

**The genera *Phillipsia*, *Chlorociboria* and *Cookeina* (Ascomycota) in
Brazil and keys to the known species**

**Os gêneros *Phillipsia*, *Chlorociboria* e *Cookeina* (Ascomycota) no Brasil
e chave para identificação das espécies conhecidas**

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ABSTRACT

Ascomycota represent the largest and most diverse group of fungi in the world and can be found in many different habitats. Unfortunately, the number registered for Brazil is

low, even lower than Basidiomycota, especially due to the lack of taxonomists interested in the group. The present work aimed to study the diversity of the genera *Chlorociboria*, *Cookeina* and *Phillipsia* in Brazil and contribute to the easy recognition of species of these genera with the elaboration of identification keys to all species known. Using the bibliographic references citing the three genera, a list of recognized species was elaborated to Brazil and to the world. Field samples were taken in the Pampa Biome, Southern Brazil to identify occurrences in this area. Five species of *Cookeina*, 4 *Phillipsia* and 2 *Chlorociboria* were recognized as occurring in Brazil. Keys to all species known of *Chlorociboria* (27 species), *Cookeina* (12) and *Phillipsia* (26) are proposed and the distribution of all species presented.

Keywords: fungi, apothecia forming, diversity, taxonomy, mycogeography.

RESUMO

Os Ascomycota representam o maior e mais diverso grupo de fungos do mundo e podem ser encontrados em muitos habitats diferentes. Infelizmente, o número registrado para o Brasil é baixo, ainda menor que o de Basidiomycota, principalmente pela falta de taxonomistas interessados no grupo. O presente trabalho teve como objetivo estudar a diversidade dos gêneros *Chlorociboria*, *Cookeina* e *Phillipsia* no Brasil e contribuir para o fácil reconhecimento de espécies desses gêneros com a elaboração de chaves de identificação para todas as espécies conhecidas. A partir das referências bibliográficas dos três gêneros, foi elaborada uma lista de espécies reconhecidas para o Brasil e para o mundo. Amostras de campo foram realizadas no Bioma Pampa, Sul do Brasil, para identificar ocorrências nesta área. Cinco espécies de *Cookeina*, 4 *Phillipsia* e 2 *Chlorociboria* foram reconhecidas como ocorrendo no Brasil. Chaves para todas as espécies conhecidas de *Chlorociboria* (27 espécies), *Cookeina* (12) e *Phillipsia* (26) são propostas e a distribuição de todas as espécies é apresentada.

Palavras chave: fungos, fungos apotecioides, diversidade, taxonomia, micogeografia.

1 INTRODUCTION

The Ascomycota comprise one of the largest group of fungi but there are only 1881 species reported to Brazil, a number lower than Basidiomycota (2741). This is because the group has fewer specialists working on its taxonomy in Brazil (Maia et al., 2015). The specialist concentrates efforts to identify mostly the pathogenic Ascomycota in this country, so that rarely we have taxonomic studies involving macroscopic Pezizales.

Among the division there are the apothecia forming group, with many genera found in South America, but all of them with problems for identification, since there are no recent identification keys for the species known. Among them, *Chlorociboria* Seaver (Chlorociboriaceae – Leotiomycetes, according to Ekanayaka et al., 2019), *Cookeina* Kuntze (Sarcoscyphaceae – Pezizomycetes, according to Ekanayaka et al., 2016) and *Phillipsia* Berk. (Sarcoscyphaceae – Pezizomycetes, according to Ekanayaka et al., 2017)

are prominent, forming large and brightly colored apothecia. *Chlorociboria* is characteristic by its blue-green apothecia and mycelium which dyes the substrate with blue green colors, by the xylindein compound produced by this genus (Liu et al., 2017). *Cookeina* is formed by large, brightly colored, stipitate apothecia and eccentrically operculate asci, with fasciculate excipular hairs and ellipsoid to fusiform and hyaline to subhyaline ascospores presenting longitudinal ribs (Ekanayaka et al., 2016). *Phillipsia* has brightly colored apothecia, frequently growing on wood, with suboperculate asci and thin and poorly differentiated outer excipulum (Ekanayaka et al., 2017).

Chlorociboria is reported to South Korea by Liu et al. (2017) who consider that approximately 19 species have been discovered worldwide, but ca. 27 have been considered as valid since then. In the monograph of *Cookeina* (Iturriaga & Pfister, 2006) eight species are keyed out, being other four recently described. Ekanayaka et al. (2017) show a table with morphological comparison of *Phillipsia* species known, enumerating 12 taxa, but 26 are recognized since then. So, it is essential that new keys could be provided to correctly identify species of these genera.

Few works have been done comprising this three genera in Brazil, with only the most common species reported, especially because of scarce bibliography on this group and inexistence of keys to all species known (Rick, 1931; Guerrero & Homrich, 1999; Dianese et al., 1997; Oliveira et al., 2013; Lodge & Sourell, 2015; Sourell et al., 2018; Lopes-Lima et al., 2019). Biodiversity has been lost with the advance of agricultural fronts and especially in Brazil. It is essential to survey what still exists and what can be used as food among native biodiversity, in the sense of valuing it, creating a perspective of preservation of the still existing plant formations (Souza et al., 2020).

More efforts are needed to better know the distribution of species of those genera also in Brazil, and to allow the easy identification of species in these genera, usually identified as the most common ones found in literature. The proposition of keys using macro and microscopic characters is presented here to help in the taxonomic/ecological works with macroscopic fungi.

2 METHODOLOGY

A bibliographic revision was done to elaborate the Brazilian list for species of *Chlorociboria*, *Cookeina* and *Phillipsia* and a list to species found all around the world. Revision of herbarium samples reported in on-line tools also were done to finish the Brazilian list.

The works published by Ramamurthi et al. (1957), Valenzuela (1997), Johnston & Park (2005) and Liu et al. (2017) for *Chlorociboria*, Iturriaga & Pfister (2005) and Ekanayaka et al (2016) for *Cookeina*, Calogne et al. (2006), Ekanayaka et al. (2017), Wang (2012) and Lima-Lopes et al. (2019) for *Phillipsia*, to start the keys construction, complemented with other references. Some species with the taxonomic position still under evaluation were included in the key to the point when its position will be clarified.

3 RESULTS AND DISCUSSIONS

The genus *chlorociboria* in brazil

Rick (1931) cited *Chlorosplenium aeruginascens* (Nyl.) P. Karst. (= *Chlorociboria aeruginascens* (Nyl.) Kanouse ex Ramam., Korf et Batra, *Chlorosplenium aeruginum* (Berk.) Sacc. and *Chlorosplenium aeruginosum* (Oeder) De Not. which are both synonyms of *Chlorociboria aeruginosa* (Pers.: Fr.) Seav. ex Ramam., Korf et Batra.

Chlorociboria aeruginascens (Nyl.) Kanouse ex Ramam., Korf et Batra, *C. aeruginascens* var. *brasiliensis* (Nyl.) J.R.Dixon and *Chlorociboria aeruginosa* (Oeder) Seaver ex Ramam., Korf et Batra are reported by Trierweiler-Pereira et al. (2008) and Loguercio-Leite *et.al* (2009) to Santa Catarina (Southern Brazil).

These are the species confirmed to Brazil up to now in this genus:

- *Chlorociboria aeruginascens* (Nyl.) Kanouse ex Ramam., Korf et Batra, with var. *brasiliensis* (Nyl.) J.R.Dixon.

- *Chlorociboria aeruginosa* (Oeder) Seaver ex Ramam., Korf et Batra.

A list of all species known of *Chlorociboria* and their worldwide distribution are shown on Table 1.

KEY TO THE KNOWN SPECIES OF CHLOROCIBORIA:

1.1 Apothecia up to 0,12 mm diam., with a small stipe up to 70 µm long, growing associated to bryophytes *C. lamellicola*

1.2 Apothecia larger than 1 mm diam., stipe from absent to very long, usually not associated to mosses2

2.1 Ascospores spiral when released from ascus3

2.2 Ascospores not spiraled when released from ascus4

3.1 Hymenium and receptacle blue green when dry*C. colubrosa*

| | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3.2 Hymenium orange brown when dry; receptacle concolor to hymenium or dark blue green | <i>C. spiralis</i> |
| 4.1 Spores 40–52 × (1.5–) 2 μm | <i>C. clavula</i> |
| 4.2 Spores with less than 30 μm long | 5 |
| 5.1 Ascospores elliptic to ovoid or fusiform, with generally pointed ends | 6 |
| 5.2 Ascospores cylindrical with rounded ends | 9 |
| 6.1 Blue-green apothecia growing on herbaceous stems; ectal excipulum with rectangular cells | <i>C. herbicola</i> |
| 6.2 If forming blue-green apothecia, rarely blue, then growing on wood or leaves; ectal excipulum with rectangular cells or not | 7 |
| 7.1 Ascospores with more than 10 μm long | 8 |
| 7.2 Ascospores up to 9,5 μm long | 21 |
| 8.1 Ascospores 10–14 × 2.5(–3) μm; tomentum hyphae 4.5–7.5 × 2.5–3 μm, short-cylindric to more or less globose, septate (0-3), walls thin, roughened | <i>C. campbellensis</i> (if spores fusoid, not allantoid and not septate) or <i>C. versiformis</i> (if spores long ellipsoid and many of them allantoid and occasionally 1-septate) |
| 8.2 Ascospores 16–25 × 2.5–3(–3.5) μm; tomentum hyphae 10 – 25 × 2–3 μm coiling, walls thin, roughened, hyaline. | <i>C. halonata</i> (if tomentum hyphae absent is <i>C. omnivirens</i>) |
| 9.1 Apothecium long stipitate, with 1–4 x 0.2–0.3 mm; tomentum hyphae absent | <i>C. procera</i> |
| 9.2 Apothecium short stipitate or sessile; tomentum hyphae present or absent..... | 10 |
| 10.1 Ascospores (21.5–)24–26(–27) μm long | <i>C. macrospora</i> |
| 10.2 Ascospores up to 17,5 μm long | 11 |
| 11.1 Hymenium white to pale yellow when fresh, pale yellow to pale blue-green when dry | 12 |

- 11.2 Hymenium yellowish, blue-green to dark blue-green when fresh, translucent yellow, dark blue-green to black when dry13
- 12.1 Ascospores asymmetrical, surrounded by a gelatinous sheath with 1 – 1,5 µm thick *C. albohymania*
- 12.2 Ascospores symmetrical, not surrounded by a gelatinous sheath.... *C. poutouensis* (if blue green receptacle and ellipsoid to fusoid spores) or *C. glauca* (if pale grey, sometimes with glaucous hue or dirty white receptacle and suballantoid spores)
- 13.1 Ascospores less than 9,5 µm long..... 14
- 13.2 Ascospores with more than 10 µm long.....15
- 14.1 Apothecia with whitish bloom, often several arising from common stromatic base; tomentum hyphae smooth-walled, coiling sometimes rare..... *C. aeruginascens*
- 14.2 Apothecia lacking whitish bloom, solitary, not arising from stromatic base; tomentum hyphae absent *C. argentinensis*
- 15.1 Tomentum hyphae rough walled16
- 15.2 Tomentum hyphae, if present, smooth walled17
- 16.1 Hymenium bright yellow when dry; ascospores (12–)13.5–15(–17) × 3–4 µm
..... *C. poutoensis*
- 16.2 Hymenium translucent blue-green when dry; ascospores (9–) 10.5–11.5(–15) × 2–2.5 (–3) µm *C. duriligna*
- 17.1 Often with several apothecia arising from a common stromatic basal mass; hymenium pale greenish when fresh, yellow when dry; receptacle when mature pale yellow with small, dark flecks; stipe tapering to base, with coarse vertical ridges; *C. pardalota*
- 17.2 Apothecia solitary, not arising from a stromatic mass; hymenium dark blue-green when fresh, black when dry; receptacle when mature dark blue-green; stipe more or less equal in diameter, not ridged..... 18
- 18.1 Tomentum hyphae strongly granulate, straight or coiling..... *C. aeruginosa*

- 18.2 Tomentum hyphae absent or, if present, smooth and sometimes coiling... 19
- 19.1 Ascospores slightly wider towards one end; ectal excipulum covered with incomplete layer of coarsely encrusted hyphae, ends of these hyphae not swollen; tomentum hyphae lacking *C. awakinoana*
- 19.2 Ascospores equal in shape toward both ends; tomentum hyphae absent, or if present, smooth-walled, coiling 20
- 20.1 Ectal excipulum covered with a more or less complete layer of darkened, smooth-walled hyphae, ends of these hyphae typically swollen clavate to fusoid ... *C. spathulata*
- 20.2 Ectal excipulum textura prismatica *C. aeruginella*
- 21.1 Apothecia with a brown to beige color with a tint of green or olivaceous disk; KOH 2% on apothecia liberates a reddish purple dye; growing on petioles or midveins of leaves *C. musae*
- 21.2 Apothecia with bluish-green to yellowish or olive-green, or glaucous to olivaceous green to brown disk; not liberating reddish purple dye with KOH; growing on branches or wood22
- 22.1 Apothecia dark sage-green; ascospores 3 – 4 μm *C. slaviicolor*
- 22.2 Apothecia bluish-green to yellowish or olive-green to glaucous or olivaceous green to brownish; ascospores with more than 4 μm long 23
- 23.1 Forming bluish-green to yellowish or olive-green receptacle and spores 4.5–5 \times 2.5–3 μm *C. olivaceous*
- 23.2 Forming glaucous or olivaceous green to brownish receptacle; spores 7 μm long or more 24
- 24.1 Apothecia receptacle glaucous; growing on tree branches and spores up to 7 μm long *C. glauca* (if spores up to 7 μm long and receptacle brownish – black sometimes slightly olive = *C. strobilina*)
- 24.2 Apothecia receptacle olivaceous-green; spores 7 – 9,5 \times 2 – 3 μm *C. rugipes*

TABLE 1 - Valid species of *Chlorociboria* and their world distribution.

| <i>Chlorociboria</i> | Locality | Reference |
|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>C. aeruginascens</i> (Nyl.) Kanouse ex C.S. Ramamurthi, Korf & L.R. Batra | New Zealand; Europe; North America; Asia; Canada; China; USA; Estonia; South Korea; Russia. | Johnston & Park (2005) Ramamurthi et al. (1957) Liu et. al (2017) |
| <i>C. aeruginella</i> (P. Karst.) Dennis ex C.S. Ramamurthi, Korf & L.R. Batra | Estonia | Liu et. al (2017) |
| <i>C. aeruginosa</i> (Oeder) Seaver | North America; Central America; South America, China, India, Japan, Philippines, Venezuela, Guatemala; New Zealand, South Korea, Canada; Patagonia, Fire land; Brazil (SC, RS); Europe; Ásia; Russia; Australia, México. | Tudor et.al (2014); Medel et. al (2013); Liu et. al (2017); Gamundí et.al (2004); Loguercio-Leite et al. (2009) Ramamurthi et al. (1957) Seaver (1951) Liu et.al (2017) |
| <i>C. awakinoana</i> | New Zealand | Johnston & Park (2005) |
| <i>C. albohymenia</i> P.R. Johnst | New Zealand | Johnston & Park (2005) |
| <i>C. argentinensis</i> J.R. Dixon | Argentina New Zealand | Dixon (1975) Johnston & Park (2005) Liu et. al (2017) |
| <i>C. campbellensis</i> P.R. Johnst. | New Zealand | Johnston and Park (2005) |
| <i>C. clavula</i> P.R. Johnst. | New Zealand | Johnston & Park (2005) |
| <i>C. colubrosa</i> P.R. Johnst. | New Zealand | Johnston & Park (2005) |
| <i>C. duriligna</i> P.R. Johnst. | New Zealand | Johnston & Park (2005) |
| <i>C. glauca</i> (Dennis) Baral & Pärtel | Scotland | Baral & Pärtel (2016) |
| <i>C. halonata</i> P.R. Johnst. | New Zealand | Liu et al. (2017) Johnston & Park (2005) |
| <i>C. herbicola</i> H.D. Zheng & W.Y. Zhuang | China | Zheng & Zhuang (2017) |
| <i>C. lamellicola</i> Huhtinen & Döbbeler | Switzerland; Austria | Huhtinen et al. (2010) |
| <i>C. macrospora</i> P.R. Johnst. | New Zealand | Johnston & Park (2005) |
| <i>C. musae</i> Dennis = <i>Moellerodiscus musae</i> (Dennis) Dumont & Korf, | Bolivia | Dennis (1959) |
| <i>C. olivaceous</i> Ekanayaka & K.D. Hyde | China | Ekanayaka et al. (2019) |
| <i>C. omnivirens</i> (Berk.) J.R. Dixon, | Tasmania; Japan | Dixon (1975) |
| <i>C. pardalota</i> P.R. Johnst. | New Zealand | Johnston & Park (2005) |
| <i>C. poutoensis</i> P.R. Johnst. | New Zealand; China; South Korea. | Johnston & Park (2005) Ren & Zhuang (2014) Liu et al. (2017) |
| <i>C. procera</i> P.R. Johnst. | New Zealand | Johnston & Park (2005) |
| <i>C. rugipes</i> (Peck) C.S. Ramamurthi & Korf | North America, India | Ramamurthi et al. (1957) |
| <i>C. salviicolor</i> (Ellis & Everh.) Korf | North and Central America; Russia. | Dixon (1974) Korf (1979) |
| <i>C. spathulata</i> P.R. Johnst. | New Zealand | Johnston & Park (2005) |
| <i>C. spiralis</i> P.R. Johnst. | New Zealand | Johnston & Park (2005) |
| <i>C. strobilina</i> (Alb. & Schwein.) Seaver | Canada, USA, Europe. | Seaver (1951) |
| <i>C. versiformis</i> (Pers.) Seaver ex CS Ramamurthi, Korf & LR Batra | North America | Ramamurthi et al. (1957) |

The genus *Cookeina* in Brazil:

Iturriaga and Pfister (2006) monographed the genus and reported only *Cookeina speciosa* (Fr. ex Fr.) Dennis (from Amazonia) and *Cookeina tricholoma* (Mont.) Kuntze

(described by Montagne as *Peziza (Lachnea) tricholoma* Mont. from Brazil- Rio de Janeiro).

Viègas (1961) reported *Cookeina colensoi* (Berk.) Seaver to São Paulo - Brazil. This species was referred by Rick (1931) to southern Brazil as *Geopyxis aluticolor* var. *ciborioides* (Starbäck) Rick as pointed out by Iturriaga & Pfister (2006). *C. colensoi* and *C. tricholoma* (Mont.) Kuntze are reported to northern Rio Grande do Sul and Santa Catarina states, respectively, by Sobestiansky (2005). Batista et al. (1966) reported *Cookeina sulcipes* and *C. tricholoma* to Pará and Amazonas (only the last one). Oliveria et al. (2013) reported *Cookeina sulcipes* and *C. tricholoma* to the Atlantic Forest of Brazil. Lodge & Sourell (2015) reported *Cookeina speciosa* and *C. tricholoma* to Mato Grosso (Southwestern Brazil). Meijer (2008) reported *Cookeina venezuelae* (Berk. & M.A. Curtis ex Cooke) Le Gal to Paraná State.

The next species are confirmed to Brazil:

- *Cookeina colensoi* (Berk.) Seaver
- *Cookeina speciosa* (Fr. ex Fr.) Dennis
- *Cookeina sulcipes* (Berk.) Kuntze
- *Cookeina tricholoma* (Mont.) Kuntze
- *Cookeina venezuelae* (Berk. & M.A. Curtis ex Cooke) Le Gal.

A list of all species known of *Cookeina* and their worldwide distribution is shown on Table 2.

Cookeina tetraspora Seaver is synonym of *Nanoscypha tetraspora* (Seaver) Denison, according to Denison (1972). *C. viridirubescens* (Bagnis) Kuntze is an inoperculate discomycete according to Iturriaga and Pfister (2006). *Cookeina globosa* Douanla-Meli is synonym of *Cookeina speciosa* (Fr. ex Fr.) Dennis according to Iturriaga and Pfister (2006).

KEY TO THE KNOWN SPECIES OF *COOKEINA*:

1.1 Hair-like appendages on margin of apothecia absent and nearly smooth outer receptacle surface; spores striate with pointed apices *C. indica* (if apothecia pinkish and spores smooth see *C. cremeirosea*)

1.2 Hair-like appendages and/or spines on margin of apothecia present; spores with or without pointed apices 2

2.1 Apothecia pinkish; ascospores with thick gelatinous sheath *C. sulcipes*

- 2.2 Apothecia not pinkish or if somewhat pinkish then ascospores without gelatinous sheath3
- 3.1 Ascospores with a sinusoid surface ornamentation *C. speciosa*
- 3.2 Ascospores with straight striae or completely smooth4
- 4.1 Ascospores with few longitudinal ribs and many transverse interconnected ribs *C. venezuelae*
- 4.2 Ascospores with only longitudinal ribs or completely smooth..... 5
- 5.1 Apothecia brownish yellow to brownish orange when fresh, pale-yellow when dry; stipes up to 1 mm long; ascospores with several longitudinal striations; hymenial setae absent *C. colensoi*
- 5.2 Apothecia bright yellow to orange or somewhat pinkish or white to pale cream when fresh; stipes 1 to 3 mm long; ascospores smooth; hymenial setae present or absent6
- 6.1 Receptacle margin showing spines and hairs; ascospores hyaline to pink7
- 6.2 Receptacle margin only with hairs; ascospores hyaline to pale-yellow8
- 7.1 Apothecia 1,8 × 3,5 cm; ascospores elliptic-fusoid to narrow *C. korfii*
- 7.2 Apothecia 1–3 × 4–8 cm; ascospores ovoid *C. tricholoma*
- 8.1 Paraphyses moniliform; hairs in a single row on apothecia margin *C. sinensis*
- 8.2 Paraphyses not moniliform (filiform); hairs on a single row or on flanks and margin 9
- 9.1 Hairs of three types, marginal twisted (when dry) hairs, straight hairs and hyphal projections covering receptacle and stipe; ascospores narrow sub-fusoidal to fusoidal, asymmetrical or distinctly curved, with pointed ends *C. insititia*
- 9.2 Hairs if present of only one type in the margins or also in the hymenial surface; ascospores globose to elliptic or ovoid10

10.1 Apothecia disc pink when fresh, reddish yellow when dry; ascospores ovoid, smooth
..... *C. cremeirosea*

10.2 Apothecia color different, or If apothecia disc pinkish then the ascospores are globose11

11.1 Hymenial hairs absent, but apothecial margin presenting a single row of hairs; ascospores ovoid with obtuse ends *C. garethjonesii*

11.2 Hymenial setae or hairs present; ascospores globose or broadly elliptic12

12.1 Apothecia disc pink to pale lead when fresh and brownish-yellow when dry; ectal excipulum 60–100 µm thick, composed of cells of textura angularis to globulosa, few layers of polygonal cells in gelatinous tissues, the outer cells globose, larger with thickened yellowish-brown walls, inner cells hyaline; ascospores globose *C. globosa*

12.2 Apothecia bright yellow to orange when fresh; ectal excipulum 30–90 µm composed of cells of textura globulosa to prismatica (8–14 µm diam.), 4–5 cell layers present; ascospores broad elliptic, unequally sided, narrowing slightly at the ends, with a short apiculum present at both ends..... *C. colensoiopsis*

TABLE 2 - Valid species of *Cookeina* and their world distribution.

| <i>Cookeina</i> species | Locality | References |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Cookeina colensoi</i> (Berk.) Seaver Syn.: - <i>Geopyxis aluticolor</i> var. <i>ciborioides</i> (Starbäck) Rick - <i>Ciboria sessilis</i> Starbäck | New Zealand; India; Australia, Africa; Argentine; Colombia; China; Mexico, Brazil; Jamaica; Samoa; Madagascar | Berkeley (1855) Seaver (1913) Rick (1931) Gamundí (1957) Cash (1937) Weinstein et al. (2002) Ortega-López et al. (2019) Viêgas (1961) Iturriaga & Pfister (2006) Starbäck (1904) |
| <i>Cookeina colensoiopsis</i> Iturriaga & Pfister | Venezuela | Iturriaga & Pfister (2006) |
| <i>Cookeina cremeirosea</i> Kropp | Estados Unidos, Samoa | Kropp (2016) |
| <i>Cookeina garethjonesii</i> Ekanayaka, Q. Zhao & K.D. Hyde | China | Ekanayaka et al. (2016) |
| <i>Cookeina indica</i> Pfister & R. Kaushal Syn.: <i>C. mundkurii</i> SC Kaushal - probably according to Iturriaga and Pfister (2006) | India; China | Iturriaga & Pfister (2006) Yang (1990) Kaushal (1986) |
| <i>Cookeina insittia</i> (Berk. & M.A. Curtis) Kuntze | China, Indonésia, Japão, Philippines e Samoa | Iturriaga & Pfister (2006) |

| | | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| <i>Cookeina korfii</i> Iturr., F. Xu & Pfister | Philippines | Iturriaga et al. (2015) |
| <i>Cookeina sinensis</i> Zheng Wang | China India | Patil et al. (2012) |
| <i>Cookeina speciosa</i> (Fr. ex Fr.) Dennis = <i>Cookeina amoena</i> , (Lév.) Kuntze = <i>Cookeina javanica</i> (Nees & Lév.) Kuntze = <i>Cookeina sumatrana</i> Boedijn | Tropics Mexico | Iturriaga & Pfister (2006) Ortega-López et al. (2019) |
| <i>Cookeina sulcipes</i> (Berk.) Kuntze = <i>Cookeina hindsii</i> (Berk.) Kuntze | Central America, Mexico, Caribe, South America, Africa and Asia, Brazil | Denison (1967) Ortega-López et al. (2019) Silva & Minter (1995) Batista et al. (1966) |
| <i>Cookeina tricholoma</i> (Mont.) Kuntze | Tropical distribution Central America, Mexico, Caribbean, South America, Africa, Asia, Australia and South Pacific; Brazil. | Iturriaga & Pfister (2006) Montagne (1834) Denison (1967) |
| <i>Cookeina venezuelae</i> (Berk. & M.A. Curtis ex Cooke) Le Gal | South and Central America; Caribbean. | Gamundí (1983) Denison (1967) |

The genus *Phillipsia* in Brazil:

Rick (1931) reported *Phillipsia olivacea* Rick, *P. kermesina* Kalchbr. & Cooke, *P. gigantea* (Berk. et Curt.) Sacc. (= *Wynnea gigantea*) and *P. plicarioides* Rick to Southern Brazil. The first species was also found in the Northeastern Brazil by Lopes-Lima et al. (2019). *Phillipsia domingensis* Berk. was reported to Rio Grande do Sul state by Guerrero & Homrich (1999). Lodge & Sourell (2015) reported *P. domingensis* and *P. lutea* to Mato Grosso – Southwestern region of Brazil. Meijer (2008) reported *P. olivacea* Rick to Paraná State and Sobestiansky (2005) to Rio Grande do Sul.

The next species are confirmed to Brazil:

- *P. brasiliensis* (Rick) Le Gal
- *P. domingensis* Berk.
- *P. kermesina* Kalchbr. & Cooke
- *P. lutea* Denison
- *P. olivacea* Rick
- *P. plicarioides* Rick

A list of all species known of *Phillipsia* and their worldwide distribution is shown on Table 3.

KEY TO THE KNOWN SPECIES OF *PHILLIPSIA*:

- 1.1 Apothecia disc hyaline or white to cream2

- 1.2 Apothecia disc deeply pigmented3
- 2.1 Disc of apothecia purely white (fresh) to cream (dry); ascospores 15–21 × 7.5–10.7 μm, with 7–10 longitudinal ridges *Phillipsia ranomafanensis*
- 2.2 Disc of apothecia hyaline to white or creamy; ascospores 27–36 × 14–17 μm, with 4–6 longitudinal surface ridges*Phillipsia gelatinosa*
- 3.1 Apothecia laterally attached (spoon shaped), with yellow disc *P. dochmia* (*P. brasiliensis* probably here)
- 3.2 Apothecia centrally to somewhat eccentrically attached or disc not yellow 4
- 4.1 Apothecia with more than 35 mm diam.5
- 4.2 Apothecia with up to 30 mm diam.11
- 5.1 Apothecia funnel-shaped, disc bright purple or red-purple, receptacle whitish or rosy; asci with 4 ascospores *Phillipsia gigantea*
- 5.2 Apothecia generally disc-shaped, colored as above or different; asci with 4 to 8 (generally) ascospores6
- 6.1 Apothecia sessile, discoid to shallow cupulate, margin even, consistency rubbery when fresh, becoming corky when dry, disc yellow *Phillipsia rugospora* (= *P. olivacea*)
- 6.2 Apothecia sessile to sub-stipitate or stipitate, disc-shaped to pulvinate-turbinate or goblet-shaped to funnel-shaped or fan-shaped, generally brick-red, bright red, purple-red, rarely purple-red with yellow patches when fresh or dark yellow-green olive, but never completely yellow 7
- 7.1 Apothecia pulvinate-turbinate with more or less dark yellow-green olive hymenial surface, sometimes with grey shades, whitish outer surface *Phillipsia olivacea*
- 7.2 Apothecia brick-red, bright red, purple-red to purple-red with yellow patches8
- 8.1 Apothecia subsessile, disc brick-red, bright red, receptacle paler
..... *Phillipsia chardoniana*

8.2 Apothecia sessile to stipitate, disc purple-red to rosy, sometimes with yellow patches, reddish brown when dry 9

9.1 Apothecia thin-fleshed, goblet-shaped to funnel-shaped or fan-shaped, with a long, slender stipe; ascospores with 3-5 striations on a side *Phillipsia carminea*

9.2 Apothecia disc-shaped, sessile to sub-stipitate; ascospores with 4 – 8 longitudinal ridges 10

10.1 Disc purple-red without yellow patches, receptacle creamy white, subglabrous to finely tomentose, becoming wrinkled; ascospores $20\text{--}32 \times 10\text{--}15 \mu\text{m}$, with 6–8 longitudinal surface ridges *Phillipsia domingensis* (with *P. polyporoides* as synonym)

10.2 Disc purple-red with yellow patches when fresh, reddish brown when dry, receptacle leathery, margins and disc concolorous to receptacle; ascospores $27\text{--}36 \times 14\text{--}17 \mu\text{m}$, with 4–6 longitudinal surface ridges *Phillipsia gelatinosa*

11.1 Apothecia 4–10 mm diam., sessile, concave, disc coral red; asci $185\text{--}200 \times 11\text{--}12 \mu\text{m}$; ascospores $17\text{--}18 \times 7.5\text{--}8 \mu\text{m}$, smooth walled *Phillipsia umbilicata*

11.2 Apothecia as above or larger, sessile to substipitate, with disc not coral red (normally orange to orange-red, yellow or pink); asci larger or if as above then disc orange to pink; ascospores as above (but then disc not coral red) or generally larger 12

12.1 Disc reddish brown to brown or purple, rosaceous tan, tan to pink13

12.2 Disc with some orange color (orange red, orange-brown) or yellow 18

13.1 Disc with some pink or rosaceous color14

13.2 Disc not pink and not rosaceous color15

14.1 Apothecia up to 30 mm diam.; asci $330\text{--}400 \times 14\text{--}17 \mu\text{m}$, ascospores $21\text{--}25 \times 12\text{--}13 \mu\text{m}$ *Phillipsia guatemalensis*

14.2 Apothecia up to 11 mm diam.; asci $180\text{--}210 \times 10\text{--}15 \mu\text{m}$, ascospores $15\text{--}19 \times 8\text{--}11 \mu\text{m}$ *Phillipsia hartmannii*

15.2 Apothecia with reddish brown disc; ascospores $26\text{--}32 \times 12\text{--}15 \mu\text{m}$, irregularly kidney-shaped, asymmetric, some sub-fusiform, few regular in shape, generally with

- rounded ends, with more or less parallel longitudinal striations
..... *Phillipsia crispata*
- 15.2 Apothecia with tan to red-purple disc; ascospores as above or shorter, generally symmetric, smooth or striate 16
- 16.1 Apothecia up to 30 mm diam.; ascospores 15–20 × 30–40 µm, smooth or with faint 2–3 striations *Phillipsia subpurpurea* (if growing on rotten wood) or *P. plicarioides* (if lobate apothecia growing on soil and ascospores up to 15 µm long) or *P. hydei* (if gelatinous sheath surrounding the ascospores)
- 16.2 Apothecia up to 20 mm diam.; ascospores if smooth showing 25–35 × 11–15 µm, or with 7 – 9 distinct striations visible in one side 17
- 17.1 Apothecia up to 20 mm diam., with tan disc; ascospores 18–24 × 11–15 µm, with 7–9 distinct striations visible on a side *Phillipsia costaricensis*
- 17.2 Apothecia up to 16 mm diam., with red purple disc; ascospores 25–35 × 11–15 µm, smooth..... *Phillipsia kermesina*
- 18.1 Disc yellowish 19
- 18.2 Disc with some orange tints20
- 19.1 Apothecia discoid to slightly concave or convex; with bright yellow disc; asci 4-spored; ascospores with 30–42 × 12–15 µm, with conspicuous longitudinal striations. *Phillipsia lutea*
- 19.2 Apothecia pulvinate-turbinata, with pale yellow disc to somewhat olive disc; asci 8-spored; ascospores 24–32 × 10–14 µm, slightly wrinkled or smooth *Phillipsia olivacea* (*P. straminea* if disc yellowish but not olive)
- 20.1 Apothecia up to 4 mm diam., gregarious, discoid, with a short stalk, disc orange-yellow when fresh, receptacle creamy white *Phillipsia carnicolor*
- 20.2 Apothecia up to 25 mm diam., isolated or not, sessile to substipitate, with orange brown to orange disc, receptacle paler than disc or white 21
- 21.1 Apothecia up to 25 mm diam.; ascospores 23–30 × 11–14 µm, ellipsoid, with 7–12 straight lines *Phillipsia chinensis*

21.2 Apothecia up to 12 mm diam.; ascospores 16–24 × 8,7–15 µm, with irregular striations or with 5 – 7 longitudinal striations 22

22.1 Ascospores with 5–7 longitudinal striations *Phillipsia crenulopsis*

22.2 Ascospores with a much finer, denser, incomplete and more irregular ascospore striation *Phillipsia crenulata*

TABLE 3 - Valid species of *Phillipsia* and their world distribution.

| <i>Phillipsia</i> | Locality | Reference |
|-------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>P. brasiliensis</i> (Rick) Le Gal | Brazil | Rick (1931) |
| <i>P. carminea</i> (Pat.) Le Gal | CA (Guadeloupe) | Denison (1969) |
| <i>P. carnicolor</i> Le Gal | Madagascar, Thailand, China, Taiwan | Le Gal (1953) Hansen et al. (1999) Zhuang (2003) Wang (2012) |
| <i>P. chardoniana</i> Seaver | Caribbean; Puerto Rico | Seaver (1928) Seaver (1925) |
| <i>P. chinensis</i> W.Y. Zhuang | China Taiwan | Zhuang (2003) Wang (2012) |
| <i>P. costaricensis</i> Denison | China Costa Rica | Zhuang (2003) Calonge et al. (2006) Denison (1969) |
| <i>P. crenulata</i> (Berk. & Broome) Le Gal | Madagascar | Le Gal (1953) |
| <i>P. crenulopsis</i> W.Y. Zhuang | China | Zhuang (2003) |
| <i>P. crispata</i> (Berk. & M.A. Curtis) Le Gal | Costa Rica; Cuba; Mexico. Probably occurs in Central America and the Caribbean | Calonge et al. (2006) Denison (1969) |
| <i>P. dochmia</i> (Berk. & M.A. Curtis) Seaver | North America | Seaver (1928) |
| <i>P. domingensis</i> Berk. Syn.: <i>P. polyporoides</i> Berk. | China; Costa Rica; Santo Domingo; Brazil (Southern Amazonia); South America; Mexico; Africa; Asia; Australia; Tahiland; Taiwan | Zhuang (2003) Seaver (1925) Calonge et al. (2006) Berkeley (1881) Denison (1969) Lodge & Sourell (2017) Dennis (1955); Ekanayaka et al. (2017) Wang (2012) |
| <i>P. gelatinosa</i> Ekanayaka, Q. Zhao & K.D. Hyde | Thailand | Ekanayaka et al. (2017) |
| <i>P. gigantea</i> Seaver | Caribbean; Central America; Jamaica | Seaver (1925) Denison (1969) Seaver (1928) |
| <i>P. guatemalensis</i> Paden | Guatemala | Paden (1977) |
| <i>P. hartmannii</i> (W. Phillips) Rifai | Africa; America; Australasia; China; | Rifai (1968); Zhuang (2003) Romero & Gamundí (1986) |
| <i>P. hydei</i> M. Zeng & Q. Zhao | Thailand | Zeng et al. (2019) |
| <i>P. kermesina</i> Kalchbr. & Cooke | South Africa; Brazil | Kalchbrenner & Cooke (1880) Rick (1931) |
| <i>P. lutea</i> Denison | Costa Rica; Central America; Brazil | Denison (1969) Lodge & Sourell (2015) |
| <i>P. minor</i> (Wakef.) Rifai | Australia | Rifai (1968) |

| | | |
|------------------------------------------------------|---------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>P. olivacea</i> Rick | Brazil; Venezuela; Ecuador; Costa Rica; Mexico | Rick (1931) Hansen et al.(1999) Romero & Gamundí (1986) Calonge et al. (2006) Lopes-Lima et al. (2019) Ortega-López et al. (2019) |
| <i>P. plicarioides</i> Rick | Brazil | Rick (1931) |
| <i>P. ranomafanensis</i> Moravec | Madagascar | Moravec (1997) |
| <i>P. rugospora</i> Paden (= <i>P. olivacea</i>) | Costa Rica | Paden (1977) |
| <i>P. straminea</i> S. Ito e S. Imai | Bonin Islands | Ito & Imai (1937) |
| <i>P. subpurpurea</i> Berk. & Broome | China | Ekanayaka et al. (2017) |
| <i>P.umbilicata</i> (Penz. & Sacc.) Boedijn | Indonesia | Boedijn (1940) |

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