

## Supplementary Material 1.

### A worldwide key to the lichenicolous fungi on *Verrucaria* s.lat. (incl. *Bagliettoa*, *Placopyrenium*)

This key was created based on the literature sources (protologue or sources which reported species on *Verrucaria* s.lat.) cited below to each species “Lit.:". Lichenicolous fungi inhabiting exclusively *Verrucaria* s.str. are given in bold font. The sizes of diaspores are rounded to the nearest 0.5 µm.

1. Spores produced in asci .....2
- 1\*. Spores not produced in asci. Conidiophores agglutinated in black synnemata, conidiogenous cell monoblastic, conidia cuneiform grey-brown, 6.5–8 × 3–4 µm. Host: *Verrucaria bryoctona*. Lit.: MOTIEJŪNAITĖ & ALSTRUP 2006 ..... ***Graphium samogiticum*** Motiej. & Alstrup
2. Ascomata apothecioid, rarely lirellate or stromatic ..... 3
- 2\*. Ascomata perithecioid or sometimes catathecioid ..... 14
3. Ascomata lirelliform, with a slit-like opening ..... 4
- 3\*. Ascomata disk-like .....9
4. Ascospores 3-septate.....5
- 4\*. Ascospores 1-septate, light brown, ellipsoid, 19–22 × 10–12 µm. Host: *Verrucaria* sp. (sterile). Lit.: VOUAUX 1913 ..... *Melaspilea leciographoides* Vouaux
5. Ascomata aggregating to clusters up to 0.5 mm or not ..... 6
- 5\*. Ascomata aggregating to gall-like strongly convex clusters up to 1–1.2 mm diam., ascospores (1–)3-septate, < 5 µm wide. Host: *Verrucaria nigrescens*, *V. viridula*. Lit.: COPPINS *et al.* 2021..... ***Opegrapha opaca*** Nyl.
6. Ascomata scattered, not forming clusters.....7
- 6\*. Ascomata forming clusters ..... 8
7. Ascospores 6–10 µm wide. Host: *Verrucaria buschirensis*. Lit: STEINER 1896; KONDRATYUK & KUDRATOV 2002 ..... *Opegrapha insidens* (J. Steiner) S.Y. Kondr.
- 7\*. Ascospores 4–5(–5.5) µm wide. Host: *Verrucaria aethiobola*. Lit.: ERTZ *et al.* 2021..... ***Opegrapha inconspicua*** Ertz, S.R. Clayden &K.E. Driscoll
8. Clusters large 350–500 µm in diam., exciple olive brown in K and red-pinkish brown in N. Host: different Verrucariaceae species including *Bagliettoa calciseda* and *Verrucaria hochstetteri*. Lit.: e.g. VONDRÁK & KOCOURKOVÁ, 2008 ..... *Opegrapha rupestris* Pers. (incl. *O. centrifuga*)
- 8\*. Clusters 150–200 µm in diam., exciple reddish brown in K and fuscous brown in N. Host: *Verrucaria hochstetteri* and *V. muralis* Lit.: COPPINS *et al.*, 2021..... ***Opegrapha hochstetteri*** Coppins
9. Ascomata stromatic, visually resembling apothecia, up to 200 µm in diam, asci 8-spored, ascospore 1-septate, light brown 25.5–30 × 11.5–15 µm. Host:

	<i>Bagliettoa marmorea</i> and other calcicolous Verrucariaceae species. Lit.: ATIENZA & HAWKSWORTH 2008 .....	
	..... <i>Lichenothelia renobalesiana</i> D. Hawksw. & V. Atienza	
<b>9*</b>	Ascomata apothecia .....	<b>10</b>
<b>10</b>	Ascomata with long excipular hairs .....	<b>11</b>
<b>10*</b>	Ascomata without long excipular hairs.....	<b>12</b>
<b>11</b>	Excipular hairs 20–35 µm long, ascospores 6–7(–7.5) × 1.5–2 µm. Host: <i>Verrucaria nigrescens</i> . Lit.: HAWKSWORTH 1982 .....	
	..... <i>Skyttea spinosa</i> D. Hawksw. & Coppins	
<b>11*</b>	Excipular hairs 30–60(–80) µm long, ascospores 6–8(–10) × 2–2.5 µm. Host: <i>Verrucaria</i> spp. Lit.: DIEDERICH 1986 .....	
	..... <i>Skyttea hawksworthii</i> Diederich	
<b>12</b>	Ascospores ellipsoid 1-septate. Host: <i>Verrucaria</i> spp. Lit.: TIMDAL 1991 .....	
	..... <i>Toninia verrucariae</i> (Nyl.) Timdal	
<b>12*</b>	Ascospores narrowly ellipsoid to bacilliform, 2- and more septate .....	<b>13</b>
<b>13</b>	Ascomata convex immarginate up to 0.4 mm, epihymenium dark bluish grey or blackish K+ violetish, ascospore 1(2–)3-septate, 13–19(–21) × (2.5–)3–4 µm. Host: <i>Placopyrenium fuscillum</i> . Lit.: KONDRATYUK <i>et al.</i> 2016 .....	
	..... <i>Toninia poeltiana</i> S.Y. Kondr., Lökös & Hur	
<b>13*</b>	Ascomata plain with a narrow and more or less persistent margin up to 0.6 mm, epihymenium olivaceous green to dark green K–, (2–)4(–6)-septate, 9.5–16 × 4.5–5.5 µm. Host: <i>Verrucaria nigrescens</i> Lit.: BRACKEL 2014 .....	
	..... <i>Toninia subfuscae</i> (Arnold ex Zwackh) Timdal	
<b>14</b>	Ascomata catathecioid .....	<b>15</b>
<b>14*</b>	Ascomata perithecioid .....	<b>16</b>
<b>15</b>	Asci 45–66 × 8–13 µm, ascospores (0–)1(–3)-septate, (9–)12.5–15(–17) × 5–6 µm. Host: <i>Verrucaria muralis</i> , <i>Verrucaria</i> sp. Lit.: EARLAND-BENNETT & HAWKSWORTH 1999 .....	
	..... <i>Lichenopeltella coppinsii</i> Earl.-Benn. & D. Hawksw.	
<b>15*</b>	Asci 45–50 × 14.5–16 µm, ascospores 1-septate, 13.5–16 × 4–5 µm. Host: <i>Verrucaria hydrela</i> , <i>V. pinguicula</i> and <i>V. pratermissa</i> . Lit.: SANTESSON 2001 .....	
	..... <i>Lichenopeltella hydrophila</i>	
<b>16</b>	Asci up to 8-spored .....	<b>17</b>
<b>16*</b>	Asci 64–100-spored, ascospores 1-septate, broadly ellipsoid, brown, (4.5–)5–6(–8) × (1.5–)2–3(–3.5) µm. Host: <i>Verrucaria nigrescens</i> , <i>Verrucaria</i> spp. Lit.: BRACKEL 2014 .....	
	..... <i>Muellerella lichenicola</i> (Sommerf.) D. Hawksw.	
<b>17</b>	Ascospores hyaline .....	<b>18</b>
<b>17*</b>	Ascospores brown to dark brown .....	<b>36</b>
<b>18</b>	Ascospores 0-septate .....	<b>19</b>
<b>18*</b>	Ascospores 1–3-septate .....	<b>23</b>

19. Ascospores ellipsoid, (5.0–)6.0–7.5(–8.0) µm wide, asci fissitunicate, (12.0–)13.0–14.0(–14.5) µm wide. Host: <i>Bagliettoa calciseda</i> . Lit.: DARMOSTUK 2019 .....	..	<i>Zwackhiomyces lecanorae</i> s.lat.	
19*. Ascospores distinctly bacilliform, up to 3 µm wide, asci unitunicate, 6–9 µm wide .....			<b>20</b>
20. Ascospores distinctly s-shaped, 12–18 × 2–3 µm. Host: <i>Bagliettoa</i> gr. <i>parmigera</i> . Lit.: TRETIACH & NAVARRO-ROSINÉS 1996 .....		<i>Sarcopyrenia sigmoideospora</i> Tretiach & Nav.-Ros.	
20*. Ascospores strain .....			<b>21</b>
21. Ascospores > 30 µm long .....			<b>22</b>
21*. Ascospores (11)–15–21 µm long. Host: <i>Verrucaria flavicans</i> . Lit.: NAVARRO-ROSINÉS & HLADUN 1990 .....		<i>Sarcopyrenia bacillospora</i> Nav.-Ros. & Hladun	
22. Ascospores (36–)43–51(–54) × 1.5–2 µm, thicker in the central part, both ends finally gradually pointed. Host: <i>Bagliettoa calciseda</i> . Lit.: NAVARRO-ROSINÉS <i>et al.</i> 1998 .....		<i>Sarcopyrenia acutispora</i> Nav.-Ros. & Cl. Roux	
22*. Ascospores (41–)42–45(–60) × 1–1.5 µm, thick throughout the length, rounded on both ends. Host: <i>Verrucaria nigrescens</i> . Lit.: NAVARRO-ROSINÉS & HLADUN 1990 .....		<i>Sarcopyrenia beckhausiana</i> (J. Lahm) M.B. Aguirre, Nav.-Ros. & Hladun	
23. Ascomata brown .....			<b>25</b>
23*. Ascomata orange .....			<b>24</b>
24. Ascomata orange, immersed on host thalli, asci 8-spored, ascospores 1-septate, 16–21 × 5–7 µm. Host: <i>Verrucaria hochstetteri</i> (as <i>V. integra</i> ), <i>Verrucaria muralis</i> . Lit.: VOUAUX 1912; ROSSMAN <i>et al.</i> 1999 .....		<i>Pronectria verrucariae</i> (Vouaux) Lowen	
24*. Ascomata orange to brownish orange, superficial on host thalli, asci 4-spored, ascospores 1-septate, 12–19 × 6–9 µm. Host: <i>Verrucaria floerkeana</i> . Lit.: BRACKEL 2014 .....		<i>Nectriopsis indigens</i> (Arnold) Diederich & Schroers	
<b>Notes.</b> MOLITOR & DIEDERICH (1997) consider this species as fungicolous on <i>Naetrocymbe saxicola</i> .			
25. Ascomata up to 250 µm in diam. ....			<b>26</b>
25* Ascomata > 250 µm in diam. ....			<b>35</b>
26. Pigment of the peridial cells granulose and located in the intercellular area.....			<b>27</b>
26*. Pigment of the peridial cells amorphous, located in the cell walls .....			<b>29</b>
27. Ascomata up to 200 µm in diam .....			<b>28</b>
27*. Ascomata (190–)205–220(–270) µm in diam., asci (6–)8-spored, ascospores (21.0–)25.5–30.0(–34.5) × (8.5–)9.0–10.5(–11.5) µm. Host: <i>Verrucaria nigrescens</i> . Lit.: this paper .....		<i>Zwackhiomyces khodosovtsevii</i>	
28. Ascomata 60–130 µm in diam., asci 8-spored, ascospores 14.5–17 × 7–8.5 µm. Host: unidentified Verrucariaceae, <i>Verrucaria nigrescens</i> . Lit.: ROUX <i>et coll.</i> 2014; DARMOSTUK 2019 .....		<i>Zwackhiomyces calcisedus</i>	

28. Ascomata 100–140 µm in diam., asci 4–6-spored, 45–65 × (14–)15–22(–25) µm, ascospores (17.0–)18.0–20.5(–24.5) × (5.5–)6.5–8.0(–8.5) µm. Host: <i>Verrucaria nigrescens</i> . Lit.: GRUBE & HAFELLNER 1990; DARMOSTUK 2019 .....	<i>Zwackhiomyces lithoiceae</i>	
29. Ascospores < 20 µm long .....		<b>31</b>
29* Ascospores > 20 µm long .....		<b>30</b>
30. Ascospores 21–22 × 6–9 µm. Host: <i>Verrucaria anceps</i> . Lit.: BOULY DE LESDAIN 1910 .....	<i>Pharcidia maritima</i> B. de Lesd.	
30*. Ascospores 21–23 × 3–4 µm. Host: <i>Verrucaria margacea</i> . Lit.: ARNOLD 1893 .....	<i>Pharcidia verrucariarum</i> (Arnold) Sacc. & D. Sacc.	
31. Asci 8-spored .....		<b>32</b>
31. Asci 4-spored. Host: crustose Verrucariaceae. Lit.: ETAYO 1994.....	<i>Stigmatidium tetrasporum</i> Etayo	
32. Ascospores 12 × 4 µm. Host: <i>Verrucaria maculiformis</i> . Lit.: ARNOLD 1976 ... .....	<i>Stigmatidium lichenum</i> (Arnold) Triebel & P. Scholz	
<b>Notes.</b> BOULY DE LESDAIN (1910) reported it as <i>Pharcidia lichenum</i> Arn. on <i>Verrucaria papillosa</i> with bigger ascospores 14–16 × 6–6.5 µm.		
32*. Ascospores > 12 µm long .....		<b>33</b>
33. Asci > 15 µm wide .....		<b>34</b>
33* Asci 10–15 µm wide, ascospores 10–15 × 4–6 µm. Host: <i>Verrucaria mucosa</i> . Lit.: SWINSCOW 1965 .....	<i>Stigmatidium marinum</i> (Deak.) Swinscow	
34. Asci 44–47 × 15–19 µm, ascospores 12.5–15.5–18.0 × 5–5.5–6.5 µm. Host: <i>Verrucaria nigrescens</i> and <i>V. viridula</i> . Lit.: ROUX & NAVARRO-ROSINÉS 1994 .....	<i>Stigmatidium clauzadei</i>	
34*. Asci 35–48 × 14–20 µm, ascospores 15–16 × 5–6 µm. Host: freshwater Verrucariaceae incl. <i>Verrucaria aquatilis</i> , <i>V. hydrophila</i> , <i>V. pachyderma</i> , <i>V. praetermissa</i> . Lit.: Arnold 1893; SHIVAROV 2017 .....	<i>Stigmatidium rivulorum</i>	
<b>Notes.</b> Other authors report smaller ascospores 12.5–14.3 × 5.4–6.3 µm (VOUAUX 1912) and 11–15 × 5–6 µm (ZHURBENKO & HAFELLNER 1999).		
35. Mature ascospores 3-septate, 15–26 × 6–8 µm. Host: <i>Verrucaria viridula</i> . Lit.: NAVARRO-ROSINÉS & ROUX 1996 .....	<i>Clauzadella gordensis</i> Nav.-Ros. & Cl. Roux	
35*. Ascospores 1-septate .....		<b>37</b>
36. Ascospores 19–20–23 × 4–4.5–7.0 µm. Host: <i>Verrucaria nigrescens</i> . Lit.: NAVARRO-ROSINÉS & HLADUN 1994 .....	<i>Rhagadostoma rugosum</i> Nav.-Ros. & Hladun	
36*. Ascospores 11–13–17 × 6.0–6.5–9 µm. Host: <i>Verrucaria</i> sp. Lit.: NAVARRO-ROSINÉS & HLADUN 1994 .....	<i>Rhagadostoma verrucariarum</i> Nav.-Ros. & Hladun	
37. Ascospores muriform .....		<b>38</b>
37* Ascospores non-septate to transseptate .....		<b>40</b>
38* Ascospores ellipsoid, > 22 µm long .....		<b>39</b>

38. Ascospores broadly ellipsoid to subsphaerical, 11.5–15(–18) × (6.5–)7.5–10(–12) μm. Host: *Verrucaria dufourii*. Lit.: TRIEBEL 1989; HAFELLNER 2011 .....*Halospora discrepans* (J. Lahm ex Arnold) Hafellner
39. Ascospores 18–27.5–31 × 10–15–17 μm. Host: *Verrucaria hochstetteri*. Lit.: ROUX *et al.* 2002; HAFELLNER 2011 .....*Halospora deminuta* (Arnold) Tomas. & Cif.
- 39\*. Ascospores 24–26 × 6.5–9 μm. Host: *Verrucaria hydrela*, *Verrucaria* sp. Lit.: HAWKSWORTH 1986 ..... *Pyrenidium hetairizans* (Leight.) D. Hawksw.
40. Ascospores 0-septate. Host: *Verrucaria hochstetteri*. Lit.: MATZER & HAFELLNER 1990; NAVARRO-ROSINÉS *et al.* 1994 .....  
.....*Adelococcus interlatens* (Arnold) Matzer & Hafellner
- 40\*. Ascospores 1- or more septate .....41
41. Ascospores up to 22 μm long .....42
- 41\*. Ascospore > 22 μm long .....44
42. Asci 2-spored. Host: *Bagliettoa baldensis*. Lit.: HAWKSWORTH & DIEDERICH 1988 .....  
.....*Polycoccum dzieduszkykii* (Boberski) D. Hawksw.
- 42\* Asci 8-spored.....43
43. Ascospores 2–3-septate, 22–25 × 6–7 μm. Host: *Verrucaria placynthii*. Lit.: ALSTRUP & HANSEN 2002.....*Phaeospora verrucariae* Alstrup & E.S. Hansen
- 43\*. Ascospores 1-septate, (20–)25–30(–36) × 14–18 μm. Host: *Bagliettoa calciseda*. Lit.: HAWKSWORTH & DIEDERICH 1988 .....*Polycoccum marmoratum*
44. Interascal tissue (hamathecium) absent, asci 8-spored .....45
- 44\*. Interascal tissue (hamathecium) present, asci initially 8-spored, then reduced to 1–7 per ascus, ascospores 18–20 × 6.5–7.5 μm. Host: *Verrucaria latebrosa*. Lit.: SHIVAROV 2019 .....*Clypeococcum hemiamyloideum* Shivarov
45. Ascospores distinctly verruculose, 10–12(–12.5) × 5.5–7.5 μm. Host: *Verrucaria macrostoma*, *V. nigrescens*, *V. viridula*. Lit.: SÉRUSIAUX *et al.* 1999 .....  
.....*Endococcus rugulosus* s.str.
- 45\*. Ascospores smooth walled, 10–12 × 6.5–7 μm. Host: *Verrucaria nigrescens*. Lit.: TRIEBEL 1989; BRACKEL 2014 .....*Endococcus propinquus* s. lat