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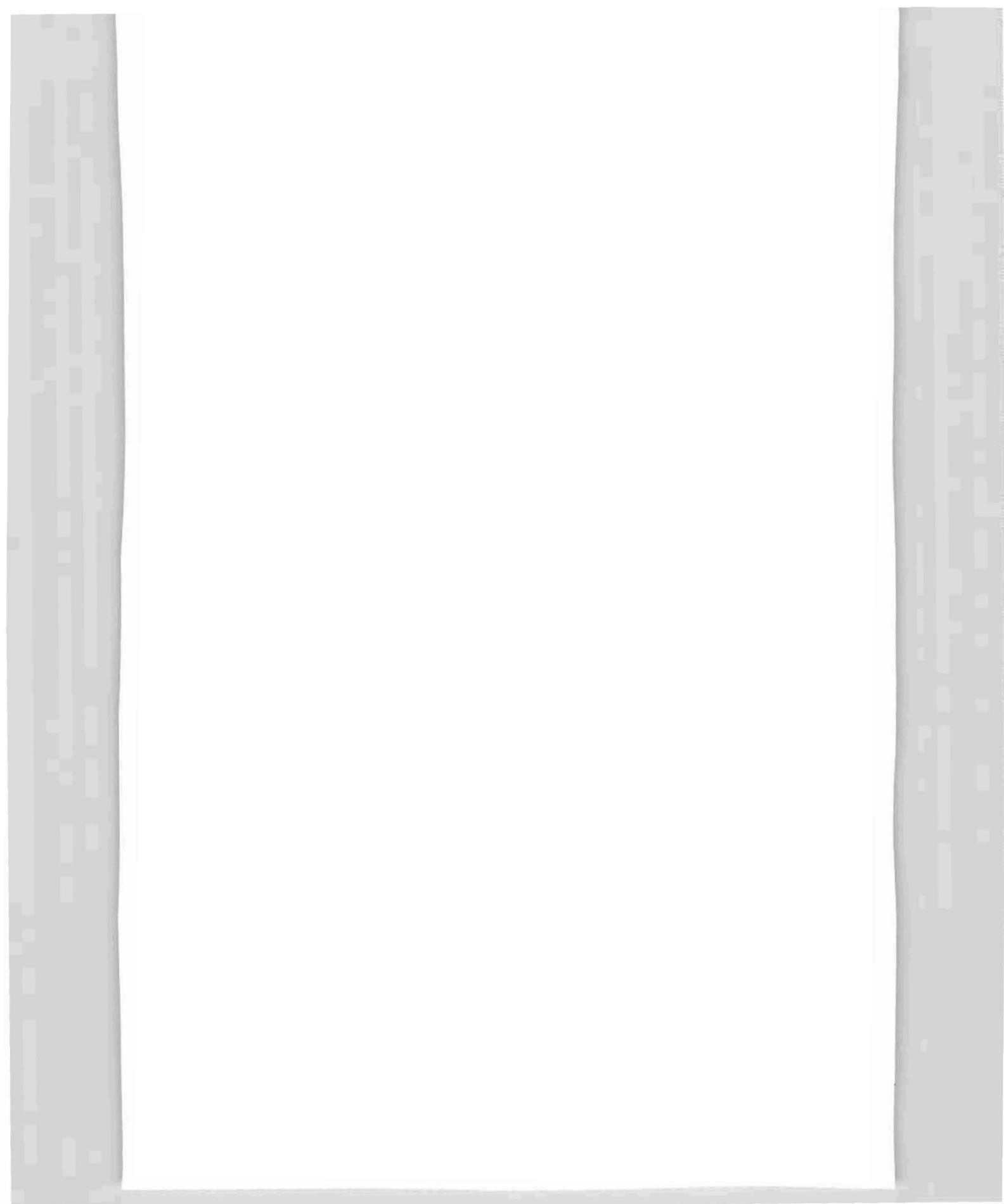
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H. HOLIEN AND T. TØNSBERG

Notes on *Cladonia asahinae*, *C. conista*
and the *C. grayi*-group in Norway

TRONDHEIM 1985



NOTES ON *CLADONIA ASAHINAE*, *C. CONISTA* AND
THE *C. GRAYI*-GROUP IN NORWAY

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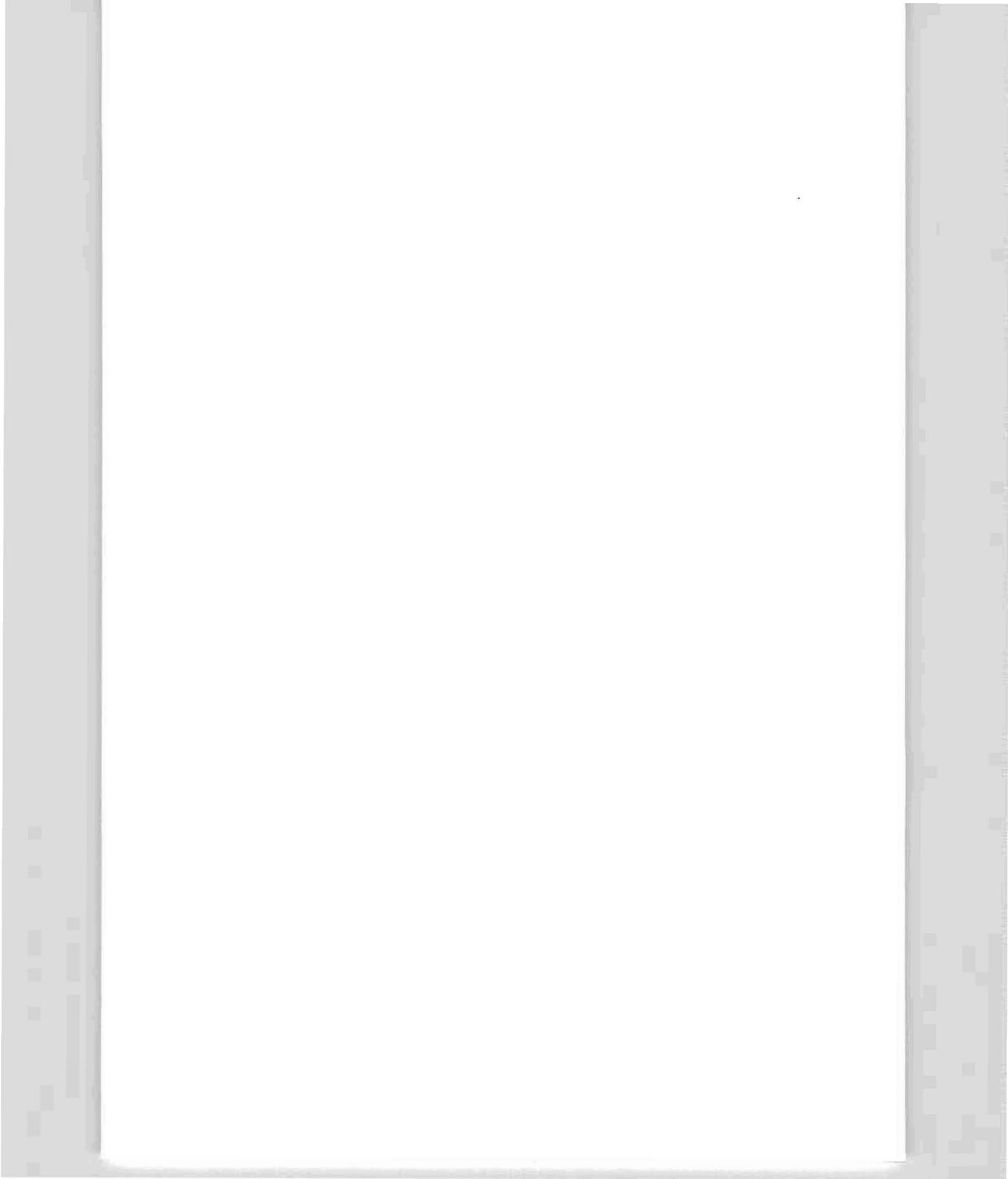
ABSTRACT

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The distribution in Norway of the *Cladonia grayi*-group and the related taxa *C. asahinae* and *C. conista* is mapped. Notes on their chemistry and morphology are given. *C. asahinae* is new to Europe.

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INTRODUCTION

Taxa in the *Cladonia chlorophaea-pyxidata* complex producing fatty acids have not previously been recognized in Norway. Two taxa, *C. asahinae* and *C. conista*, are presented here.

The *Cladonia grayi*-group (see Ahti 1977) comprises *C. cryptochlorophaea*, *C. grayi* and *C. merochlorophaea* in Norway. In Europe it has been discussed by Ahti (1966), Leuckert et al. (1971), Nourish & Oliver (1976) and Sipman (1973), mainly based on collections from Finland, Central Europe, Great Britain and the Netherlands respectively. No account of the group in Norway has been published, but regional studies have been carried out by Holien (1982), Jølle (1978), Nordnes (1983), Schei (1984) and Tønsberg (1975). Information on the related species *C. cyathomorpha* W. Watson and *C. conoidea* Ahti (syn. *C. conistea* ("Delise") Asah.) is given by Jølle (1977) and Tønsberg (1978, 1980) respectively.

The main purpose of the present paper is to present distribution data on *Cladonia asahinae*, *C. conista* and the *C. grayi*-group. Notes on the chemistry and morphology are also given.

MATERIAL AND METHODS

The material comprises all Norwegian specimens deposited in Bergen (BG), Oslo (O), Tromsø (TROM), and Trondheim (TRH). All collections filed under the names *C. chlorophaea*, *C. fimbriata* and *C. pyxidata* were also examined in order to discover misidentifications. Of *C. pocillum* only parts of the numerous collections were examined. The type specimen of *C. asahinae* (WIS) was studied. The authors' own collections (O, TRH) are mainly from Central Norway, HH and TT, and the SE parts of Nordland county, TT. In addition TT has collected specimens in various localities throughout most of the country. Also examined was material recently collected by H. Chr. Gjerlaug (material from Hedmark county), O. Jølle (SW-Norway, O), G. Nilsen (Trollheimen), J. Nordnes (Setesdalen, O), T. Reve (Jæren, SW-Norway, TRH), and A.J. Schei (Dovrefjell National Park, O). In total about 1700 Norwegian collections were examined: *C. asahinae* (62), *C. conista* (8), *C. cryptochlorophaea* (80), *C. grayi* (140), *C. merochlorophaea* (360), and 1050 specimens containing

fumarprotocetraric acid as the only diagnostic substance (*C. chlorophaea* s. str., *C. fimbriata*, *C. pocillum*, and *C. pyxidata*). The specimens were identified by their chemical constituents.

The material was subjected to thin-layer chromatography (TLC) according to the standard methods described by Culberson (1972), Culberson & Kristinsson (1970) and modified by Menlove (1974). For the identification of fatty acids specimens of *Ramalina duriaei* (De Not.) Bagl. (bourgeanic acid, see e.g. Krog & Østhaugen 1980), and *Cladonia rangiformis* (rangiformic acid, norrangiformic acid, see e.g. Huneck & Steglich 1983) were used. UV-light and the standard colour-reagents PD, K, C and KC were also used.

The nomenclature agrees with Santesson (1984).

CHEMISTRY

The main chemical substances in *C. asahinae*, *C. conista* and the *C. grayi*-group are set out in Table I.

The *Cladonia grayi*-group is thoroughly investigated chemically (Asahina 1940, 1943; Culberson & Kristinsson 1969; Leuckert et al. 1971, Nourish & Oliver 1976). The group is easily distinguished from related taxa containing fumarprotocetraric acid only or fumarprotocetraric acid with fatty acids as diagnostic substances, by the strong fluorescens under UV-light. Fumarprotocetraric acid is accessory in *C. grayi* and *C. merochlorophaea*. Specimens without this substance react negatively with PD. In specimens with fumarprotocetraric acid the satellite compounds protocetraric acid, Cph-1 and Cph-2 (Culberson et al. 1981) were often present. As these satellite compounds were found to be of no diagnostic value, they are not considered below. Unidentified substances in minor concentrations may also occur with cryptochlorophaeic acid in *C. cryptochlorophaea*, with merochlorophaeic acid and 4-O-methylcryptochlorophaeic acid in *C. merochlorophaea*, and with grayanic acid in *C. grayi*. In addition to the substances found in *C. merochlorophaea* by the present authors, Hennings (1983) reports cryptochlorophaeic acid and paludosic acid as accessory substances in trace amounts in material from Western Washington, N-America.

Table I. The major chemical substances in *Cladonia asahinae*, *C. conista* and the *C. grayi*-group in Norway.

	grayanic acid	cryptochlorophaeic acid	merochlorophaeic acid	4-O-methylcryptochlorophaeic acid	sekikaic acid	homosekikaic acid	bourgeanic acid	rangiformic acid	nor-rangiformic acid	fumarprotocetraric acid
<i>C. asahinae</i>	-	-	-	-	-	-	-	+	+	+
<i>C. conista</i>	-	-	+	-	-	+	+	-	-	+
<i>C. cryptochlorophaea</i>	-	+	-	-	-	-	-	-	-	+
<i>C. grayi</i>	+	-	-	-	-	-	-	-	-	+
<i>C. merochlorophaea</i> I	-	-	+	+	-	-	+	-	-	+
<i>C. merochlorophaea</i> II	-	-	-	-	+	+	-	-	-	+

Fig. 1 shows the chromatograms of *C. cryptochlorophaea*, *C. grayi* and *C. merochlorophaea*. According to Culberson (1972) and Culberson & Kristinsson (1970) cryptochlorophaeic acid should have the R_F -classes 5, 5-6, 5 and 5, 5, 5, respectively. On our chromatograms the R_F -classes are 4, 5, 5.

Cladonia asahinae and *C. conista* produce higher aliphatic acids (Table I, Fig.2). Although both contain fatty acids they are not closely related chemically. Bourgeanic acid and rangiformic acid have very different structures. Specimens with lichesterinic and protolichesterinic acids are unknown in Norwegian material of *Cladonia*.

Colour-reactions and fluorescens-abilities of the various aromatic compounds are given by e.g. Krog et al. (1980). However, our results deviate from this study. Podetia with merochlorophaeic acid react K^+ winered (the reaction occurs slowly) as recorded by Asahina (1943), Dey (1978) and Santesson (1973), and not K^- as given by Krog et al. (1980). The positive reaction with C on

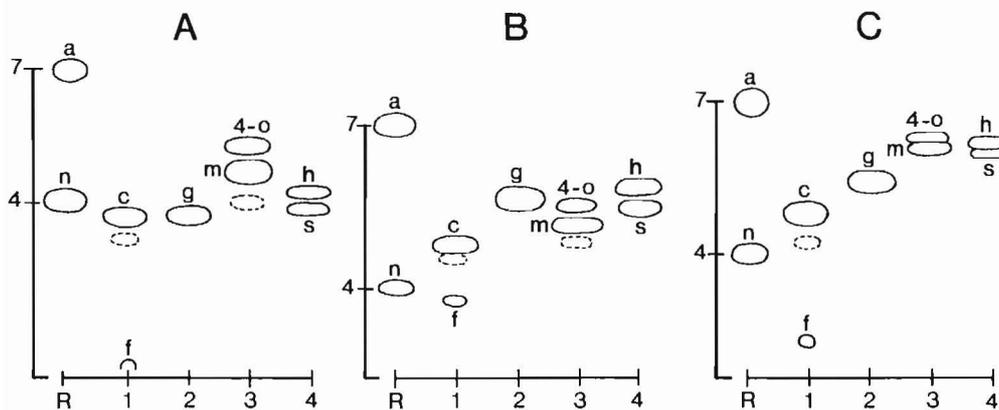


Fig. 1. Chromatograms of the major compounds in the *Cladonia grayi*-group in solvent systems A, B and C. R: References (*Parmelia acetabulum* (Neck.) Duby and *Platismatia glauca* (L.) W. Culb. & C. Culb.). 1: *C. cryptochlorophaea*; 2: *C. grayi*, 3: *C. merochlorophaea*, chemotype I, 4: *C. merochlorophaea*, chemotype II. a: atranorin, c: cryptochlorophaeic acid, f: fumarprotocetraric acid, g: grayanic acid, h: homosekikaic acid, m: merochlorophaeic acid, n: norstictic acid, s: sekikaic acid, 4-0: 4-0-methylcryptochlorophaeic acid.

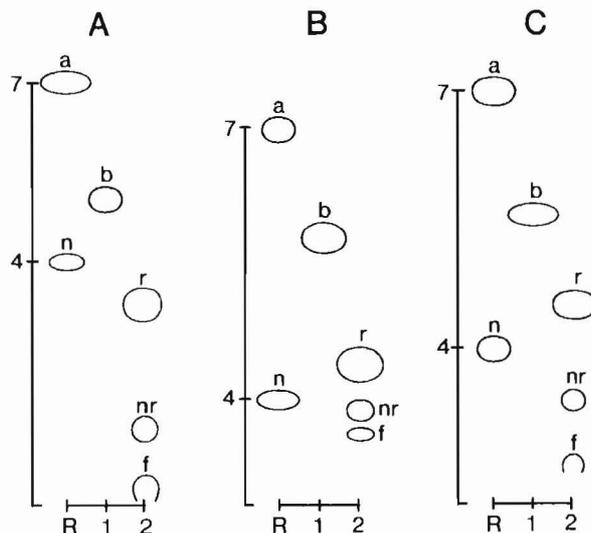


Fig. 2. Chromatograms of the chemical constituents of *Cladonia asahinae* and *C. conista* in solvent systems A, B and C. R: References (as in Fig. 1). 1: *C. conista*, 2: *C. asahinae*. a: atranorin, b: bourgeanic acid, f: fumarprotocetraric acid, n: norstictic acid, nr: nor-rangiformic acid, r: rangiformic acid.

podetia with cryptochlorophaeic acid reported by Krog et al. (1980) (C+ yellow), and Dey (1978), Santesson (1973) (C+ red), proved difficult to see unless the "filter paper method" described by e.g. Brodo & Hawksworth (1977) is applied, when a weak C+ yellow-orange reaction was observed. Further information about chemical properties are given under the various taxa.

THE TAXA

Cladonia asahinae Thomson

Podetia greyish green, usually 1-1,5 (-2,5) cm tall. The lower part of the stalk corticated with squamules or corticated granules. The scyphi and the upper part of the stalk with small corticated granules or coarse soredia. Scyphi 3-5 (-8) mm broad, occasionally with marginal proliferations with simple or compound brown apothecia. The granules and/or the soredia were frequently shed revealing the white medulla. Basal squamules rounded and deeply divided, up to about 5 mm broad, greenish above, whitish below.

TLC: Rangiformic acid, norrangiformic acid, fumarprotocetraric acid.

Cladonia asahinae was described from western North America by Thomson (1976). The taxon is not easily distinguished on morphology alone. The most conspicuous feature may be the frequent occurrence of squamules on the lower part of the podetial stalk, see Fig. 3, - a character it shares with forms of *C. grayi* and *C. pyxidata*. According to the protologue *C. asahinae* should contain protolichesterinic acid. However, Hennings (1983) reports rangiformic and norrangiformic acid as the diagnostic substances in the type specimen. This agrees with our results. The Norwegian specimens were in full accordance with the type specimen.

In Norway *C. asahinae* occurs in a broad belt along the coast from the Oslo region in the SE to Troms county in the north, Fig. 4. It seems to prefer humid localities. It does not occur in the continental mountains of Dovre (cfr. Schei 1984), but it is frequent in the coastal mountains of Trollheimen (G. Nilsen, personal communication). Usually it grows on soil rich in humus, but it

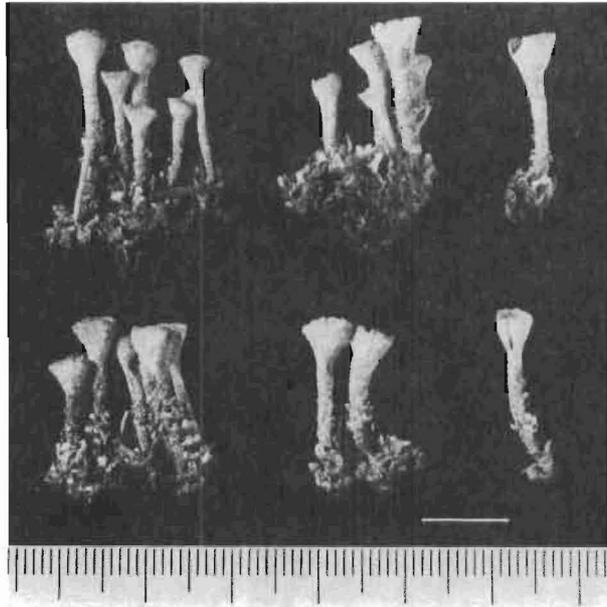


Fig. 3. *Cladonia asahinae* Thomson. Norway, Hedmark, Kongsvinger W of Hagasetra W of Brandval. H. Chr. Gjerlaug, no 1652, herb. Gjerlaug. Rule 1 cm.



Fig. 4. Known distribution of *Cladonia asahinae* Thomson in Norway.

is also found on sand dunes and on lignum. It has been collected from sea level to 1150 m altitude in Trollheimen and Børggefjell, respectively. To date we have established that it is present in Sweden (Väster-götland) and Czechoslovakia (Haida, Böhmen), (Sandstede, *Cladonia exsiccatae*, nos 1008 and 1153 (both TRH), respectively). It has not been mentioned in investigations from Finland, Central Europe, Great Britain and the Netherlands, see Ahti (1966), Leuckert et al. (1971), Nourish & Oliver (1976) and Sipman (1973), respectively, but it may be found in Great Britain, as it appears to have oceanic trends in its Scandinavian distribution. *Cladonia asahinae* is here reported as new to Europe.

Cladonia conista (Nyl.) Robbins

Podetia 1-2 (-3,5) cm tall, regular and greyish green to brownish green. The upper part of the stalk and the scyphi with farinose to coarse soredia. The lower part of the stalk corticated. Podetial squamules not seen. Scyphi 4-6 (-10) mm broad, occasionally with simple, brown apothecia on marginal proliferations. Basal squamules more or less isodiametric, deeply divided, thin, to about 5 mm broad.

TLC: Bourgeanic acid, fumarprotocetraric acid.

Ahti (1977) suggests that *C. conista* might be looked upon as a chemical variant of *C. conoidea* (syn *C. conistea* ("Delise") Asah.). However, *C. conista* is distinguished from *C. conoidea* by the taller podetia and by the production of the higher aliphatic substance bourgeanic acid rather than the para-depside atranorin. There are also distributional differences. In Europe *C. conoidea* seems to be a coastal species with abundant occurrences in the British Isles and in the Netherlands (Nourish & Oliver 1976, Sipman 1973). In Norway it is found in Vest-Agder and Hordaland (Tønsberg 1979). *C. conista*, however, has a continental distribution. In Fennoscandia it has previously been reported from Finland (Ahti 1966) and from Norway (Schei 1984). It is absent in the British Isles (Hawksworth et al. 1980) and is sparse in the Netherlands (Sipman 1973).

From Norway we have seen 8 specimens of *C. conista*, mainly from the inner part of the Oslofjord region, Fig. 5. It appears to grow on soil rich in humus in open habitats. In Dovrefjell National Park it has been collected at 1280 m altitude.



Fig. 5. Known distribution of *Cladonia conista* (Nyl.) Robbins in Norway.

Cladonia cryptochlorophaea Asah.

Podetia 1-2 (-3) cm tall, brownish or greyish green to pale green, occasionally with a pink tinge. Soredia usually present, but the podetia vary from being totally corticated to being covered by farinose soredia almost to the base. Squamules usually absent. Scyphi relatively broad, 4-6 (-10) mm even on extremely short podetia. Occasionally the scyphi bears marginal proliferations with compound, brown apothecia. Basal squamules more or less rounded and deeply divided, up to about 5 mm broad, greenish or brownish above, whitish below.

TLC: Cryptochlorophaeic acid, fumarprotocetraric acid.

There is great disagreement concerning the taxonomic treatment of *C. cryptochlorophaea*. In North Europe it is given specific rank by Hawksworth et al. (1980). It is treated as a mere chemical strain of *C. grayi* by Krog et al. (1980) and of *C. merochlorophaea* by Carlin (1981). Chemically there is a great difference between *C. cryptochlorophaea* and *C. grayi*. Cryptochlorophaeic acid

is a metadepsid while grayanic acid is a depsidone (Culberson et al. 1977). Moreover Eurasiatic specimens of *C. cryptochlorophaea* always contain fumarprotocetraric acid. In *C. grayi* this substance is accessory. There seems also to be small morphological differences. In a collection from Orkdal, S-Trøndelag county, Central Norway (TT no 4606) (TRH), Fig. 6) *C. cryptochlorophaea* and *C. grayi* grew side by side on the same small bit of soil. There is a distinct morphological difference between podetia with cryptochlorophaeic acid and podetia with grayanic acid. The former are thicker, have broader scyphi, more farinose soredia and are paler than the podetia with grayanic acid. Generally *C. cryptochlorophaea* differs from *C. grayi* morphologically in having usually esquamulose podetia (podetia often distinctly squamulose in *C. grayi*) with broader scyphi (usually 4-6 mm in *C. cryptochlorophaea*, 2-5 mm in *C. grayi*). It is therefore convenient to treat them as two distinct entities. Based on Norwegian material there is no morphological evidence in support of Carlin (1981) in regarding *C. cryptochlorophaea* as conspecific with *C. merochlorophaea*.

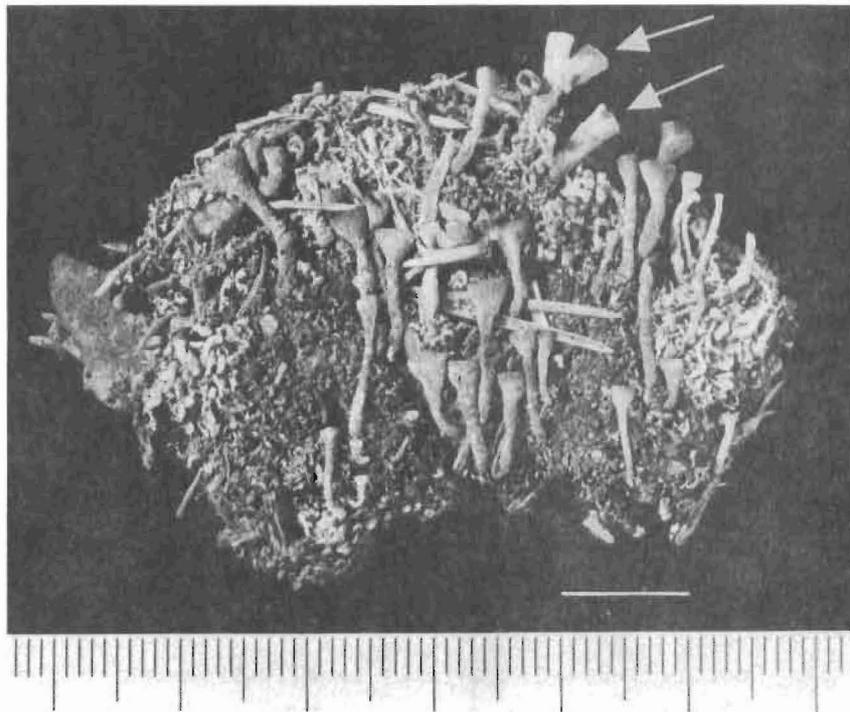


Fig. 6 *Cladonia cryptochlorophaea* (arrows) and *C. grayi*. Norway, S-Trøndelag, Orkdal, Tønsberg no 4606 (TRH). Rule 1 cm.

The distribution in Norway is shown in Fig. 7. The taxon seems to have a tendency towards an eastern distribution in Norway. In western Norway it is rare and it is more frequent in Dovrefjell National Park than in the mountains of Trollheimen. It is collected from about sea level to 1750 m altitude (Dovrefjell National Park). *C. cryptochlorophaea* is a taxon of soil rich in humus in open habitats.

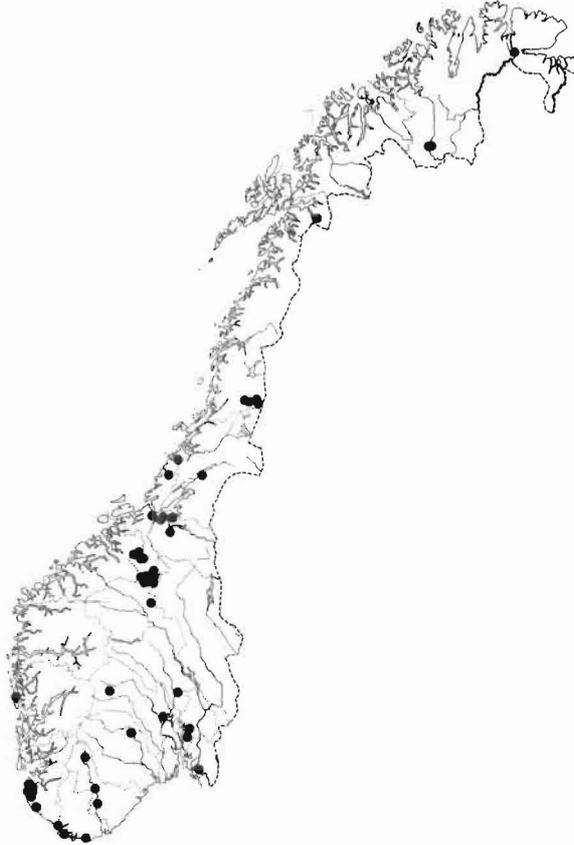


Fig. 7. Known distribution of *Cladonia cryptochlorophaea* Asah. in Norway.

Cladonia grayi Merr. ex Sandst.

Podetia 1-2 (-3) cm tall, usually brownish, but occasionally greyish green to pale green. Podetia varying from totally corticated to sorediate almost to the base. Soredia coarse or, more rarely, farinose. Podetial squamules frequently present.

Scyphi 2-5 (-7) mm broad, occasionally with marginal proliferations with compound, brown apothecia. Basal squamules more or less rounded and deeply divided, up to about 5 mm broad, brownish above, whitish below.

TLC: Grayanic acid, +/- fumarprotocetraric acid.

Cladonia grayi is often abundantly squamulose (Fig. 8). This feature led Sandstede (1931) to describe the form *f. squamulosa*. *F. squamulosa* may be confused with *C. asahinae* which also frequently have podetial squamules. However the two taxa are easily separated by their chemical constituents. It is sometimes impossible to separate esquamulate forms of *C. grayi* from *C. merochlorophaea* morphologically. In this case only chemical characters appear to be conclusive.

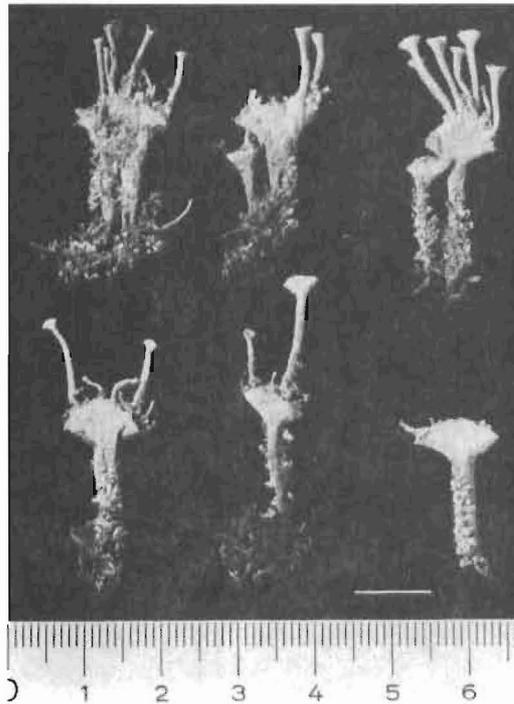


Fig. 8. *Cladonia grayi* Merr. ex Sandst. Squamulose specimen. Norway, Oslo, Østmarka, Skullerud. 7.3.1974. T. Tønsberg s. n. (TRH). Rule 1 cm.

Of 140 collections of *C. grayi* 42 % contained fumarprotocetraric acid. Fig. 9 and 10 show the distribution of specimens with and without this accessory substance. Specimens with fumarprotocetraric acid dominate in the Oslofjord region and in the



Fig. 9. Known distribution of *Cladonia grayi* Merr. ex Sandst. with fumarprotocetraric acid in Norway.



Fig. 10. Known distribution of *Cladonia grayi* Merr. ex Sandst. without fumarprotocetraric acid in Norway.

outer parts of western Norway N of Jæren, SW Norway. In the mountains it is rare. It has been collected up to 750 m altitude (Trollheimen). The type without fumarprotocetraric acid appears, on the other hand, to have a tendency towards an eastern distribution. This type is unknown in western Norway between Jæren and N parts of Møre and Romsdal county and has some inland stations in Oppland and Hedmark counties. It is frequent in the mountains (Trollheimen, Dovrefjell National Park) and has been collected up to 1300 m altitude (Dovrefjell).

C. grayi usually grows on soil rich in humus in open habitats, but it is more frequent in forested areas than *C. cryptochlorophaea*. On the sand dunes in southern Norway *C. grayi* is less frequent than *C. cryptochlorophaea* (Tønsberg & Høiland 1980).

Cladonia merochlorophaea Asah.

Podetia 1-2 (-3) cm tall, usually chocolate-brown, but greenish when growing in shaded habitats, entirely corticate or, more rarely, with soredia. Cortex usually rough. Soredia, when present, usually coarse. Podetia with farinose soredia to the base appear to be very rare. Scyphi 2-6 (-8) mm broad, often with marginal proliferations with compound, brown apothecia. Basal squamules more or less isodiametric and deeply divided, up to 5 mm broad, brownish above, whitish below.

TLC: (I) merochlorophaeic acid, 4-0-methylcryptochlorophaeic acid, unidentified substance (probably the lower homologue of merochlorophaeic acid mentioned by Hennings (1983)), +/- fumarprotocetraric acid (= var. *merochlorophaea*). (II) sekikaic acid, homosekikaic acid, +/- fumarprotocetraric acid (= var. *novochlorophaea* Sipman).

There is no morphological difference between the two chemotypes. For morphological delimitation against *C. cryptochlorophaea* and *C. grayi*, see under these taxa.

Of the 360 collections of *C. merochlorophaea* 75 % belonged to chemotype I and 25 % to chemotype II. Of chemotype I 67 % contained fumarprotocetraric acid. Of chemotype II only 22 % contained this accessory substance.

Fig. 11-14 show the distribution in Norway of *C. merochlorophaea*. *C. merochlorophaea* with fumarprotocetraric acid

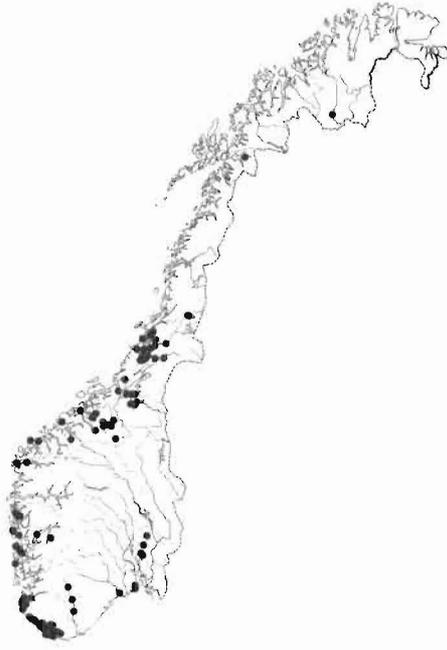


Fig. 11. Known distribution of *Cladonia merochlorophaea* Asah., chemotype I with fumarprotocetraric acid in Norway.



Fig. 12. Known distribution of *Cladonia merochlorophaea* Asah., chemotype I without fumarprotocetraric acid in Norway.



Fig. 13. Known distribution of *Cladonia merochlorophaea* Asah., chemotype II with fumarprotocetraric acid in Norway.



Fig. 14. Known distribution of *Cladonia merochlorophaea* Asah., chemotype II without fumarprotocetraric acid in Norway.

appears to be largely restricted to coastal sites in South Norway, being absent or rare in North Norway. *C. merochlorophaea* without fumarprotocetraric acid has only occasionally been collected in western parts of South Norway S of Trøndelag. It has a slightly eastern distribution pattern. In North Norway N of the Polar Circle only specimens of chemotype I are known, fumarprotocetraric acid deficient specimens being the most frequent.

Chemotype I has been collected up to 1750 m altitude (fumarprotocetraric acid deficient specimen) and 800 m altitude (fumarprotocetraric acid containing specimen) in Dovrefjell National Park and Trollheimen, respectively. The corresponding limits for chemotype II are 1050 m and 1100 m in Trollheimen and Dovrefjell National Park, respectively. Except for chemotype I without fumarprotocetraric acid which has been commonly collected in the mountains of Trollheimen, Dovrefjell and Børgefjell, *C. merochlorophaea* appears to have a preference for lowland sites.

C. merochlorophaea is a taxon of soil rich in humus in open habitats.

DISCUSSION

The delimitation of the taxa included here is mainly based on chemical properties. Certain divergent distributional, ecological and/or morphological trends are present, but are too vague to act as a basis for a reliable identification. Although the occurrence of podetial squamules indicates *Cladonia asahinae* or *C. grayi*, and chocolate-brown podetia with rough cortex indicate *C. merochlorophaea*, these characters are not constant. Chemical tests are necessary for an adequate separation of taxa in all cases.

The taxa treated here may be divided into two geographical defined groups: (1) Taxa with preference for coastal sites: *Cladonia asahinae* and fumarprotocetraric acid containing types of *C. grayi* and *C. merochlorophaea*. (2) Taxa with a more or less distinct eastern distribution in Norway: *C. conista*, *C. cryptochlorophaea*, and fumarprotocetraric acid deficient types of *C. grayi* and *C. merochlorophaea*. The close allies *C. chlorophaea* s. str. and *C. pyxidata* - both with fumarprotocetraric acid as the only chemical constituent - are distributed throughout the whole country and show no preference for coastal or continental sites

(Holien & Tønsberg unpublished). All the taxa treated appear to be southern in distribution except for the fumarprotocetraric acid deficient type of chemotype I of *C. merochlorophaea* which is also common in N-Norway. In this chemotype fumarprotocetraric acid decreases along a gradient from south to north. This is an example which is in accordance with Leuckert & Poelt (1978) who found that chemical diversity of a number of lichen species is decreasing along a gradient from south to north in Europe. They concluded that "this gradient should not be interpreted as a consequence of relatively recent evolution but rather of increasing impoverishment in northern regions due to glaciation periods and the climatic conditions prevailing up to the present time".

Culberson et al. (1977) discuss chemical variation with emphasis on production of fumarprotocetraric acid in the *Cladonia grayi*-group and related taxa in N-Carolina, N-America. The greatest chemical diversity was found in material from the mountains. The percentage of specimens containing fumarprotocetraric acid increased along a gradient from the coastal plain to the mountains. This is quite contrary to the present results. In Norway specimens of the *C. grayi*-group with fumarprotocetraric acid are most frequent in coastal lowland areas of S-Norway. This decreased production of fumarprotocetraric acid along a gradient from coastal lowland to the mountains represents apparently a parallel phenomenon to that discussed by Leuckert & Poelt (1978).

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