the latter by the lack of rosette-like basal squamules. *Cladonia chlorophaea* is also likely to be confused with *C. pyxidata*. It is sorediate, but some forms of *C. pyxidata* may produce small soredia-like granules and areoles, which are difficult to distinguish from soredia (AHTI 2002). For a more detailed discussion confer comments under *C. chlorophaea*.

Forms presently subsumed under *C. pyxidata* probably belong to different taxa (AHTI 2000). This is suggested by phylogenetic analyses of STENROOS et al. (2002) including each one sample with fumarprotocetraric acid alone and fumarprotocetraric and homosekikaic acids, which did not group together. Even the distinction of *C. pyxidata* from *C. chlorophaea* is not fully understood (AHTI 2000).

Ecology: Consistent with results summarized in AHTI (1966) and SANTESSON et al. (2004), more than 55 % of the specimens was found on soil, whereas only 10 % was collected from tree bark. The frequency on different substrata in Poland is as follows: soil (112), rocks (40), humus (8), mosses (8), *Fagus sylvatica* (7), wood (6), stumps (3), *Abies alba* (1), *Betula pendula* (1), *Fraxinus excelsior* (1), *Juniperus communis* (1), *Quercus* sp. (1), *Picea abies* (1), *Salix* sp. (1), gypsum (1), peat (1), thatched roof (1).

Distribution: *Cladonia pyxidata* is common in southern Poland, but relatively rare in the north of the country (Fig. 2F). In the past, *C. pyxidata* was frequently reported from all parts of Poland, but many records were misidentified specimens of other similar species, including *C. merochlorophaea*, *C. chlorophaea*, *C. grayi*, and *C. monomorpha*. *C. pyxidata* is widespread and common in the arctic and temperate zones (AHTI 2000). However, AHTI (2000) treated the species in a wider sense, and after revision many specimens may prove to belong to other species.

Number of specimens examined: 198

Key to the species of *Cladonia chlorophaea* group occurring in Poland

1 Thallus contains only fumarprotocetraric acid as major secondary compound; thallus P+ red, K–, C– & KC– **2**
1* Thallus contains other substances as well; fumarprotocetraric acid present or absent; thallus P– or + red, K– or + yellow, C– or + red & KC– or + red **6**

2 Podetia with soredia; soredia farinose or granular **3**
2* Podetia without soredia, surface corticate, covered with corticate granular structures or/and bullate plates **4**

3 Soredia farinose, present at least on some parts of podetia, soredia sometimes in consoredia ..... ***C. fimbriata***
3* Soredia bigger, granular, sometimes recalling corticate granules, but always loosely attached ..... ***C. chlorophaea***

4 Podetia corticate up to the margin of the scyphi, cortex more or less areolate, very well developed at the base of the podetia; bullate plates, commonly with whitish margin, present outside (usually only very few) and/or inside (numerous) of the scyphi; apothecia (if present) glomerulose ..... ***C. monomorpha***
4* Podetia different, apothecia, when present, simple globose and/or ring-like **5**

5 Primary thallus rosette-like, of thick, adnate and shiny primary squamules; on calcareous substrata ... ***C. pocillum***
5* Primary thallus thin, not forming rosettes; habitat different ..... ***C. pyxidata***

6 Podetia KC+ ruby colored, thallus contains cryptochlorophaeic acid or merochlorophaeic and 4-O-methylcryptochlorophaeic acids **7**
6* Podetia KC–, substances different **8**

7 Thallus always contains cryptochlorophaeic acid, fumarprotocetraric acid present in all Polish specimens ..... ***C. cryptochlorophaea***
7* Thallus always with merochlorophaeic and 4-O-methylcryptochlorophaeic acids, fumarprotocetraric acid present or absent ..... ***C. merochlorophaea***

8 Grayanic acid present, P– or + red; podetia often very granular sorediate ..... ***C. grayi***
8* Grayanic acid absent **9**

9 Homosekikaic and sekikaic (rarely absent) acids present, thallus P– or P+ red ..... ***C. novochlorophaea***
9* Atranorin or fatty acids present **10**

10 Fatty acids present **11**
10* Atranorin present **12**

11 Bourgeanic acid present ..... ***C. conista***
11* Rangiformic and norrangiformic (minor or absent) acids present ..... ***C. asahinae***

12 Podetia small, with relatively short and corticate stalk, scyphi covered with farinose to granular soredia ..... ***C. humilis***
12* Podetia covered with distinctly granular soredia (*C. chlorophaea*) or the primary squamules thick, coalescent and forming rosettes (*C. pocillum*) ..... rare chemotypes of ***C. chlorophaea*** and ***C. pocillum***

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