

Revision of the lichen genus *Candelaria* (Ascomycota, Candelariales) in Upper Austria

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Abstract: A first assessment of the distribution and morphology of the revised lichen genus *Candelaria* in Upper Austria is presented. *Candelaria*, originally a monospecific genus in Europe, was expanded by separating a second species which shows distinct morphological and genetical characters (*C. pacifica*). This report summarizes first data and proves an astonishing percental quota of the separated species *C. pacifica* (27.6%) in Upper Austria.

Zusammenfassung: Eine erste Einschätzung zur Verbreitung und Morphologie der revidierten Flechten-Gattung *Candelaria* in Oberösterreich wird vorgestellt. *Candelaria*, eine ursprünglich monospezifische Gattung in Europa, wurde durch die Abtrennung einer zweiten Art erweitert, die deutliche morphologische und genetische Unterschiede zeigt (*C. pacifica*). Dieser Bericht fasst die ersten Ergebnisse zusammen und belegt einen erstaunlichen, prozentuellen Anteil der abgetrennten Art (27.6%) *C. pacifica* in Oberösterreich.

Key Words: *Candelaria*, taxonomy, distribution, Upper Austria.

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Introduction

The small lichen genus *Candelaria*, comprising eight species world-wide, represents a well-known and cosmopolitan group. The genus had been described by only one common species occurring in Europe, *Candelaria concolor*, until the analyses by M. WESTBERG & U. ARUP in 2011 recognized a new species on this continent, *Candelaria pacifica*. Although this species had already been discovered in 1998 by the same authors during lichen field trips in Baja California (USA), it had not yet been properly described. During the studies on *Candelaria* for the Sonoran Lichen Flora by WESTBERG & NASH in 2002, it turned out that the species was similar to *C. concolor*, but differed in the structure of the lower surface and had 8-spored asci. Furthermore it was only collected from the Pacific coast of North America. In the course of time the investigation of herbarium material from Sweden gave convincing evidence for the existence of *C. pacifica* in northwestern Europe and Scandinavia. The paper by M. WESTBERG & U. ARUP, published in 2011, introduced the species as new to science.

The discussion on this topic led the author of the present article to the consideration that many specimens collected in Upper Austria under the taxon *C. concolor* could correspond with the newly described species *C. pacifica*. Encouraged by papers from Germany (BOMBLE 2012, STAPPER 2012, DOLNIK 2013), the

author started revising older specimens and collecting new *Candelariaceae*. Approximately 28% of the specimens turned out to be *Candelaria pacifica*, a legitimate reason to introduce the new species in Upper Austria and probably new to Austria.

After a first statement in an article in ÖKO-L. (NEUWIRTH 2013), this paper is being published for the purpose of giving some details about distribution in our country.

Knowledge about structure and physiology of lichens in general are assumed to be well-known and therefore not mentioned in this publication.

Geographical and geological aspects

The federal province of Upper Austria consists of four quarters in an area of 11,982 km² which have been given geographical names: Hausruckviertel, Innviertel, Mühlviertel and Traunviertel.

From a geological point of view these parts of the country belong to three large geological formations: The Bohemian Massif, the Molasse Zone and the Northern Calcarean Alps.

The Mühlviertel, extending from the border of the Czech Republic in the north to the river Danube in the south, is entirely situated on the „Bohemian Massif“. This geological formation, currently forming a fold residual plateau, consists of eroded cry-



Fig. 1: Habitats of *Candelaria concolor*. - **a**, thallus of *C. concolor* on *Malus* sp., diameter 7 mm (hb. Neuwirth 12010); **b**, thallus and ascocarps of *C. concolor* on bark; apothecia up to 1.8 mm in diameter (LI 540062); **c**, thallus of *C. concolor* on moss; total width of photo 10 mm (LI 541070); **d**, *C. concolor* on granite; total width of photo 6 mm (LI 769406).

stalline rocks such as granite and gneiss, which have their origin in the Middle-European Variscan orogenic system. In some places outcrops of crystalline rocks are visible in the Sauwald south of the Danube.

The central part of Upper Austria, geographically determined by the Innviertel and the Hausruckviertel, reaches from the rivers Inn and Salzach in the west to the river Enns in the east and is characterised by extensively large woodlands in the west (Kobernaubergwald, Hausruckwald) and plains in the eastern part. The geological term „Molasse Zone“ describes a large basin which corresponds with the foothills of the alps, originating from a flat marginal, continental sea named „Paratethys“ which extended from the Rhone to the Alpine foreland in Bavaria and Austria. From the Eocen age to the Miocen period this area was filled with significant tertiary sediments and deposits, e.g. gravel, marl, sands and clay stones. The rock material

developed predominantly from erosion products of older rocks during the alpine tectonic movements.

The Traunviertel is not only the eastern region of the federal province, but above all forms the southern Upper Austria. This is the area of the „Northern Calcarean Alps“ and Upper Austria’s highest elevation, the Dachstein (2995 m) and its typical „limestone facies“ with its many fossil deposits. The sedimentary material was formed by tectonical movements, pressed, folded and stratified in overlying rock strata from the Jura until the tertiary period.

Material and methods

The morphology was studied using a Euromex Mic 1642 ZHT stereo microscope at a magnification of 7-45X and a Rei-

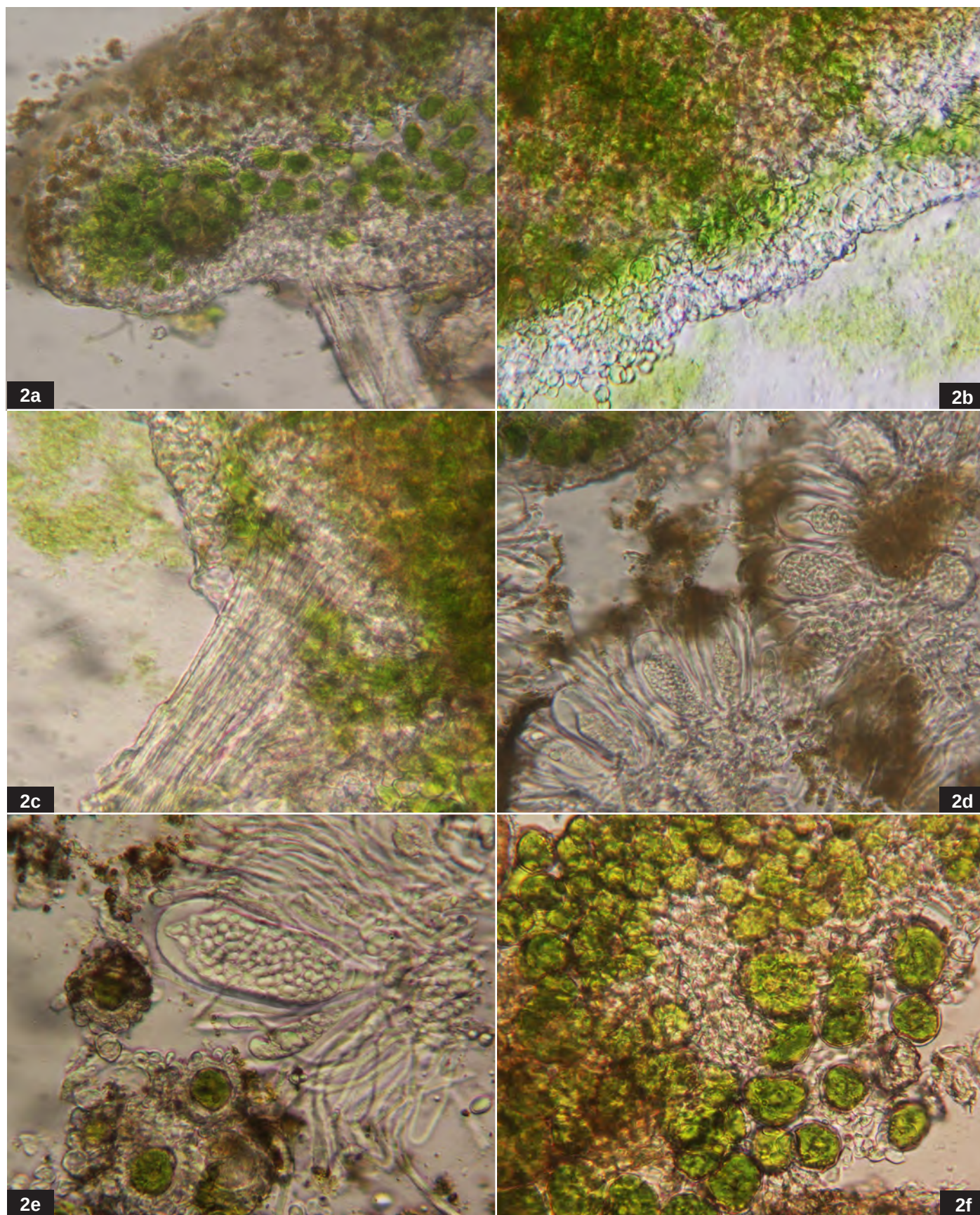


Fig. 2: Anatomical details of *Candelaria concolor*. - **a**, Thalline structure of *C. concolor*: upper cortex (brown), algae (green), lower cortex (white); hb. Neuwirth 12002; **b**, Lower cortex with paraplectenchyma (15-25 µm) and layer of green algae (hb. Neuwirth 12002); **c**, Hyphae forming bunches of rhizines on lower cortex, 25 µm in length (hb. Neuwirth 12010); **d**, Clavate asci and numerous ascospores in hymenium; spore dimensions (8-10 x 4-5 µm); hb. Neuwirth 12010; **e**, Ascus with spores, LI 717929; **f**, Green algae layer in *C. concolor*, diameter of cells 5-15 µm, LI 638537.



Fig. 3: Habitats of *Candelaria pacifica*. - **a**, *C. pacifica* on *Betula pendula*, Ried I/I; **b**, Thallus of *C. pacifica* on *Betula pendula*, d 30 cm; **c**, Habitus of *C. pacifica*, 5 mm in diameter.

chert Neovar compound microscope at a magnification of 10–1000X. The anatomical features were identified by preparing sections of thalli and ascomata mounted in water. All images were taken with a Canon EOS 600D camera connected to a LM-Scope camera adapter and a Sony Cyber-shot camera by G. Neuwirth (2014).

The complete *Candelaria* collection, deposited as *Candelaria concolor* in the herbarium of the Biology Centre of the Upper Austria State Museum in Linz (LI), was investigated as well as many specimens from the private herbarium of the author. The maps of Upper Austria were provided by the Biology Centre Linz and adapted by the author.

Anatomical and morphological features of *Candelaria*

The genus *Candelaria* is closely related to *Candelariella*, but differs in having foliose lobes and well-developed rhizines. The thalli of *Candelariella* are exclusively crustose. Details for identifying *Candelaria* are given by N. STAPPER (2012).

Candelaria concolor (DICKS.) ARNOLD

The species is easy to distinguish by its microfoliose thallus which form distinct rosettes with a diameter of up to 2.4 cm in

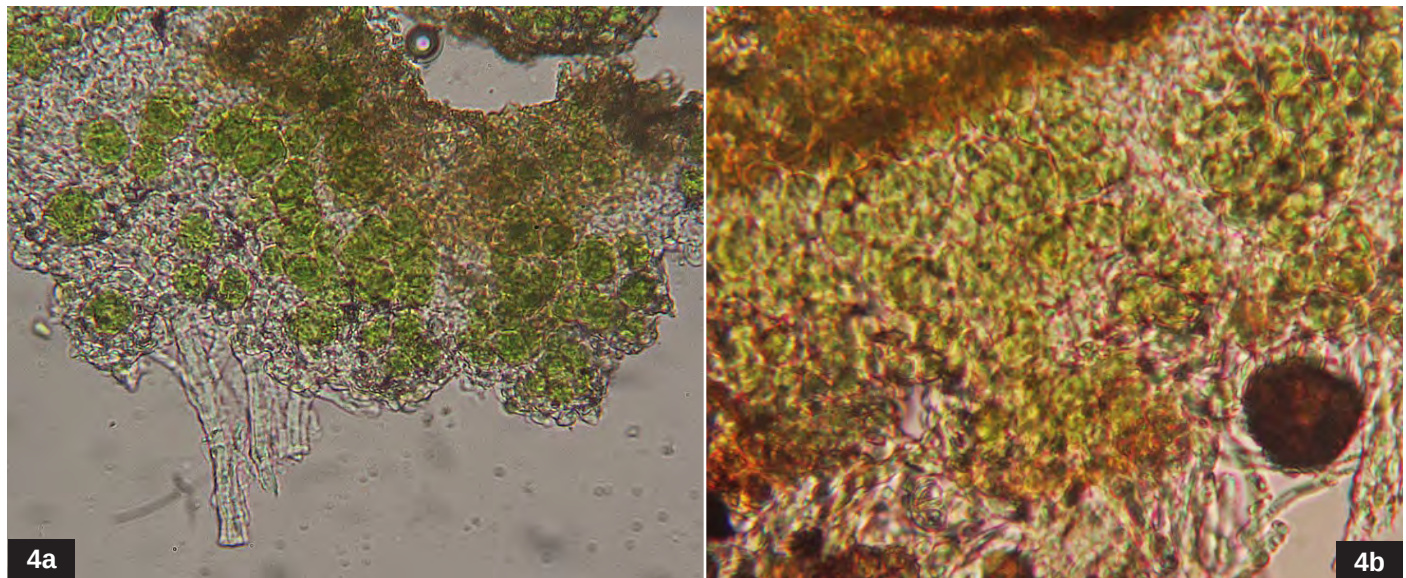


Fig. 4: Anatomical details of *Candelaria pacifica*; **a**, Thallus section 100 µm: upper cortex (brown), algae layer (green), lower surface with diffuse hyphae (white); **b**, Upper cortex (brown), green algae shining through, lacking lower cortex. Note: diffuse, arachnoid structure (60-75 µm) instead of paraplectenchyma.

the examined specimens on different habitats: bark, moss and granite (Fig. 1 A-D). The lobes appear along the substrate and not erected as in *C. pacifica*. The thalline margins develop isidia in most specimens and sometimes small blastidia. The most conspicuous features were seen on the lower surface, which is white, smooth and does not show any arachnoid structures as in *C. pacifica*. POELT (1974) described the lower cortex of *C. concolor* as a 3-4 cell thick paraplectenchyma, built of numerous hyphae and with bundles of white rhizines (Fig. 2 A-C). Furthermore, the production of ascomata could be observed in several specimens having polyspored asci (Fig. 2 D-F). Above all, the lower surface gives the impression of an compact cortex, in contrast to the arachnoid lower surface in *C. pacifica*.

Candelaria pacifica M. WESTBERG & ARUP

The yellow, foliose thalli reach a diameter of only 5 mm (Fig. 3A), however often unite to form large lichen associations of up to 30 cm (Fig. 3B). The thalli, consisting of minute scattered squamules, develop abundant blastidia (35-40 µm in the examined specimens) at the margins, only visible through a magnifying glass (Fig. 3C). The significant feature separating the species from *C. concolor* is the lower surface lacking a cortex (Fig. 4A). This anatomical character gives the lower surface the arachnoid appearance formed by fungal hyphae, white coloured and transparent, mostly presenting the chlorococcoid algae shining through (Fig. 4B).

C. pacifica was originally described having lecanorine apothecia with more or less dark yellow discs, which could be observed rarely in the specimens from the USA. But only one fertile example from Europe was discovered in Turkey.

The results in this report correspond with the paper of WESTBERG & ARUP (2011) and WESTBERG & CLERC (2012). The publication above reports 8-spored asci in contrast to polyspored asci in *C. concolor*.

Unfortunately not any fertile specimen had been found in Upper Austria and therefore the ascospore number could not be determined. V. WIRTH et al. (2013) describe the species as ecologically similar to *C. concolor*.

Nevertheless there is no doubt, that all the remaining characters prove the identity of *Candelaria pacifica*.

Discussion and ecological aspects

Altogether 58 specimens of *Candelaria* with clear combinations of characters could be identified, 42 species as *C. concolor* and 16 belonging to *C. pacifica*. 24 of them are deposited in lichen herbarium of the Biology Center in Linz, 36 specimens

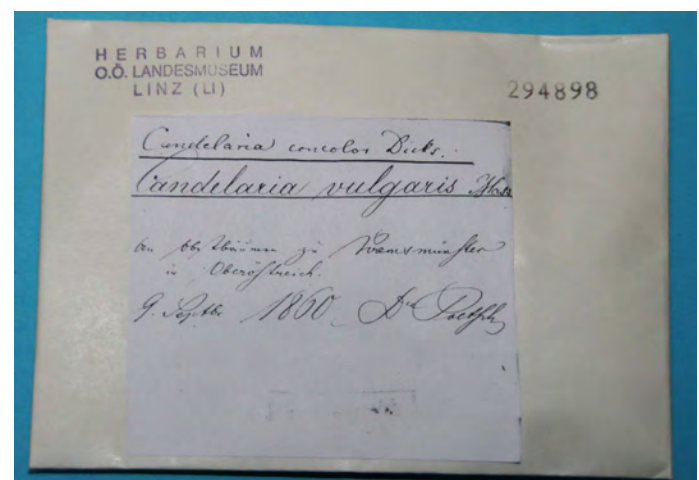


Fig. 5: Original specimen collected as „*Candelaria vulgaris*“ by Dr Pötsch in 1860; LI 294898.

are included in the author’s private herbarium. The oldest specimen, collected by Dr. Pötsch in 1860 in Kremsmünster (Fig. 5), is deposited under the name „*Candelaria vulgaris*“ LI 294898, which has been considered by M. WESTBERG & ARUP (2012) to be a synonym of *C. concolor*. The latest specimens were collected in October 2014 by the author of this paper.

Both species of the genus *Candelaria* can hardly be mistaken for other genera because there is no chemical reaction recognizable in KOH. The similar species *Massjukiella candelaria* reacts in a deep red color by spotting KOH and the KOH-negative *Candelariella reflexa* has a mainly soresiose thallus, intermixed with granules and squamules in green color. The thalli of *C. concolor* and *C. pacifica*, on the other hand, are dominated by an intensive yellow color.

The typical habitats of both species are deciduous trees with nutrient-rich bark in free-standing positions or at the edge of forests. Unfortunately the statistic data are incomplete because some authors did not mention the phorophyts, but the following species of trees have been documented:

Tab. 1: Occurrence of *C. concolor* and *C. pacifica*: 16 species of trees, 2 species on moss, 1 species on granite.

	<i>Candelaria concolor</i>	<i>Candelaria pacifica</i>
<i>Acer campestre</i>	1	
<i>Acer pseudoplatanus</i>	1	1
<i>Aesculus hippocastanum</i>	1	1
<i>Betula pendula</i>	1	2
<i>Fagus sylvatica</i>	1	
<i>Fraxinus excelsior</i>	3	
<i>Juglans regia</i>	3	
<i>Malus</i> sp.	5	
<i>Populus nigra</i>	4	
<i>Populus tremula</i>	2	
<i>Prunus</i> sp.	1	
<i>Pyrus</i> sp.	5	5
<i>Quercus robur</i>	2	5
<i>Sambucus nigra</i>	1	
<i>Thuja occidentalis</i>	1	
<i>Tilia platyphyllos</i>	2	2
Bryophyta	2	
Granite	1	

C. concolor has been collected on the bark of 16 species of trees (Tab. 1), taking a total number of 39 specimens into consideration.

Remarkable specimens are LI 539483 and LI 541070, found on moss (Fig. 1C). An unusual find is the occurrence of *C. concolor* on rocks (LI 769406). In 2005, F. PRIEMETZHOFFER collected the species from granites in the eastern Mühlviertel, which might be the only documented specimen from Upper Austria (Fig. 1D). In lichen literature this habitat has been categorized as rare (SMITH et al. 2009) or has not been mentioned at all.

10 specimens were collected from the bark of *Malus* sp. and *Prunus* sp., so these fruit-trees might be a dominant habitat in this investigation on *Candelaria*.

Acknowledgements

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Appendix - specimens examined

Candelaria concolor in Upper Austria



Fig. 6: Currently known distribution of *C. concolor* in Upper Austria (red).

- 1 Innviertel, Tumeltsham, 2 km NE of Ried i/I, River Antiesen, on a felled *Populus* sp., 443 m; N 48°13'10.8"/E 13°30'29.8"; Neuwirth 11804.
- 2 Innviertel, Tumeltsham, 2 km NE of Ried i/I; *Malus* sp. on private property, 448 m; 01.09.2013; N 48°13'09.1"/E 13°30'26.7"; Neuwirth 12010.
- 3 Innviertel, Neuhausen, Pattighamried, *Malus* sp. on private property, 485 m, 04.09.2013; N 48°10'17.7"/E 13°28'01"; Neuwirth 12011.
- 4 Innviertel, Reichersberg, below the convent, riparian forest by the river Inn, on *Betulus* sp., 323 m, 24.07.2012; N 48°20'25.1"/E 13°21'37"; Neuwirth 11837.
- 5 Traunviertel, Kirchdorf, Windischgarsten, Gasthof Wurzbauer, 850 m, on *Sambucus nigra*; MTB 8252/3; N 47°43'33"/E 14°20'27"; leg. Susanne Wagner, Türk 48312; LI 717921.
- 6 Traunviertel, Spittal am Pyhrn, tree-lined road, W. Hausmayr, MTB 8352/1, 620 m; *Aesculus hippocastanum*; 02.10.1987; leg. Susanne Wagner, det. R. Türk 26588; LI 537584.
- 7 Mühlviertel, Linz Dornach/ Auhof, northern banks of the Danube; Breuß 29172, LI 638537.
- 8 Traunviertel, Krenglbach, SW of Buchkirchen, on *Malus domestica*, 320 m; MTB 7750/3; 03.04.1999; leg. et det E. Schininger; LI 420691.
- 9 Traunviertel: „An Obstbäumen zu Kremsmünster in Oberösterreich, 9. Sept. 1860, Dr. Poetsch"; Hb. Schiedermayr; LI 294898.
- 10 Traunviertel, Pyhrn-Eisenwurzen, Losenstein, Nagelschmiedweg from Stiedelsbach to Kesselbach, c. 400–530 m; 21.05.2002, Breuß 20565; LI 485725.
- 11 Traunviertel, Steyr, Wolfers, Gründberg, 370 m, on *Juglans regia*; MTB 7952/1; N 48°04'04.5"/E 14°10'39.5"; 14.08.2000: W. Mayer L 1303; LI 490474.
- 12 Traunviertel, Steyr, Garsten, Dambachtal, above Grabenbauer, on *Juglans regia*, 580 m. N 47°58'26.8"/E 14°27'46"; W. Mayer 1930; LI 490588.
- 13 Traunviertel, Steyr, Christkindl, Schwaming, 365 m, on *Juglans regia*; MTB 7952/3; N 48°02'17.8"/E 14°20'57.6"; 15.07.2001. W. Mayer L 1344; LI 490487.
- 14 Traunviertel, Flora of Windischgarsten, leg. et det. Susanne Wagner, 1995/96; LI 468295.
- 15 Mühlviertel, Rottenegg, "on *Thuja occidentalis*"; Dr. H. Haslinger, Aug. 1928; LI 300041.
- 16 Traunviertel, Kirchdorf a. d. Krems, city park, MTB 8050/4; 26.03.1996; leg. S. Wagner, rev. H. Wittmann, LI 606240.
- 17 Traunviertel, Scharnstein, banks of the river Alm, on *Malus domestica*, 490 m, MTB 8049; leg. Türk; LI 71482.
- 18 Hausruckviertel, E of Neumarkt, W Michaelnbach, Unterreitbach, 390 m, on *Fraxinus excelsior*; MTB 7748/2; 30.10.1999. E. Schininger 1490; LI 420688.
- 19 Traunviertel, Windischgarsten, SE of Hengstpass, Puglalm, 920 m, on moss on limestones, 05.10.1987; MTB 8352/2, leg. S. Wagner; Türk 29810; LI 539483.
- 20 Traunviertel, Ebensee, near Langwieserstraße, 440 m, on *Acer pseudoplatanus*; MTB 8148; 03.11.2000; leg. S. Brennsteiner; Türk 29915; LI 540062.
- 21 Traunviertel, Kremsmünster, Windfeld, 420 m, on *Pyrus communis*, MTB 7950, 22.02.1998; Türk 24855; LI 541742.
- 22 Innviertel, Gemeinde Eggelsberg, Heratingersee, 1.3 km NW of Ibml, 425 m; N 48°04'20"/E 12°57'00". 10.07.1995, leg. et det. M. Strauch; LI 606307.
- 23 Innviertel, MTB 4777, Güterweg Obermauer, 4 km SE of Peterskirchen, on *Pyrus* sp. along the road, c. 450 m, 28. 09.2014. Neuwirth 12202.
- 24 Innviertel, MTB 4777, E of Geiersberg, Oberrühling 3, Haus Genböck; on *Malus* sp., 28.09.2014; Neuwirth 12206.
- 25 A: Innviertel, MTB 4777, Ried im Innkreis; new city park, Schönaauerweg; on *Populus* sp., 430 m; 16.04.1996; Neuwirth 3501; c. Apo. B: Steinbauerweg, on *Prunus* sp.; 445 m, 23.02.1997; Neuwirth 3562. C: Roseggerstr.36, on *Tilia* sp.; 440 m, 22.05.1997; Neuwirth 3624. D: Hohenzellerstr., on *Pyrus* sp., 450 m, 05.04.1996; Neuwirth 3468, 3469.
- 26 Innviertel, Graben am Inn, Gaishofer Auen, on *Populus nigra*, 337 m; 05.02.1990; Neuwirth 1940, 1942, 1944.
- 27 Innviertel, Atzing, Kraxenberg, 7 km W of Ried, on *Quercus robur*, 460 m, 02.01.1990; Neuwirth 1790.
- 28 Innviertel, Bruck bei Palting, 9 km W of Friedburg, 3.2 km N of Mattsee; on *Fraxinus exc.*, 495 m; N 48°00'54.2"/E 13°07'20.2", 22.04.1990; Neuwirth 2200.
- 29 Innviertel, Sauwald, Königsedt, Mitteredt, on *Pyrus communis*, 740 m, N 48°27'04.7"/E 13°41'31", 05.05.1990; Neuwirth 2224.
- 30 Innviertel, Geretsdorf, 8 km SE Braunau, 3 km NW of Mauerkirchen, on *Populus nigra*, 407 m, N 48°08'20.4"/E 12°50'36.3", 20.05.1990; Neuwirth 2267.
- 31 Innviertel, Schwand, Ginshörling, 10 km SW of Braunau, 6 km W of Neukirchen, on *Populus nigra*, 421 m; N 48°10'37"/E 12°58'01.4", 24.05.1990; Neuwirth 2277.
- 32 Innviertel, St. Radegund, on *Acer campestre*, 380 m; N 48°04'13.3"/E 12°45'27.8"; 13.03.1990; Neuwirth 2081.

- 33 Innviertel, Mehrnbach, 3 km W Ried i/I; on *Fraxinus excelsior*, 390 m, N 48°12'45.8"/E 13°26'18.1"; 14.09.1990; Neuwirth 2135.
- 34 Innviertel, Eggenberg; 5.3 km E of Schärding, 2.5 km W of Rainbach; on *Tilia* sp., 439 m; N 48°26'45.1"/E 13°30'11.5"; 11.08.1990; Neuwirth 2436.
- 35 Innviertel, Simling, 4.5 km NW of Ostermiething, 2 km E of Tittmoning; reparation forest of the Salzach, on *Populus* sp., 383 m, N 48°03'04"/E 12°47'50.7"; 18.07.1999; Neuwirth 5062.
- 36 Hausruckviertel, Frankenburg, on the way from Mitterriegel to Rothhauptberg; at the edge of the forest, on *Fagus sylvatica*, 11.05.2008. Neuwirth 9355.
- 37 Innviertel, Überackern, reparation forest of the river Salzach, 356 m, on *Fraxinus excelsior*, 21.07.1990; N 48°11'35.2"/E 12°51'53.3". Neuwirth 2368.
- 38 Innviertel, 3.6 km NW of Burghausen, 13.1 km SW of Braunau, reparation forest of Salzach, 360 m; N 48°15'23.1"/E 13°01'; Neuwirth 2368.
- 39 Hausruckviertel, Grünberg, 3 km N of Frankenburg, on *Acer platanoides*, 610 m, Neuwirth 8698.
- 40 Mühlviertel, Struden, Burg Werfenstein, between Grein and St. Nikola, 250 m, on granite; rare. Priemetzhofer 5579, LI 769406.
- 41 Mühlviertel, Freistadt, on deciduous trees; Priemetzhofer 1999.
- 42 Traunviertel, SE of the Hengstpaß, Puglalm, on moss on limestones within a pasture, 800 m, 17.04.1988; leg. S. Wagner; Türk 29300; LI 541070.
- 7 Hausruckviertel, NW of Neumarkt, SW of Pehring, 400 m, on *Pyrus communis*; MTB 7748/1; 01.11.1999; E. Schininger 1584, LI 420687.
- 8 Hausruckviertel, W of Eferding, Alkoven, Aham, 260 m, on fruit tree; MTB 7650/3; 02.11.1998. E. Schininger 435; LI 420686.
- 9 Traunviertel, Kremstal, Micheldorf, on *Acer pseudoplatanus*, 28.08.1973; leg. Türk; LI 71481.
- 10 Innviertel, Taufkirchen a. d. Pram, „Straßenbäume bei Milchtrockenwerk“, 385 m, 17.02.1967; leg. F. Grims, det. Klement (als *C. concolor*).
- 11 Innviertel, Lamprechten, on the Kochbach, on *Quercus robur*, 380 m, 21.04.1990; Neuwirth 2171.
- 12 Innviertel, Ried im Innkreis, Kasernstraße, cemetery, on *Aesculus hippocastaneum*; 21.09.2014; Neuwirth 12199.
- 13 Innviertel, 7 km S of Pram, 1.5 km W of Pramerdorf, Rödham, on *Tilia* sp., 28.09.2014; Neuwirth 12204.
- 14 Innviertel, 1 km NW of Pattigham, 0.4 km SE of Parz; 510 m, of *Quercus robur*, 29.09.2014; N 48°09'45.2"/E 13°27'48.7". Neuwirth 12227.
- 15 Hausruckviertel, Redleiten near Frankenburg, 554 m, on *Quercus robur*; N 48°04'52.5"/E 13°28'09.1". Neuwirth 12228.
- 16 Innviertel, Zell an der Pram, Reischenbach; on *Quercus robur*, 370 m; 17.03.1990; N 48°18'09.3"/E 13°37'49.3", 434 m; Neuwirth 2025.

Candelaria pacifica in Upper Austria

- 1 **A:** Innviertel, Ried i/I, Bahnhofstr. 56, in front of the court building, 450 m, on *Quercus* sp., 03.07.2012; Neuwirth 11814.
B: Innviertel, Ried i/I, Kasernstr., along the cemetery, on *Betula pendula*, 430 m, 15.09.2013, N 48°12'/E 13°30'; Neuwirth 3580, 12041, 12042, 12043.
C: Innviertel, Ried i/I, cemetery car park, on *Betula pendula*, 13.11.2012; Neuwirth 11952, 11955.
- 2 Innviertel, Tumeltsham, Rabenberg, on *Pyrus* sp., 30.12.2012; Neuwirth 11958.
- 3 Hausruckviertel, Geiersberg, Oberrühring, on *Tilia* sp., 480 m, 10.09.1989; Neuwirth 1594.
- 4 Traunviertel, SE from Eferding, Emlinger Holz, 260 m, auf *Pyrus communis*, MTB 7750/1; 29.06.1998; E. Schininger 394, LI 420690.
- 5 Traunviertel, E from Wels, Schleißheim, road in the direction of Ottsdorf and Blindenmarkt, Dietach, 320 m, auf *Pyrus communis*; MTB 7850/1-2; 13.06.1999; leg. Schininger 943, LI 420692.
- 6 Mühlviertel, Putzleinsdorf: „An einem Birnbaum im Garten des Gasthauses Huber, mit einer Buellia“. Leg. Dr. Haslinger 1090, 27.07.1958.



Fig. 7: Currently known occurrence of *C. pacifica* in Upper Austria (yellow).

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