

A new taxonomy of the *Caloplaca citrina* group in the Nordic countries, except Iceland

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Abstract: The *Caloplaca citrina* group in the Nordic countries, except Iceland, is analysed with regard to morphology, anatomy, ecology, and chemistry. Their genetic relationship is also analysed using the ITS ribosomal DNA gene. The results show that there are at least five species within what has been called *C. citrina*, of which four are closely related to one another and to several non-soresiate species. Three of these, *C. citrina*, *C. flavocitrina* and *C. arcis* have previously been recognized at specific or varietal level some time during the last two centuries, whereas the fourth species, *C. dichroa*, is described as new. The fifth species, *C. phlogina*, is not related to the other species but shows a close relationship to the *Xanthoria candelaria* group. The species are described and illustrated in colour. Distribution maps are given for the study area and a key to soresiate, yellow to orange species occurring in the Nordic countries, except Iceland, is also provided.

Key words: *Caloplaca citrina*, DNA, key, new species, Nordic countries, taxonomy

Introduction

The *Caloplaca citrina* group includes an unknown number of species producing yellow to orange, or sometimes grey soresia. *Caloplaca citrina* (Hoffm.) Th. Fr. and *C. phlogina* (Ach.) Nyl. were both described in the late 18th century, while *C. flavocitrina* (Nyl.) H. Olivier was described almost a century later. Until Wade (1965) united them into one species, *C. citrina*, with *C. flavocitrina* as a variety, they were widely accepted as separate species. After Wade's publication on British species of *Caloplaca* it has been the prevailing opinion to unite them into one species (e.g. Purvis *et al.* 1992; Nimis 1993; Wirth 1995). Wetmore (2001) also included them all in one species in his treatment of the *Caloplaca citrina* group in North America. The possible occurrence of more than one species in the *C. citrina* complex was, however, pointed out by Arup (1993). Some years later, van den Boom *et al.* (1998) stated that *C. flavocitrina* should be recognized as a separate species

from *C. citrina* and that there were both morphological and spore differences between the species. One year later Sérusiaux *et al.* (1999) again also regarded *C. phlogina* as a good species and presented a table of characters separating the three species. In this paper, further evidence is presented for treating them as three species, but I also present two new species of the group from the Nordic countries. The results are based on both morphological and a molecular studies.

Material and Methods

Material and taxon sampling

This study is based on material from BG, C, H, LD, O, S, UPS, and private collections of G. Thor and myself. Material for DNA-studies was mostly freshly collected specimens that are deposited in LD or in my private herbarium. A total of *c.* 670 specimens are included in the study. Most of the yellow to orange, soresiate species of *Caloplaca* occurring in the study area were included in the genetic analyses. Specimens were chosen to cover different geographical origins, different substrata and morphological variation.

The specimens were examined by interference contrast and light microscopy. Anatomical features were measured on hand-cut sections or squash preparations

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mounted in water. Morphological characters were measured on dry material using a dissecting microscope ($\times 40$). Soredia were measured to the nearest $5\ \mu\text{m}$ in a dissecting microscope on dry material on ten soredia per specimen. Spore dimensions are average values from five to ten measurements per specimen. Data on spore dimensions are presented in the following way: (c. 7.5% of the variation–)85% of the variation(–7.5% of the variation).

The chemistry was examined by high-performance thin-layer chromatography (HPTLC) as described in Arup *et al.* (1993).

DNA-extraction, PCR-amplification and sequencing

Apothecia, soredia or parts of the thallus were used for extracting the DNA using DNeasy Plant Mini Kit (Qiagen). DNA-extracts were used for PCR-amplification of the ITS regions including the 5.8S gene of the nuclear rDNA. Primers for amplification were ITS1F (Gardes and Bruns 1993) and ITS4 (White *et al.* 1990). The PCR settings used followed the manufacturer's recommendations. In a few cases, a procedure called Direct PCR was conducted. This method was originally developed by Wolinski *et al.* (1999), who mounted fungal tissue on microslides, which were then put into the PCR tubes for subsequent amplification. The procedure used here is similar, but has been simplified even further. Fungal tissue, in this case apothecium sections or soredia, were placed directly in water in the PCR tubes and the PCR chemicals were added. The amount of water was calculated to fit to the PCR chemicals to give a normal $50\ \mu\text{l}$ PCR reaction. A subsequent, second PCR was often carried out using $2\text{--}5\ \mu\text{l}$ of the first PCR product as template and the same primer pair as in the first PCR.

Products were cleaned using QIAquick PCR purification Kit (Qiagen). PCR cycling parameters included an initial hold at 94°C for 5 min, then denaturing at 94°C for 1 min, annealing at 56°C for 1 min, decreasing 1°C per cycle for the first 6 of the 39 cycles (touchdown), and extension at 72°C for 3 min. Both complementary strands were sequenced using the BigDye Terminator Cycle Sequencing kit (Applied Biosystem) using the primers mentioned above, and run on a ABI PRISM 3100 Genetic Analyzer.

Sequence alignment and phylogenetic analyses

A total of 40 ingroup taxa and two outgroup taxa were aligned by hand. The alignment included the ITS1, 5.8S, and ITS2 regions for a total of 592 bases. Indels and ambiguously aligned parts were excluded. *Caloplaca chlorina* (Flot.) H. Olivier and *C. cerina* (Ehrh. ex Hedw.) Th. Fr. were used as outgroup because they belong to *Caloplaca* s. str. while the ingroup belongs to the *Xanthoria* clade including *Caloplaca* species, for example *C. marina* (Wedd.) Zahlbr. that is related to *C. citrina* (Arup & Grube 1999).

A phylogenetic analysis was carried out using PAUP*4.0b10 (Swofford 2002) under the maximum

parsimony optimality criterion. The characters were given equal weight and gaps were treated as missing data. A heuristic search was performed with 1000 random addition sequence replicates, using tree bisection-reconnection (TBR) branch-swapping. Bootstrap proportions were estimated using 1000 bootstrap replicates, each with 10 random addition sequence replicates. Because test runs indicated that large numbers of trees were found in some replicates the maximum tree limit was set to 1000 per random addition sequence replicate.

Results

For the analysis 27 new nrDNA ITS sequences were produced, and three were down-loaded from the GenBank (Table 1). A further twelve were already available from earlier analyses (Arup & Grube 1999). A total of 209 parsimony-informative characters were used in the final phylogenetic analysis. The analysis resulted in 20 trees of 705 steps, $\text{CI}=0.549$, $\text{RI}=0.788$, $\text{RC}=0.433$. The strict consensus tree (Fig. 1) shows that *C. citrina* s. str. belongs to a group of mixed sorediate and non-sorediate species of *Caloplaca*, the *C. citrina/marina* group. In addition to *C. citrina*, there are three further sorediate taxa, *C. flavocitrina*, *C. arcis* and *C. dichroa*, previously included in *C. citrina*, which branch as separate, well-supported, monophyletic groups within the *C. citrina/marina* group. However, three samples of a fifth species, *C. phlogina*, form a monophyletic, well-supported clade together with the *Xanthoria candelaria* group. As a sister species to *C. citrina* we find *C. maritima* (de Lesd.) de Lesd., a non-sorediate species on maritime rocks. Two other, non-sorediate species, *C. marina* and *C. microthallina* (Wedd.) Zahlbr., on maritime rocks seem to be close to another sorediate species, *C. flavocitrina*. Another pair of sorediate and non-sorediate species is *C. arcis* and *C. calcitrapa* Nav.-Ros., Gaya & Cl. Roux. The position of the latter is, however, not supported. The fourth sorediate species in the group is *C. dichroa*, a previously unrecognized species. As a basal branch of the *C. citrina/marina* group we find an isidiate species, *C. coronata* (Kremp. ex Korb.) J. Steiner, with a south to central European distribution.

TABLE 1. Sequences used in the analyses, with location, collector, and GenBank accession numbers. Specimens in bold have been down-loaded from the GenBank

Species	Specimen	GenBank accession number
<i>Caloplaca arcis</i>	Austria, <i>Arup</i> L97514	DQ173213
<i>C. arcis</i>	Sweden, <i>Frödén & Ekman</i> 949	DQ173214
<i>C. arcis</i>	England, <i>Arup</i> L92118	DQ173215
<i>C. arnoldii</i>	Austria, <i>Arup</i> L97312	AF353952
<i>C. biatorina</i>	Austria, <i>Arup</i> L97802	AF353953
<i>C. calcitrata</i>	Spain, <i>Navarro-Rosines et al.</i> 13387	DQ173227
<i>C. cerina</i>	Sweden, <i>Foucard s.n.</i>	AF353958
<i>C. chlorina</i>	Austria, <i>Arup</i> L97333	AF353959
<i>C. citrina</i>	Sweden, <i>Arup</i> L03065	DQ173222
<i>C. citrina</i>	Sweden, <i>Arup</i> L03027	DQ173223
<i>C. citrina</i>	Sweden, <i>Arup</i> L03013	DQ173224
<i>C. citrina</i>	Sweden, <i>Arup</i> L02203	DQ173225
<i>C. citrina</i>	Sweden, <i>Arup</i> L02316	DQ173226
<i>C. coronata</i>	Austria, <i>Arup</i> L00038	DQ173239
<i>C. dichroa</i>	Sweden, <i>Arup</i> L04005	DQ173228
<i>C. dichroa</i>	Sweden, <i>Arup</i> L03054	DQ173229
<i>C. dichroa</i>	Sweden, <i>Arup</i> L03108	DQ173230
<i>C. dichroa</i>	Sweden, <i>Arup</i> L03020	DQ173231
<i>C. dichroa</i>	Sweden, <i>Arup</i> L03022	DQ173232
<i>C. flavocitrina</i>	Sweden, <i>Arup</i> L04024	DQ173216
<i>C. flavocitrina</i>	Sweden, <i>Arup</i> L04021	DQ173217
<i>C. flavocitrina</i>	Sweden, <i>Arup</i> L03012	DQ173218
<i>C. flavocitrina</i>	Sweden, <i>Arup</i> L03052	DQ173219
<i>C. flavocitrina</i>	Sweden, <i>Arup</i> L03080	DQ173220
<i>C. flavocitrina</i>	Austria, <i>Arup</i> L99002	DQ173221
<i>C. marina</i>	England, <i>Arup</i> L92106	AF353946
<i>C. maritima</i>	Wales, <i>Arup</i> L92092	AF353948
<i>C. phlogina</i>	Sweden, <i>Arup</i> L03051	DQ173233
<i>C. phlogina</i>	Sweden, <i>Arup</i> L91077	DQ173234
<i>C. phlogina</i>	Sweden, <i>Göransson</i> L02055	DQ173235
<i>C. saxicola</i>	Austria, <i>Arup</i> L97162	AF353951
<i>C. subsoluta</i>	Austria, <i>Arup</i> 97072	AF353954
<i>C. subsoluta</i>	Italy, <i>Arup</i> L97829	DQ173238
<i>C. verruculifera</i>	Unknown	AY081163
<i>Xanthomendoza fallax</i>	Austria, <i>Arup</i> L97529	AF353955
<i>X. poeltii</i>	Unknown	AY081158
<i>X. mendozae</i>	Canada, <i>Arup</i> L89265	DQ173237
<i>Xanthoria calcicola</i>	Sweden, <i>Arup</i> L97372	AF353944
<i>X. candelaria</i>	Unknown	AY081154
<i>X. parietina</i>	Italy, <i>Arup</i> L97905	AF353943
<i>X. polycarpa</i>	Minnesota, <i>Wetmore</i> 80511	DQ173236

There are many other yellow, sorediate/blastidiate species of *Caloplaca* in northern Europe and most of these have also been analysed genetically (results not shown), but none of them belong to the *C. citrina/marina* group. These species include *C. britannica* R. Sant., *C. chrysodeta* (Vain. ex Räsänen) Dombr., *C. chrysophthalma* Degel., *C. decipiens* (Arnold) Blomb. & Forssell, *C. obliterans*

(Nyl.) Blomb. & Forssell, *C. proteus* Poelt, *C. soropelta* E. S. Hansen, Poelt & Søchting) Søchting, *C. tominiü* L. I. Savicz and *C. xanthostigmoidea* (Räsänen) Zahlbr.

It can be seen in the tree (Fig. 1) that neither *Caloplaca* nor *Xanthoria* form monophyletic groups. It is also clear that the *C. citrina/marina* group is not closely related to *Caloplaca* in a strict sense, in the tree

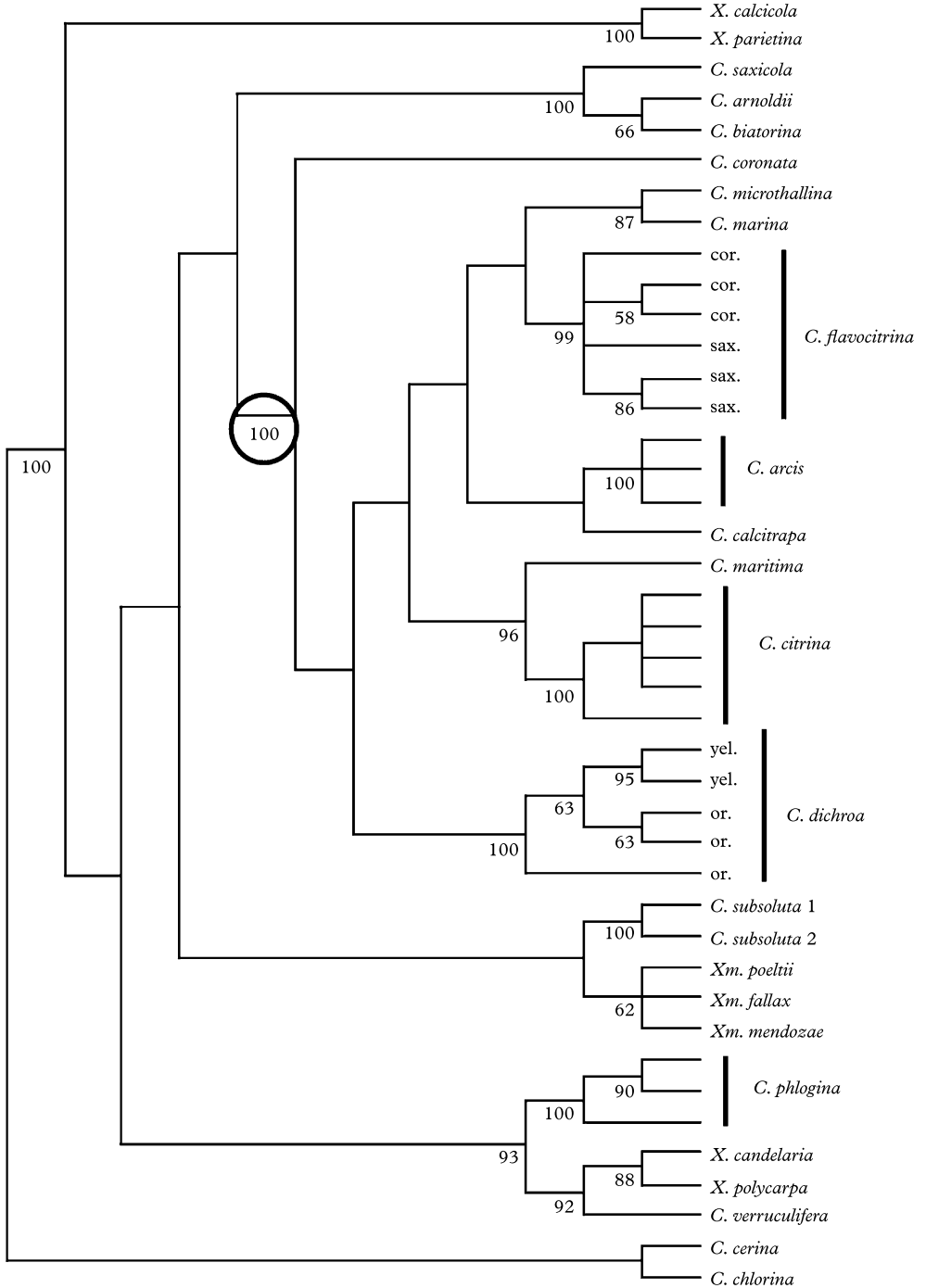


FIG. 1. Strict consensus tree of 20 trees from the parsimonious analysis based on nrDNA ITS data. Number below branches are bootstrap values. Vertical lines indicate soresiate species previously included in *Caloplaca citrina*. The node of the *C. citrina/marina* group is marked by a circle. *C.*=*Caloplaca*, *X.*=*Xanthoria*, *Xm.*=*Xanthomendozae*, cor.=corticolous, or.=orange, sax.=saxicolous and yel.=yellow.

TABLE 2. Morphology of the *Caloplaca citrina* group. n=number of specimens studied. One-way analysis of variance (ANOVA) was carried out between *C. citrina*, *C. flavocitrina*, and *C. phlogina* on each of the characters separately

Character	<i>arcis</i> n=3	<i>citrina</i> n=11	<i>dichroa</i> n=10	<i>flavocitrina</i> n=10	<i>phlogina</i> n=10	P
Max. thallus thickness (mm)	0.25 (0.05)† 0.20–0.30	0.36 (0.13) 0.20–0.60	0.22 (0.05) 0.15–0.30	0.25 (0.06) 0.20–0.35	0.19 (0.05) 0.15–0.30	0.284
Soredia/blastidia (µm)	74 (1) 73–75	44 (4) 37–51	43 (5) 37–53	33 (2) 30–35	39 (4) 33–43	0.022*
Max. width of apothecia (mm)	1.27 (0.21) 1.1–1.5	0.9 (0.36) 0.5–1.5	0.72 (0.15) 0.5–1.0	0.66 (0.11) 0.5–0.8	0.79 (0.13) 0.6–1.7	0.267
Min. thalline margin (µm)	17 (14) 0–25	11 (13) 0–25	15 (13) 0–25	5 (11) 0–25	5 (11) 0–25	1.000
Max. thalline margin (µm)	83 (14) 75–100	76 (27) 25–100	70 (27) 40–125	60 (27) 25–100	70 (28) 25–125	0.448
Min. proper margin (µm)	28 (6) 25–35	24 (13) 0–50	40 (12) 25–50	28 (5) 25–40	30 (7) 25–40	0.544
Max. proper margin (µm)	70 (17) 50–80	74 (4) 70–80	64 (13) 40–75	58 (13) 40–85	51 (7) 35–60	0.145
Hymenium (µm)	83 (8) 75–90	74 (4) 70–80	83 (17) 60–125	73 (7) 65–85	72 (8) 55–80	0.735
Spore length (µm)	12.8 (0.3) 12.6–13.2	12.5 (1.0) 11.1–14.1	14.2 (1.1) 11.8–15.6	11.1 (0.8) 10.0–12.1	11.4 (0.5) 10.8–12.1	0.462
Spore width (µm)	7.2 (0.4) 6.9–7.7	6.2 (0.7) 5.0–7.1	7.1 (0.6) 6.3–8.2	6.0 (0.6) 5.1–6.9	5.3 (0.4) 4.6–6.0	0.032*
Spore septum (µm)	3.8 (0.2) 3.7–4.0	3.9 (0.4) 3.2–4.5	3.3 (0.3) 2.8–3.9	4.1 (0.4) 3.5–4.7	3.4 (0.4) 3.0–4.5	0.001**
Ratio spore length/width	1.79 (0.15) 1.64–1.93	2.05 (0.22) 1.76–2.53	2.02 (0.13) 1.88–2.28	1.87 (0.11) 1.72–2.02	2.16 (0.21) 1.76–2.58	0.001**
Ratio spore septum/length	0.30 (0.02) 0.28–0.32	0.31 (0.04) 0.26–0.37	0.23 (0.02) 0.21–0.26	0.37 (0.04) 0.32–0.44	0.29 (0.04) 0.20–0.36	<0.001***

†Mean (standard deviation) and range from lowest to highest mean value for each character for each species.

*Indicates level of significance.

represented by *C. cerina*, the type species of this genus, and *C. chlorina*.

Morphological and anatomical differences are presented in Table 2.

Discussion

Caloplaca citrina has either been treated as one variable species occurring on many different substrata or as two to three separate species. However, the results of the genetic analysis clearly shows that there are at least five species involved in what has been united in *C. citrina*. First, there is *C. citrina* s. str., a wide-spread species described from France. Then there are *C. flavocitrina* described from Great Britain and *C. phlogina*, probably from Germany. These three species have for two centuries been either separated or united.

The fourth species, *C. arcis*, was described in 1990 as a variety under *C. citrina*. The fifth species *C. dichroa*, is described in this paper. Beside the genetic differences between the species there are corresponding morphological, anatomical and ecological differences as well as differences in distribution. It is especially interesting to see that *C. phlogina* is not even closely related to *C. citrina*, despite their overall similarities in morphology and anatomy. Even if the two taxa are clearly different species there are still specimens that are difficult to determine, particularly poorly developed specimens and specimens without apothecia.

Caloplaca flavocitrina is both corticolous and saxicolous and there are small differences between the forms on the two substrata. However, in the genetic analysis there

is no clear separation of the corticolous from the saxicolous forms and the genetic differences between specimens are very small. There is therefore no data supporting further separation of taxa in *C. flavocitrina*. The new species *C. dichroa* occurs in two different colour forms, a yellow and an orange form, which often grow side by side. In the phylogenetic tree the two yellow specimens form a monophyletic group, but the orange ones do not. The genetic differences are very small and the yellow and orange forms are clearly

very closely related. I therefore believe that these forms are best treated as one species.

It has been pointed out several times that *Xanthoria* as well as *Caloplaca* as understood today are paraphyletic and we need a new taxonomy for the family *Teloschistaceae* (Arup & Grube 1999; Søchting & Lutzoni 2003; Gaya *et al.* 2003). In a joint project U. Søchting, the author and P. Frödén are working on a new taxonomy for the family, using a multi-gene approach.

Key to sorediate species of *Caloplaca* with yellow to orange soredia occurring in the Nordic countries, except Iceland

- | | | |
|------|--|----------------------------|
| 1 | Saxicolous, terricolous, or on bryophytes and plant debris over these substrata | 2 |
| | Corticolous, lignicolous or on bryophytes over these substrata | 16 |
| 2(1) | Saxicolous or on mosses over rocks | 3 |
| | Terricolous or on mosses and plant debris on the ground | 14 |
| 3(2) | Thallus distinctly lobate at margin, often forming rosettes | 4 |
| | Thallus without lobes or with indistinct, mainly small lobes | 8 |
| 4(3) | Thallus yellow; lobes short, wide and flat; blastidia coarse, scattered in centre of thallus; often with apothecia | C. arcis |
| | Thallus often orange; lobes usually elongate, convex; soralia more distinctly delimited; usually without apothecia | 5 |
| 5(4) | Soralia mainly lip-shaped on short lobes, but may occur along margins of areoles, ± concolorous with thallus; mainly in exposed sites | C. decipiens |
| | Soralia crater-like, punctuate to irregular; mainly in shaded sites | 6 |
| 6(5) | Thallus 1–3(–5) mm, orange to reddish orange, as rosettes with finger-like lobes well separated from each other | C. proteus |
| | Thallus larger | 7 |
| 7(6) | Thallus normally as rosettes with narrow lobes paler at tips due to white pruina; soralia crater-like to level with thallus surface, round, citrine-yellow, contrasting against thallus | C. cirrochroa |
| | Thallus normally a thin crust, areolate or not, sometimes with marginal lobes, tips not paler or pruinose; soralia round to irregular, sometimes crater-like, orange, concolorous with thallus | C. obliterans |
| 8(3) | Thallus completely leprose, golden to brownish yellow; on shady and humid calcareous rocks; without apothecia | C. chrysodeta |
| | Thallus different, sometimes completely sorediate but not leprose; often fertile | 9 |
| 9(8) | Thallus brownish orange to olive-orange, as thin crust or composed of convex areoles with coralloid, often olive-orange, consoredia–isidia | C. xanthostigmoidea |
| | Thallus yellow to orange, completely sorediate or composed of convex to flat areoles, squamules, or lobes; soredia yellow to orange without olive tinge, not coralloid | 10 |

- 10(9) Areoles often adnate, gradually thinning into a prothallus; thallus and soralia yellow-orange to reddish orange; soralia often somewhat crater-like; mostly on shaded, siliceous or calcareous, vertical rocks; rarely with apothecia
 **C. obliterans**
 Areoles yellow to orange, adnate or not; prothallus usually absent; soralia not crater-like, yellow to orange-yellow; in exposed sites or when on shaded vertical rocks yellow; often with apothecia 11
- 11(10) Thallus units 0.5–2.0 mm across, consisting of convex areoles, squamules or small lobes with scattered, fine granules or blastidia 50–100 µm in diameter
 **C. arcis**
 Thallus units 0.1–1.0(–1.5) mm across, usually consisting of areoles; soralia 25–60(–75) µm 12
- 12(11) Areoles 0.1–0.3 mm wide, 0.1–0.2 mm thick, gradually disintegrating into soredia/blastidia or up to 0.6 mm but with a finely granulose surface, orange or yellow; soralia indistinct or sometimes absent; spores of sand-clock type; spore wall 1.2–2.0 µm thick **C. dichroa**
 Areoles 0.1–1.0(–1.5) mm wide, 0.1–0.4 mm thick; soralia distinct or covering the whole thallus; spores not of sand-clock type; spore wall 0.5–1.0 µm thick . 13
- 13(12) Thallus areolate, somewhat squamulose or with some flat lobes; surface usually flat; soralia covering 10–50(–100)% of thallus, mainly marginal, often on slightly lifted margin, contrasting against thallus; apothecia –0.6(–0.8) mm, adnate; thalline margin usually not sorediate; average spore length 10–12 µm
 **C. flavocitrina**
 Thallus partly to completely sorediate; soredia covering (5–)25–100% of thallus; areoles flat to convex, sometimes squamulose or lobe-like; soralia irregular, sometimes initiating at margin but spreading irregularly, concolorous with thallus; apothecia –1.0(–1.5) mm, sessile; thalline margin often sorediate; average spore length 11–14 µm **C. citrina**
- 14(2) Thallus brownish orange to olive-orange, as thin crust or composed of convex areoles with coralloid consoredia–isidia; soralia often olive-orange
 **C. xanthostigmoidea**
 Thallus completely sorediate, thick and cracked or areolate–squamulose with irregular soredia or soredia at margin of incised squamulose; soralia yellow to orange-yellow 15
- 15(14) Thallus composed of incised squamules or areoles with marginal soralia; directly on sand and soil **C. tominii**
 Thallus completely dissolved into soredia or nearly so, often thick and cracked, or areoles only partly dissolved into soredia; soralia irregular, not marginal; on mosses, plant debris or other lichens on the ground **C. citrina**
- 16(1) Thallus inconspicuous; soralia punctuate, round, dense, brownish to greenish orange; sterile; mainly on old oaks **C. lucifuga**
 Thallus conspicuous, leprose or dissolved in soredia; soralia different; sometimes with apothecia 17
- 17(16) Thallus brownish orange to olive-orange, as thin crust or composed of convex areoles with coralloid consoredia–isidia; soredia often olive-orange, on wood
 **C. xanthostigmoidea**
 Thallus and soralia different 18

- 18(17) Thallus leprose, completely sorediate or nearly so 19
 Thallus only partly dissolved into soredia 20
- 19(18) Thallus completely leprose, golden to brownish yellow; in shady and humid sites; mainly saxicolous but sometimes on roots and bark; sterile . . . **C. chrysodeta**
 Thallus usually completely dissolved into soredia but not leprose; in \pm exposed sites on bark; usually with apothecia **C. phlogina**
- 20(18) Thallus very thin crust, pale yellow to grey; soralia breaking through cortex, almost crater-like **C. chrysophthalma**
 Thallus areolate, squamulose or almost lobate, yellow to orange-yellow; soralia mainly marginal **C. flavocitrina**

The Species

Caloplaca arcis (Poelt & Vězda) Arup comb. nov.

Caloplaca citrina (Hoffm.) Th. Fr. var. *arcis* Poelt & Vězda. *A. Vězda: Lichenes Selecti Exsiccati, Fasc. XCIX*, nos. 2451–2475 (1990); type: Austria, Stiria, distr. Feldbach, Riegersburg, alt. 400 m s. m. Ad saxa andesitica sub arcem, 22 October 1990, *G. Kantvilas, H. Mayrhofer & A. Vězda. A. Vězda: Lichenes Selecti exsiccati no. 2470* (GZU!—holotype, LD!—isotype).

(Fig. 2)

Thallus composed of rosettes, 2–10 mm in diameter, 0.1–0.4 mm thick, with lobate margin or irregular areoles, squamules or small lobes; *areoles/squamules* (0.2–)0.5–2.0 mm across; *marginal lobes* 0.4–1.0 \times 0.2–1.0 mm, flat, flexuose or slightly wrinkled; centre with scattered fine granules or coarse

blastidia; colour yellow to orange-yellow. *Blastidia* (45–)50–100(–120) μ m, \pm concolorous with thallus. *Prothallus* not observed. *Cortex* paraplectenchymateous.

Apothecia often present and sometimes abundant, adnate to sessile, round to irregular, zeorine, 0.3–1.5 mm wide; disc slightly concave to convex, sometimes flexuose, orange-yellow; *proper margin* 25–80 μ m, slightly raised or level with disc, concolorous with disc, consisting of radiating, thick-walled hyphae; *thalline margin* mostly present, but sometimes excluded, (0–)25–75(–100) μ m, even to weakly crenulate or blastidiate, concolorous with thallus; *epihymenium* yellowish orange, granular interspersed; *hymenium* 75–90 μ m thick, hyaline; *hypotheicum* 50–150 μ m thick, hyaline; *paraphyses* simple to branched two to three times, 2–2.5 μ m broad with upper cells

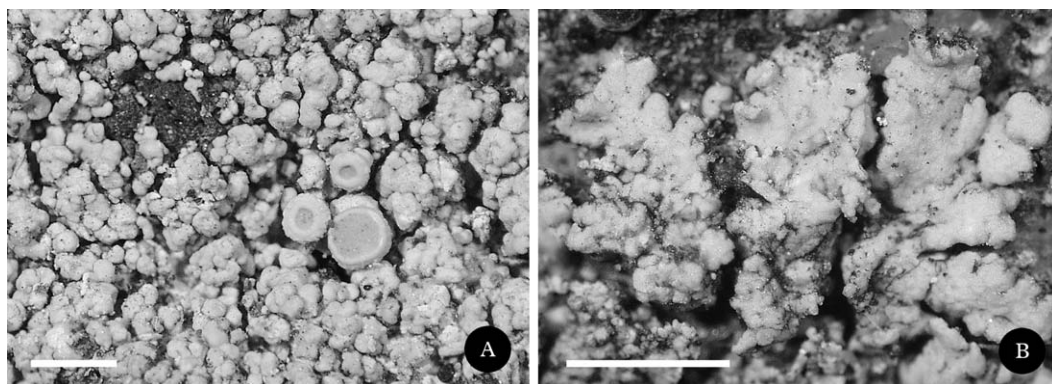


FIG. 2. *Caloplaca arcis*. A, thallus composed of irregular, convex areoles or squamules, no soredia but some scattered granules/blastidia (1975 Poelt); B, close up showing marginal lobes (Arup L97507). Scales: A & B = 1 mm.

wider, up to 6 µm. *Asci* cylindrical, 47–63 × 12–15 µm, 8-spored; *ascospores* polaribilocular, ellipsoid to broadly ellipsoid, (10.0–)11.0–14.5(–15.0) × (5.5–)6.0–8.7(–9.0) µm, septum 3.0–4.5(–5.5) µm wide, ratio of septum/spore length (0.21–)0.26–0.36(–0.46).

Pycnidia often present, immersed, orange. *Conidia* bacilliform to narrowly ellipsoid, 3.0–3.5 × 1.2–1.5 µm.

Chemistry. The thallus and apothecia contain parietin as a major compound, and small amounts of fallacinal, emodin, teloschistin and parietinic acid, which corresponds to chemosyndrome A of Søchting (1997).

Habitat and distribution. The ecology is not yet fully known since the material is scarce. In Austria it grows on calciferous basalt and serpentine. In Sweden *C. arcis* is found on calciferous stone, pure limestone and concrete on church yard walls. In the British Isles it is found on limestone pebbles and calciferous rocks near the seashore. It seems to grow on both vertical and horizontal surfaces, but prefers rather exposed sites. The known distribution comprises scattered sites in Austria, Wales, England, and three localities in Skåne, southernmost Sweden. It is difficult to say how common the species may be but it seems to be rare in most countries.

Remarks. This species is characterized by a thallus consisting of yellow rosettes with flat, rather broad, marginal lobes and the coarse blastidia which are often mixed with apothecia. It may be confused with some forms of *C. citrina*, but differs in the rather distinct marginal lobes and the coarser blastidia. The coarse blastidia are shared by *C. limonia* Nimis & Poelt, but this species lacks distinct marginal lobes and the apothecia are light brown (Nimis *et al.* 1994). In coastal sites it is also possible to confuse *C. arcis* with *C. microthallina*. Both may have marginal lobes and the squamules in *C. microthallina* sometimes dissolve into smaller units which could be confused with coarse blastidia. The

apothecia and spores are also very similar and do not provide useful diagnostic characters. The best way to separate them is the more distinct rosettes of *C. arcis* and the presence of blastidia, not just dissolved parts of the thallus.

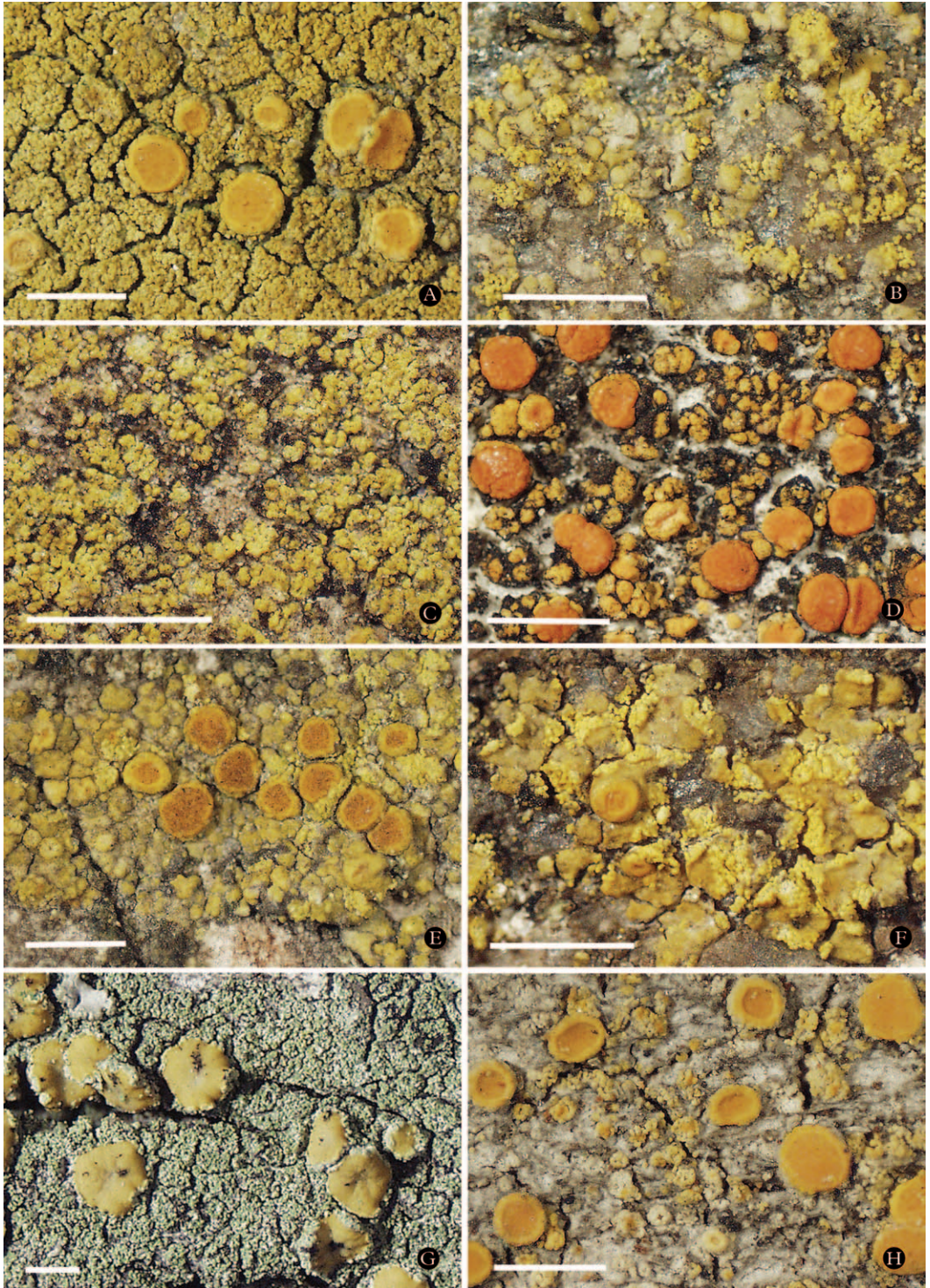
Selected specimens. **Austria:** *Steiermark:* Feldbach, Riegersburg, 1975 *Poelt* (GZU), *Arup* L97507, L97514 (hb. Arup). *Burgenland:* Güssing, *Friedl* 13080 (GZU); Bernsteiner Gebirge, Bernstein, *Hafellner & Maurer* 31240 (GZU).—**Great Britain:** *England:* **V. C. 6,** North Somerset, Weston-super-Mare, Brean Down, *Arup* L92117, L92118 (LD). *Wales:* **V. C. 45,** Pembrokeshire, *c.* 15 km WSW of Haverfordwest, St. Brides, *Arup* L92115 (LD).—**Sweden:** *Skåne:* Bromma par., at the church, *Frödén & Ekman* 948, 949 (LD); Mellan-Grevie par., at the church, *Ekman* (field observation); Räng par., Räng church, 2003, *Ekman* (BG).

***Caloplaca citrina* s. str. (Hoffm.) Th. Fr.**

Acta Soc. Regiae Sci. Upsal. **3:** 218 (1860).—*Verrucaria citrina* Hoffm. *Deutschlands Flora:* 198 (1796); type: *Lecanora citrina*, Svecia, (H!—neotype, selected by Nordin 1972).

(Figs 3A & B, 4)

Thallus very variable, discontinuous to continuous, a few mm wide to many cm, 0.1–0.6 mm thick, consisting of scattered to continuous areoles that are more or less dissolved into soredia (Fig. 3A); areoles 0.1–1.0(–1.5) mm wide, esorediate parts flat-convex, often irregular and flexuose or almost squamulose, surface smooth or dissolved into soredia; colour pale greyish or greenish yellow to intense yellow, orange-yellow or rarely yellow-orange. **Soredia** (25–)30–60(–75) µm, usually concolorous with the thallus or paler, covering (5–)25–100% of the areoles, starting at the margin or on the surface of the areoles, spreading in irregular patterns over the areoles (Fig. 3B), in many cases the whole thallus is dissolved into soredia and becomes cracked areolate. **Prothallus** normally not present, sometimes very thin, white or pale yellow. **Cortex** usually poorly developed or indistinctly paraplectenchymateous.



Apothecia often present, sometimes abundant, adnate to sessile, round to irregular, zeorine, 0.3–1.5 mm wide; disc slightly concave to convex, sometimes flexuose, beige-yellow, pale brownish yellow, orange-yellow to yellow-orange, sometimes with a thin white pruina; *proper margin* (10–)25–50 (–75) μm , slightly raised or level with disc, concolorous with disc, consisting of irregularly radiating, thick-walled, rather short-celled hyphae; *thalline margin* mostly present, but sometimes excluded, (0–)25–100 μm , even to crenulate or sorediate, concolorous with thallus; *epihymenium* yellowish orange, granular inspersed; *hymenium* 70–80 μm thick, hyaline; *hypothecium* 40–75 μm thick, hyaline; *paraphyses* simple to branched once above, 2–2.5 μm broad with upper cells wider, up to 7 μm . *Asci* cylindrical, 55–65 \times 12–15 μm , 8-spored; *ascospores* polaribilocular, ellipsoid to broadly ellipsoid, (10.0–)10.5–14.8(–15.2) \times (4.0–)5.0–7.5 (–8.0) μm , septum (2.5–)3.0–5.0(–5.7) μm wide, ratio of septum/spore length (0.23–)0.25–0.39(–0.44).

Pycnidia often present, immersed, orange. *Conidia* bacilliform to broadly ellipsoid, 2.5–3.8 \times 1.0–1.5 μm .

Chemistry. The thallus and apothecia contain parietin as a major compound, and small amounts of fallacinal, emodin, teloschistin and parietinic acid, which corresponds to chemosyndrome A of Søchting (1997).

Habitat and distribution. *Caloplaca citrina* has the widest ecology of all the species investigated. It grows on pure limestone, concrete, slate, asbestos, bone, roof tiles,

siliceous rocks, and sandstone as well as on calciferous ground and mosses. Rarely it occurs also on manured worked timber, but it does not seem to grow on bark, at least not in the study area. The species is best developed in exposed sites, but occurs also on vertical surfaces under overhangs in shaded habitats. The optimal sites seem to be calcareous or manured habitats because here the thallus and the apothecia are best developed.

Of the species treated here *C. citrina* has the widest distribution occurring in many provinces in the Nordic countries, from the south to the northern parts (Fig. 4). The distribution map is based on the material studied, which leaves some provinces without any reference material. Some of these have been cited in, for example, Santesson *et al.* (2004), where *C. citrina* is claimed to occur in all Swedish provinces. This is probably true, but it is rare in the north and has rarely or never been collected in some provinces. In Norway and Finland it seems to be the only sorediate species of the group in most parts of the countries. Outside the investigated area *C. citrina* is common in many parts of Europe and in North America. It is, however, difficult to say without further detailed studies whether records elsewhere belong to *C. citrina* in the strict sense or to other species.

Remarks. This is the most variable species of those treated in this paper. Well-developed specimens are normally easy to recognize by their soredia covering most or all of the thallus and by the rather large apothecia. In these cases *C. citrina* is very similar to *C. phlogina*, but this species

FIG. 3. Sorediate species of *Caloplaca*. A, *C. citrina* (Arup L03088), typical specimen similar to the type with thallus completely dissolved into soredia and apothecia with sorediate margin; B, *C. citrina* (Santesson 10806a), thallus from vertical rock with poorly developed soredia developing irregularly; C, *C. dichroa* (Arup L03023), yellow specimen with thin thallus of small granules partly dissolved into soredia; D, *C. dichroa* (Arup L03090), orange specimen with larger areoles without soredia, but abundant apothecia; E, *C. flavocitrina* (Arup L04021), specimen from bark with some soralia and typical apothecia; F, *C. flavocitrina* (Magnusson 9514), typical specimen with cracked areolate thallus, mainly marginal soredia on areoles lifting slightly at edge, and an adnate apothecium; G, *C. phlogina* (type), specimen with well-developed, grey thallus dissolved into soredia and abundant apothecia; H, *C. phlogina* (1946 *Almborn*) common form with poorly developed, pale orange thallus and scattered soralia, but abundant apothecia. Scales: A–H=1 mm.

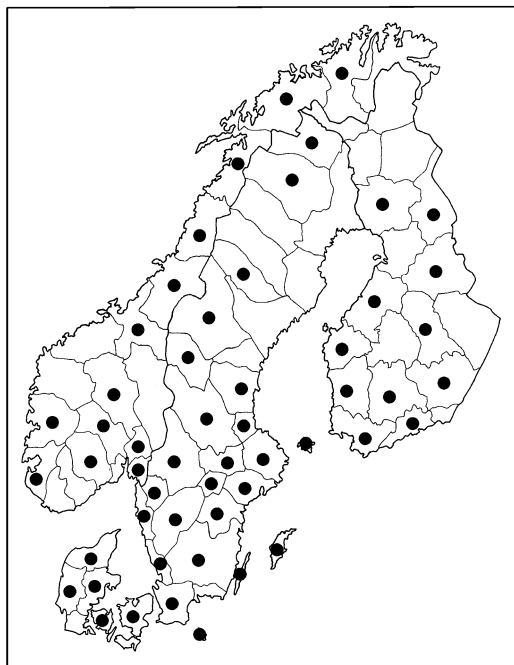


FIG. 4. The distribution of *Caloplaca citrina* in the Nordic countries, except Iceland, based on the material studied.

normally has a thinner thallus without areoles or cracks. In addition, it seems to grow only on bark and wood of trees, only rarely on worked timber. However, it cannot be ruled out that *C. citrina* does occur on substrata other than those given above, but so far specimens very similar to *C. phlogina* on concrete have turned out to be *C. citrina* on checking their DNA. The spores in *C. phlogina* are in general slightly smaller in all respects, but they cannot be used for determination since the overlap is too large. The conidia in *C. citrina* are mostly bacilliform or narrowly ellipsoid, but sometimes broadly ellipsoid, as in *C. phlogina*. Thus, apart from the small morphological differences, ecology seems to be the best way to separate the two species. There is also a risk of confusion with *C. chrysodeta*, another sorediate species. It can, however, be separated by the complete absence of areoles, the very loose structure of the soredia, and their more brownish tinge. It is never found fertile. *Caloplaca*

chrysodeta inhabits mainly shady and humid calcareous rocks and cave entrances, but also occurs on roots in humid places and occasionally on bark of standing trees.

In all cases where parts of the areoles in *C. citrina* are not completely dissolved into soredia, confusion with *C. flavocitrina* is possible. When fertile, the somewhat shorter spores with a septum/length ratio that is somewhat greater in *C. flavocitrina* are useful characters. In addition the apothecia are usually adnate, smaller and the thalline margin less sorediate in the latter species. When sterile the species can be separated only by the shape of the areoles and by the development of soralia. In *C. citrina* the areoles in forms with poorly developed soralia are often convex and irregularly shaped. The soredia are formed both from the margin and the surface of the areoles and spread in irregular patterns. In *C. flavocitrina* the areoles are generally flat and the soredia form mainly at the margin in a stricter pattern and the margin is often turned slightly upwards where the soredia are formed. Finally, the colour of the soredia in *C. flavocitrina* often contrasts with that of the thallus and the soredia are on average smaller. In *C. citrina* the soredia are usually concolorous with the thallus and are on average larger (Table 2). The forms of *C. citrina* with poorly developed soralia occur mainly in shaded habitats under overhangs or on substrata with low pH. It seems that *C. flavocitrina* rarely occurs in such habitats, at least in the area investigated. On vertical rock surfaces and under overhangs it is also possible to confuse it with *C. obliterans*. This species differs by the more orange colour, frequent presence of a thin prothallus, and soralia that often are somewhat crater-like, at least some on each thallus.

Selected specimens. Denmark: Bornholm: Just N of Sandvig, Thor 7327 (S). *Langeland:* D. 34. Kellsnor light, Svane 91SS8493-1 (C). *Nordjylland:* D. 6. Hansted. Svane 79SS4521-4 (C). *Sjælland:* Zealand, Karlslunde, SW of Copenhagen, Skytte Christiansen 84001 (C). *Vestjylland:* Oksby, ruin v. Krogsande, Skytte Christiansen 7230 (LD). *Østjylland:* Dr. 23, Tunø W of Samsø, Svane 82SS5247-1 (C).—*Finland: Etelä-Häme:* Asikkala: Asikkla church, Ahti 49773 (H). *Etelä-Pohjanmaa:* Vaasa, Vanha-Vaasa, 1954, Suominen (H).

Etelä-Savo: Ruokolahti, Reinikkala, *Vitikainen* 5378 (H). *Keski-Pohjanmaa*: Kälviä, Ruotsalo, *Takala* 3231 (H). *Kainuu*: Kajaani, 1924, *Räsänen* (H). *Kollismaa*: Kuusamo, Paljakka, *Vitikainen* 10170b (H). *Pohjois-Savo*: Knopio, Sūkalahiti, 1942, *Räsänen* (H). *Satakunta*: Rauma, Rauman kirkon seinärappauksella, 1935, *Kivenheim* (H). *Uusimaa*: Helsinki, Laajasalo, Tullisaari, *Ahti* 15561 (H). *Varsinais-Suomi*: Korpo island Jurmo, *Vitikainen* 11936a (H). *Åland*: Ekerö, Storby, 1935, *Räsänen* (H).—**Norway**: *Buskerud*: Hole, Sundvolden, 1905 *Havaas* (O). *Hordaland*: Os, Bjørnen, *Botnen* 81/135 (BG). *Nord-Trøndelag*: Stjørdal, 1 km SW of Langstein, *Botnen* 85/147 (BG). *Nordland*: Rombaken, Strömsnes, 1915, *Häyrén* (H). *Opland*: Ringebu kd, Fåvang, 1948, *Ahlner* (O, S). *Oslo*: Maridalens kirke, 1925, *Lynge* (O). *Rogaland*: Rennesøy, Møsterøy, Utstein kloster, *Jørgensen & Øvstedal* 3497 (BG). *Telemark*: Bamble, Langesundtangen, *Bratli & Timdal* 8773 (O). *Troms*: Storfjord, Skibotndalen, Gustavsvingen, *Arup* L03547 (LD). *Østfold*: Askim, Askim church, *Bratli & Løfall* 2860 (O).—**Sweden**: *Bohuslän*: Öckerö par., Rörö, *Tibell* 383 (UPS). *Dalarna*: Lima par., Årsjöberget, *Hermansson* 2383 (UPS). *Dalsland*: Skållerud par., Ryr, 1971, *Nilsson* (UPS). *Gotland*: Sundre par., Holmhällar, *Arup* L03088 (hb. *Arup*); Västerhejde par., Högkint, *Arup* L03065 (hb. *Arup*). *Gästrikland*: Gefle, Strömdalen, 1945, *Ahlner* (S). *Härjedalen*: Tännäs par., Funäsdalen, *Arup* L02316 (LD). *Jämtland*: Åre par., Enafors, Enaforsholm, *Arup* L02203 (LD). *Lule Lappmark*: Kvikkjokk, coll. unknown (S). *Närke*: St. Mellösa par., Ytterby, 1891, *Hellbom* (C, S). *Skåne*: Trolle-Ljungby par., Trolle-Ljungby castle, *Arup* L03013 (hb. *Arup*). *Småland*: Kalmar, Kalmar castle, *Arup* L03027 (hb. *Arup*). *Södermanland*: Fröderyd par., Limmeshagen, 1976, *Nicklasson* (UPS). *Torne Lappmark*: Jukkasjärvi par., Torneträsk area, N-slope of Njulla, *Alstrup* 84183 (C). *Uppland*: Kalmar par., Djupvikén, *Nordin* 4759 (UPS). *Värmland*: Bogen par., Bogen vid Holmtjärn, *Sundell* 5142 (UPS). *Västergötland*: Otterstad par., Källandsö, *Santesson* 10806a (UPS). *Västmanland*: Västanfors par., Västanfors, at Billsjön söder om Lindbo, *Nordin* 5299 (UPS). *Åsele Lappmark*: Risbäck par., NE slope of the dolomite mountain Kalvberget, *Santesson* 33047 (UPS). *Öland*: Mörbylånga par., Bårby borg, *Nordin* 2442b (UPS). *Östergötland*: Värna par., Bersbo, *Santesson* 29553 (UPS).

Caloplaca dichroa Arup sp. nov.

Similis *C. calcitrapae* sporis typo horologii arenarii, differt thallo sorediato vel blastidiato, apotheciis areolisque minoribus. Ab itidem simili *C. citrinae* differt typo sporarum areolisque granulosis.

Typus: Sweden, Västergötland, Klefva infra Mösseberg. In saxi calcaris, 1914, *Vrang*. Malm: *Lichenes suecici exsiccati* No. 525 (LD—holotypus, C, H, S—isotypi).

(Figs 3C & D, 5, 6A, 7)

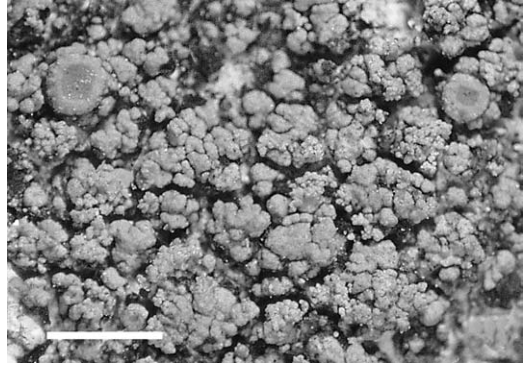


FIG. 5. *Caloplaca dichroa* (*Arup* L03089), typical thallus with convex areoles and granules partly dissolving into soredia or blastidia. Scale=1 mm.

Thallus discontinuous to continuous, 1–3 cm in diam., 0.1–0.2(–0.3) mm thick, consisting of scattered to continuous areoles that are more or less dissolved into blastidia or granules; areoles 0.1–0.6 mm wide, convex or flat with convex margins, round to irregular and flexuose or almost squamulose or minutely lobate at margin, surface dissolved into soredia, blastidia or fine granules to various degrees, from 0–90%, sometimes appearing almost isidiate; colour either of two variants, yellow to yellow with an orange tinge or orange to reddish orange. *Soredial/blastidia* (25–)30–60(–70) µm, concolorous with the thallus, appearing in a diffuse shallow layer or irregularly scattered over the thallus. *Prothallus* normally not present, sometimes very thin, yellow or orange. *Cortex* indistinctly paraplectenchymateous or usually poorly developed.

Apothecia rather often present, sometimes abundant, adnate to sessile, round to irregular, zeorine, 0.3–1.0 mm wide; disc ± plane or slightly convex, orange-yellow or dark orange to dark reddish orange, without pruina; *proper margin* 25–75 µm, slightly raised or level with disc, concolorous with or slightly paler than disc, consisting of radiating, thick-walled hyphae; *thalline margin* mostly present, but sometimes excluded, (0–)25–75(–125) µm, uneven to crenulate, rarely sorediate, concolorous with thallus; *epihymenium* yellowish orange, granular interspersed; *hymenium* 60–85(–125) µm thick,

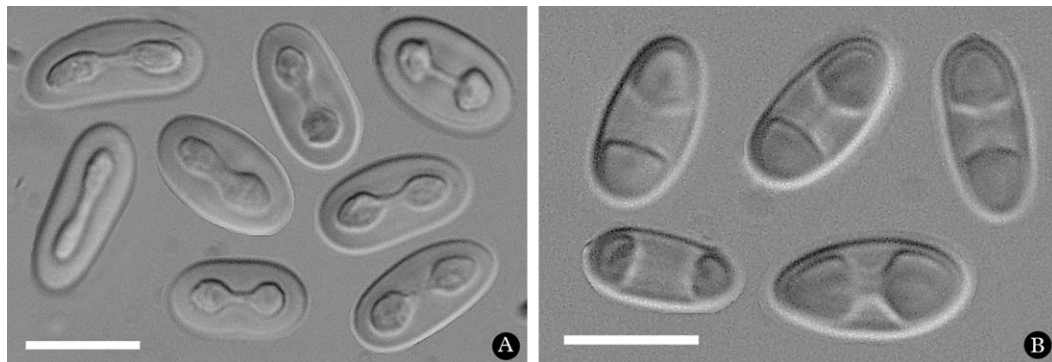


FIG. 6. Immature and mature spores of *Caloplaca*. A, *C. dichroa* (holotype), spores of sand-glass type with immature spores to the left and gradually more mature spores to the right, all with thick spore walls; B, *C. citrina* (Arup L03088), mature ascospores corresponding to a normal type in *Caloplaca* with an immature spore in the lower right corner, all with thin spore walls. Scale = 10 µm.

hyaline; *hypothecium* 40–75 µm thick, hyaline; *paraphyses* simple to branched once or twice, sometimes anastomosing, 2–2.5 µm broad with upper cells wider, up to 6 µm, in fresh material with oil-droplets. *Asci* clavate, 45–67 × 12–15 µm, 8-spored, *ascospores* polaribilocular, of sand-clock type (Fig. 6A), ellipsoid to broadly ellipsoid, (11.0–)12.0–16.5(–17.0) × (5.8–)6.0–8.5(–9.0) µm, septum (2.0–)2.5–4.0(–4.5) µm wide, mostly incompletely developed, ratio of septum/spore length (0.15–)0.19–0.27(–0.32) µm; *ascospore wall* 1.0–2.0 µm thick.

Pycnidia often present, immersed, orange. *Conidia* bacilliform, 2.5–3.0 × 1.0–1.2 µm.

Chemistry. The thallus and apothecia in both the yellow and the orange forms contain parietin as a major compound, and small amounts of fallacinal, emodin, teloschistin and parietinic acid, which corresponds to chemosyndrome A of Søchting (1997).

Etymology. The name *dichroa* refers to the occurrence of two colour forms of the species, one yellow and one orange.

Habitat and distribution. *Caloplaca dichroa* is a pure saxicolous species, growing mainly on calcareous substrata such as limestone rocks and boulders, sometimes on pebbles, and rarely on concrete and mortar. It does

not seem to be especially favoured by strong manuring by birds, as is *C. citrina*. The habitat is usually sun-exposed and shady sites are avoided. The complete distribution of this species is not fully known (Fig. 7). In Sweden it is most common in the south-east, especially on the islands of Gotland and Öland, which are rich in natural limestone. On the mainland, this kind of habitat is rare and the species is mostly found on stone walls with at least parts of limestone (limestone plates often come from Öland or Gotland). In Norway it is almost absent, but there are several specimens collected on the island of Vega. Probably, the climate conditions with mild winters favours the occurrence there. In Denmark and Finland the few collections imply that *C. dichroa* is very rare. However, in Denmark I suspect that it is more common than the two specimens collected in the north suggest. I have also collected *C. dichroa* in Austria and seen material from Germany.

Remarks. This new species is often easily recognized by the finely granulose, thin thallus dissolved into soredia/blastidia. It is also characterized by the two colour forms that often occur side by side. When fertile the spores can be checked and even in immature spores the thick, 1.0–2.0 µm, spore wall can be recognized. The spore wall in the genus is generally thinner, 0.5–1.0 µm. This spore feature is unique to this

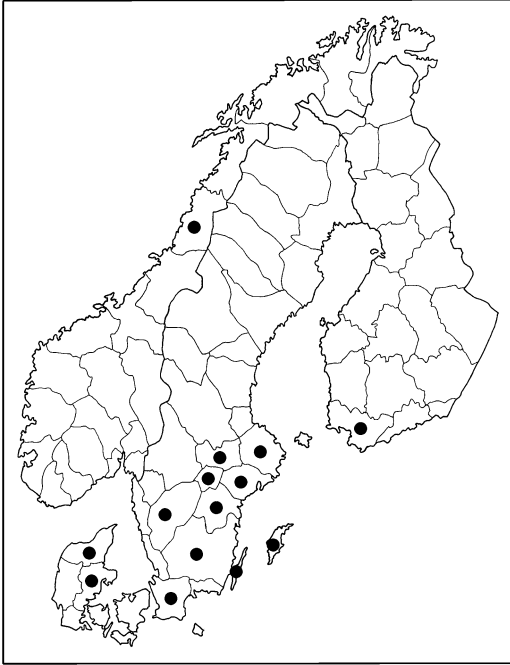


FIG. 7. The distribution of *Caloplaca dichroa* in the Nordic countries, except Iceland, based on the material studied.

Caloplaca species in northern Europe, but occurs in *C. calcitrata*, a related species in the Mediterranean (Navarro-Rosinés *et al.* 2000). However, it differs from *C. calcitrata* in the occurrence of soredia/blastidia and in having two colour forms. The geographic distribution also seems to differ. In the Himalayas there are also species with a similar spore type (Poelt & Hinteregger 1993). Of these only *C. lobulascens* is saxicolous, but it grows on siliceous stone and in addition is clearly different morphologically.

In some of the forms of *C. dichroa* the soredia/blastidia are poorly developed but the areoles appear as small granules, rather like isidia. Such forms have in the Nordic countries been confused with *C. coronata*. However, this species has a more southern distribution and all records from the countries investigated here refer to *C. dichroa*. It differs from this species in the more uniform true isidia and in having smaller spores with thin walls. It is also

possible to confuse yellow forms of *C. dichroa* with *C. arcis*, but the thallus in this species is thicker and the spores have thin walls. Although *C. dichroa* has mostly been included in *C. citrina*, these species are not very similar. Only very thin and poorly developed forms of both species are actually similar, and may be impossible to determine.

Selected specimens studied. **Austria:** Burgenland: N of Neusiedlersee, Bärenhöhlen, Arup L98128 (hb. Arup).—**Denmark:** Nordjylland: D. 6, Thy, Vust par. Bolbjerg, Skytte Christiansen 9211 (C). Østjylland: D. 22b, Glatved, S of Grenå, Svane 7 (C).—**Germany:** München, Harthausen, Arnold, *Lich. monacenses exsicc.* No. 151 (S).—**Finland:** Varsinais Suomi: Korpo (Korpoo) par., on the small island of Källklot NW of Åvensör, Santesson 32665 (UPS), Ahti 48306 (H).—**Norway:** Nordland: Vega par., Vega Island, Brandsvika, 1974, Degelius (UPS); Hillholmen, 1975, Degelius (UPS); Veta, 1978, Degelius (UPS); Andøy, 1975 Degelius (UPS); Holand, 1973, Degelius (UPS); Vallsjön, 1974, Degelius (UPS).—**Sweden:** Gotland: Boge par., Klinte, Klinteberget, Arup L03108, (hb. Arup); Sundre par., Holmhällar, Arup L03089 (hb. Arup), L03090 (LD); Visby par., Visby, Arup L03054 (LD). Närke: Glanshammar, Nytinge, 1952, Kjellmert (UPS, S, O). Skåne: Degeberga par., Degeberga church yard, Arup L04005 (hb. Arup). Småland: Kalmar, Kalmar castle, Arup L03022 (hb. Arup), Arup L03023 (LD). Södermanland: Sorunda par., the small island Karta, Thor 11057 (hb. Thor). Uppland: Övergran par., at the parish church, Santesson 29965b (UPS). Västmanland: Sala par., Sala, Nordin 4333 (UPS). Öland: Mörbylänga par., 1.5 km NW of Gösslunda, Arup L03020 (hb. Arup). Östergötland: Omberg, 1915, Malme (S).

Caloplaca flavocitrina (Nyl.) H. Olivier

Lich. d'Europe 2: 110 (1908–1910).—*Lecanora flavocitrina* Nyl. *Flora* 69: 461 (1886); type: Great Britain, Staveley. 1886 *Martindale* (H-Nyl.),—lectotype selected by Wade 1965).

(Figs 3E & F, 8, 9)

Thallus discontinuous to continuous, 0.5–2 cm in diam., 0.1–0.25(–0.35) mm thick, consisting of scattered to contiguous areoles with mainly marginal soredia, sometimes cracked areolate; areoles 0.1–1.1 mm wide, usually ± flat but flexuose, round to irregular and flexuose or minutely lobate at margin, margin often dissolved into fine soredia that cover 10–50(–100)% of the

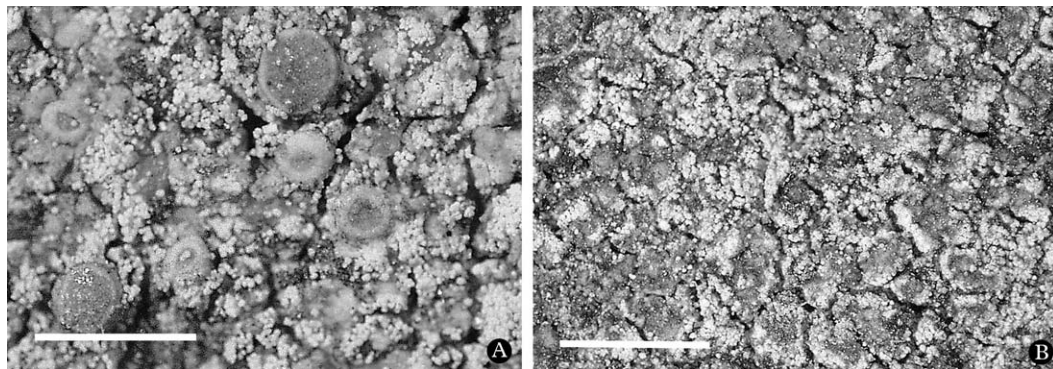


FIG. 8. *Caloplaca flavocitrina*. A, specimen with less typical thallus where the soredia partly develop more irregularly, but the apothecia are very typical (Skytte Christiansen 8030); B, sterile thallus with typical marginal soralia (1916, Magnusson). Scales: A & B=1 mm.

areoles (Fig. 3E–F); colour yellow to orange-yellow. *Soredia* (20–)25–40(–55) μm , usually brighter or paler yellow than thallus and rarely concolorous. *Prothallus* not observed. *Cortex* indistinctly paraplectenchymatous.

Apothecia rather often present, sometimes abundant, adnate to rarely sessile, round to irregular, zeorine, 0.3–0.8 mm wide; disc \pm plane or slightly convex, orange-yellow to orange or beige-orange, rarely with thin white pruina; *proper margin* 25–60 (–85) μm , slightly raised or level with disc, concolorous with or slightly paler than disc, consisting of irregularly radiating, thick-walled hyphae; *thalline margin* often excluded or restricted to base of apothecium, 0–50(–100) μm , even to uneven and rarely sorediate, concolorous with thallus; *epihymenium* yellowish orange, granular inspersed; *hymenium* 60–85 μm thick, hyaline; *hypothecium* 25–70(–125) μm thick, hyaline; *paraphyses* simple to branched once or twice, sometimes anastomosing, 2–2.5 μm broad with upper cells wider, up to 7 μm , in fresh material with oil-droplets. *Asci* clavate, 42–58 \times 11–16 μm , 8-spored, *ascospores* polaribilocular, ellipsoid to broadly ellipsoid, (9.0–)9.3–13.0(–14.0) \times (4.5–)4.8–7.0(–8.0) μm , septum (2.0–)2.5–4.0(–4.5) μm wide, ratio of septum/spore length (0.25–)0.28–0.47(–0.52).

Pycnidia often present, immersed, orange. *Conidia* bacilliform, 2.5–3.5 \times 1.0–1.4 μm .

Chemistry. The thallus and apothecia contain parietin as a major compound, and small amounts of fallacinal, emodin, teloschistin and parietinic acid, which corresponds to chemosyndrome A of S ochting (1997).

Habitat and distribution. *Caloplaca flavocitrina* is the only species of those treated here that is both saxicolous and corticolous. When saxicolous it occurs on man-made calcareous substrata such as mortar and concrete, but also on natural limestone rocks, boulders and pebbles. When corticolous it clearly prefers bark with a fairly high or high pH, such as *Ulmus*, *Fraxinus*, and *Acer*. It occurs in open situations and in contrast to *C. citrina* it does not seem to benefit from manuring by for example birds.

Caloplaca flavocitrina is clearly a species with a southern distribution, becoming more and more rare to the north (Fig. 9). In Norway it appears to be rather rare, but it is probably overlooked in the southern part of the country. In Finland, it is presumably very rare. In Sweden it is rather common in the lowland, especially along the coasts, and in Denmark it is probably more common than *C. citrina*. Outside this area it is known from a number of other countries in Europe. I have also seen at least one specimen from Pennsylvania, N America, but the complete distribution range is not known yet.

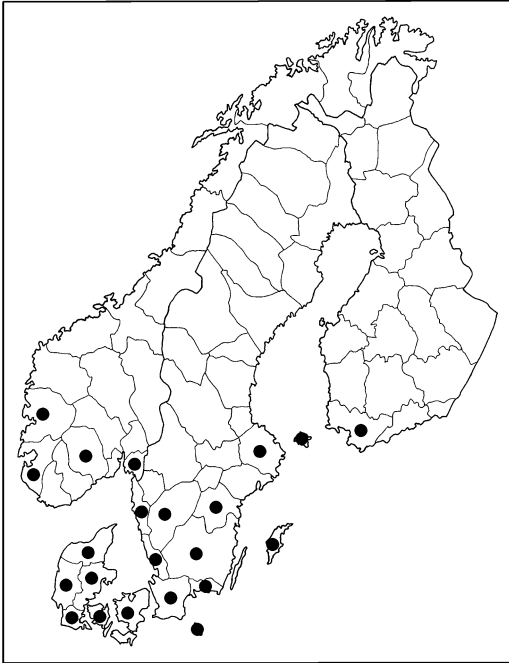


FIG. 9. The distribution of *Caloplaca flavocitrina* in the Nordic countries, except Iceland, based on the material studied.

Remarks. In its typical form this species is easily recognized by the areolate thallus with marginal soredia contrasting against the rest of the thallus. When growing on bark *C. phlogina* is one of two species, with which it can be confused. However, this species is completely dissolved into soredia, or nearly so. The second species, *C. chrysophthalma*, is much more difficult to separate from *C. flavocitrina* as in both species only part of the thallus is dissolved into soredia. In *C. chrysophthalma* the thallus is thinner, pale yellow or almost grey, and the soredia break through the cortex and form more irregular, excavate soralia, that do not form at the margin of the areoles or thallus parts. When saxicolous *C. flavocitrina* may be confused with forms of *C. citrina* with large parts of the thallus not dissolved into soredia (see that species for separating characters).

Some of the corticolous specimens in the herbaria originally determined as *C. microphyllina*, but later included in *C. citrina* by

Nordin (1972), belong to *C. flavocitrina*. *Caloplaca microphyllina* is a common species in North America, but is not known from Europe (Wetmore 2004).

Selected specimens. **Austria:** Steiermark: Graz, Arup L99002 (LD).—**Denmark:** Bornholm: just N of Sandvig, Thor 7327 (S). Langeland: D. 34, Kellsnor light, Svane 91SS8493-1 (C). Nordjylland: D. 1, Hirsholmene NE of Fredrikshavn, Svane 79SS4004-1 (C). Sjælland: Farum par., Farum, Skytte Christiansen 8030 (LD). Sydjylland: D. 49, Gram, Svane 87SS7189-1 (C). Vestjylland: D. 27, Gammel Gab/Lønne, W of N. Nebel, Svane 75SS2292b (C). Østjylland: D. 23, Tunø W of Samsø, Svane 82SS5247-1 (C).—**Finland:** Uusimaa: Sippo, Sipoo village, Ahti 26512 (H). Åland: Lemland, Herrö S, 1992, Bruun (H).—**Norway:** Hordaland: Bergen, under Floifjeld, 1915 Lyng (O). Rogaland: Vid Oyne på Jæren, Havås Lich. Norv. 622, 1915, Havås (O). Telemark: Porsgrunn, Brevik, Brevik church, Tønsberg 13701, 13703 (BG). Østfold: Moss, Jeløen, 1919, Lyng (O).—**Sweden:** Blekinge: Äryd par., Tjärö, Nordin 5701 (UPS). Bohuslän: Ljung, Hofhult, Magnusson 9514 (UPS); Stenkyrka, Djupvik, Magnusson 16560a (UPS). Gotland: Sundre par., Holmhällar, Arup L03080 (LD); Visby par., Visby, Arup L03052 (LD). Halland: Lindome, Ekered, Magnusson 14776 (UPS). Skåne: Bara par., Torup, Arup L04024 (hb. Arup); Bonderup par., Södra Ugglarp, Arup L04021 (hb. Arup); Tommarp, 1916, Magnusson (UPS). Småland: Kalmar par., Kalmar, Nordin 4978 (UPS). Uppland: Björklinge par., Sätuna, Moberg 1108 (UPS). Västergötland: Göteborg, Lundby, Magnusson 603 (UPS). Östergötland: Rök, Nordin 4341c (UPS).

Caloplaca phlogina (Ach.) Flag.

Mém. Soc. Emulat. Doubs: 250 (1886).—*Parmelia citrina* var. *phlogina* Ach. *Method. Lich.:* 180 (1803).—*Lecanora phlogina* (Ach.) Nyl. *Act. Soc. Limn. Bord.* 21: 324 (1857); type: Sweden. Skåne: Lund, at the crossing of Tunavägen and Pälssjövägen, on *Ulmus*, 12 January 2005, Arup L05001 (LD—neotype, selected here; BC, C, GZU, MIN, UPS—isotypes).

Verrucaria flava Hoffm. *Deutschlands Flora:* 198 (1796).

(Figs 3G & H, 10)

Thallus discontinuous to continuous, 0.3–3 cm diam., 0.1–0.2(–0.3) mm thick, consisting of small areoles which are ± completely dissolved into soredia (Fig. 3G & H); areoles 0.1–0.3 mm wide, convex, round to irregular, usually completely dissolved into soredia, sometimes seen here and there;

concolorous with soredia. *Soredia* (25–)30–50(–60) μm , grey, yellow-grey, greenish grey, greenish yellow, pale yellow to yellow, usually thin and loose without cracks. *Prothallus* not observed. *Cortex* poorly developed.

Apothecia usually present but scattered, sessile to slightly raised, round to irregular, zeorine, 0.3–0.8(–1.7) mm wide; disc initially slightly concave, later plane to convex, yellow to orange-yellow, often with thin white pruina; *proper margin* 25–50(–60) μm , lower than, to slightly raised above, the disc, paler than disc, consisting of irregularly radiating, thick-walled hyphae; *thalline margin* 0–75(–125) μm , uneven to sorediate, concolorous with thallus; *epihymenium* yellowish orange, granular interspersed; *hymenium* 55–80 μm thick, hyaline; *hypothecium* 25–65 μm thick, hyaline; *paraphyses* usually simple, sometimes branched once, 1.5–2.5 μm broad with upper cells wider, up to 7 μm ; asci clavate, 45–58 \times 10–12 μm , 8-spored, *ascospores* polaribilocular, ellipsoid to broadly ellipsoid, (9.1–)10.0–13.0(–13.5) \times (4.0–)4.2–6.0(–7.3) μm , septum (2.5–)2.9–4.0(–4.2) μm wide, ratio of septum/spore length (0.22–)0.25–0.35(–0.39).

Pycnidia sometimes present, immersed, orange-yellow. *Conidia* broadly ellipsoid, 2.5–3.0(–3.5) \times 1.2–1.5 μm .

Chemistry. In pale or grey forms the thallus contains low amounts of parietin. More strongly coloured thalli, as well as the apothecia, contain parietin as a major compound, and small amounts of fallacinal, emodin, teloschistin and parietinic acid, which corresponds to chemosyndrome A of Søchting (1997).

Habitat and distribution. *Caloplaca phlogina* seems to be an almost strictly corticolous species, but may occur on wood of standing trees, rarely other types of wood. There are collections of *C. phlogina* from almost all tree genera, including *Pinus* and *Betula*, but there is a strong preference for bark with a high pH, for example, *Ulmus*, *Fraxinus*, and *Acer*. The distribution is similar to *C. flavocitrina* but it seems to be more common in the central, higher parts of southern Sweden

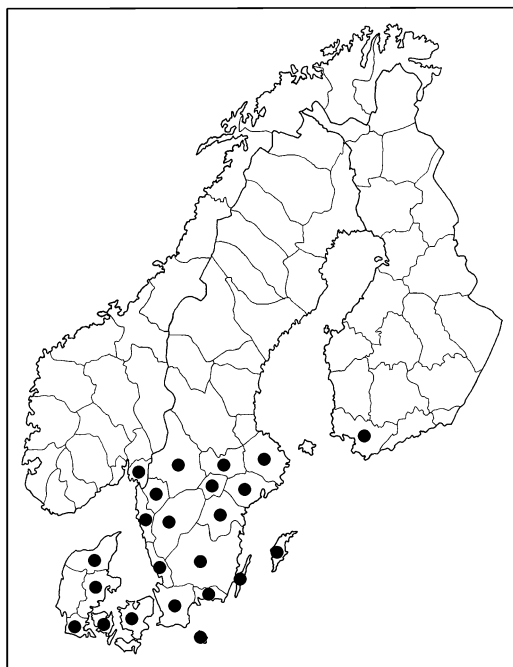


FIG. 10. The distribution of *C. phlogina* in the Nordic countries, except Iceland, based on the material studied.

(Fig. 10). In Norway and Finland only one specimen is known from each country. The Finnish specimen was collected from *Pinus* and is very sparse, but the material seems to agree with *C. phlogina*. In Denmark and southern Sweden it is probably a rather common species on roadside trees, in churchyards and in parks. Outside the study area *C. phlogina* occurs in large areas of Europe, but material outside of Europe has not been investigated.

Remarks. *Caloplaca phlogina* is characterized by the mainly sorediate thallus with only occasional small areoles. The colour is often pale yellow to yellow with contrasting orange-yellow apothecia. Sometimes it is sterile and very pale yellow or grey, and it may be difficult to separate it from an orange-grey form of *Lepraria incana*. This form contains parietin (Lindblom 1995) in addition to divaricatic acid, zeorin, and \pm atranorin. *Caloplaca chrysodeta* is another

similar taxon, that rarely occurs on bark. It differs in the more brownish orange colour, leprose thallus, complete absence of areoles and apothecia, and a strong preference for humid places. Also *C. flavocitrina* has been mistaken for *C. phlogina*, but on bark it always has a large portion of the areoles not dissolved into soredia. Sometimes *Caloplaca ulcerosa* Coppins & P. James is confused with *C. phlogina*, but it has small greenish grey soralia formed as irregular craters that become more diffuse in old specimens. However, there is always a thin grey thallus surrounding the soralia.

Nomenclatural notes. *Caloplaca phlogina* was first recognized by Hoffmann (1796), who described it as *Verrucaria flava*. A few years later Acharius (1803) reduced it to varietal level under *Parmelia citrina*, but he needed a new name for the variety since the epithet Hoffmann had used at species level, *flava*, was occupied by *Parmelia citrina* var. *flava* (bas. *Lichen flavus* Schreb., but now known as *Chrysothrix candelaris*). The species epithet *flava* cannot be taken up for the taxon as long as the species remains in the genus *Caloplaca*, because *C. flava* is occupied by an African saxicolous species.

Acharius used Hoffmann's taxon, but did not cite any material. Hoffmann's material was later destroyed and any specimens that could be used as type was lost. A neotype of this species has therefore been chosen by me.

Selected specimens. **Denmark:** *Bornholm:* D. 47, on the shore from Allinge to Sandkås, *Svane* 87SS7292-2 (C). *Fyn:* D. 31, Our par., Oure by, *Skytte Christiansen* 13103 (C). *Langeland:* D. 34, Skovgård E of Hennestved Avenue, *Svane* 91SS8533-2 (C). *Nordjylland:* D. 3, Læso. Byrum, *Svane* 78SS3574-1 (C). *Sjælland:* D. 42, Årby par., Asnæs, *Skytte Christiansen* 12182 (C, O). *Syddjylland:* D. 49, Gram, *Svane* 87SS7189-1 (C). *Østjylland:* D. 24, SE of Skanderborg, Ring kloster, *Svane* 75SS2335a (C).—**Finland:** *Varsinais-Suomi:* Lojhan kunta, Kirkonkylä, Pykälä 12822 (H).—**Norway:** *Østfold:* Sarpsborg, Skjeberg church, *Bratli* 2142 (O).—**Sweden:** *Bohuslän:* Uddevalla, northern part, *Magnusson* 18154 (S, UPS). *Dalsland:* Ånimskog par., Torp, 1970, *Nilsson* (UPS). *Gotland:* Tingstäde par., Furubjergs, 1932 *Degelius* (UPS). *Halland:* Vallda, the churchyard, *Magnusson* 13794 (UPS). *Närke:* Götunda, Sickelsjö, 1952, *Kjellmert* (O, S, UPS). *Skåne:* Kyrkheddinge par., at

the church, *Göransson* L02055 (LD); Träne par., Ovesholm, 1946, *Almborn* (LD), *Arup* L91077 (hb. Arup). *Småland:* Visingsö par., the island Visingsö, Kumlaby church, *Thor* 9786a (S). *Södermanland:* Dunker par., Björndammen, 1939, *Degelius* (UPS). *Uppland:* V. Ryd par., vid kyrkan, 1949, *Ahlner* (S). *Värmland:* Tveta par., Tveta kyrka, *Sundell* 6031 (UPS). *Västergötland:* Alingsås, Nohaga, *Magnusson* 4159a (UPS). *Västmanland:* Ångsö par., Ångsö castle, *Santesson* 20168b (UPS). *Öland:* Vickleby sn: Tveta, 1944, *Gelting* (C). *Östergötland:* Alvastra, 1914, *Malme* (S).

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