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Uncovering hidden biodiversity: over 40 new records of pyrenocarpous lichens for the Philippines

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Abstract: As part of ongoing efforts to document the lichen biota of the southern Philippines, we report 41 additional species as new records for the country, of which 14 are new to Southeast Asia and 4 species are new to Asia. The Philippine archipelago now emerges as one of the hotspots of pyrenocarpous lichens in Southeast Asia, with an updated list of 224 species, encompassing 39 genera and 10 families. Given the accelerating habitat loss and sporadic attention for lichens in the country, our findings underscore the urgent need for continued biodiversity exploration efforts not only to catalogue the lichen diversity but also to integrate these underrepresented organisms into broader conservation planning essential for supporting the ecological integrity of Philippine forests.

Keywords: Bukidnon, Davao, Dinagat, Mindanao, Misamis Oriental, tropical lichen

INTRODUCTION

Accelerating habitat loss, extensive land-use, and climate-driven disturbances continue to pose threats to the already dwindling global biodiversity, with impacts occurring at an unprecedented rate across the tropical regions (Sodhi et al., 2010; Joppa et al., 2011; Rull, 2021; Keck et al., 2025). The Philippines is among the tropical and biodiversity hotspot countries (Myers et al., 2000; Posa et al., 2008), with an archipelagic environment that harbors unique natural biota, including highly endemic and threatened species. Despite its natural wealth, the Philippine ecosystem remains under intense anthropogenic pressures, including the rapid decline of forest cover, with only 24.09 % (7.23×10^4 hm^2) of the total landmass of the country remaining forested (FMB, 2021). These pressures not only threaten well-studied taxa (Ambal et al., 2012), but also to large groups of organisms that remain poorly documented, including lichens.

Considered as a megadiverse island of the southern Philippines, Mindanao is also home to the country's highest mountains and diverse forest ecosystems (Amoroso, 2000; Alcala, 2004), which serve as a critical refuges to several endemic and threatened species (Rickart et al., 2003; Heaney et al., 2006; Barcelona et al., 2009; Lillo et al., 2019; Molina, 2020). By landmass, Mindanao is the second-largest island group, with at least 34% of the country's total land area of 300,000 km^2 and comprises six economic regions, 24 provinces, 14 cities, and 400 towns (PhilAtlas, 2022). Despite its area and biological richness, lichen studies have only received sporadic attention compared to flora and fauna. This underrepresentation underscores the urgency of targeted biodiversity assessments to uncover these overlooked taxa before they disappear without ever being fully recorded.

Recently, the largely unexplored assemblage of lichens has begun to receive gradual attention (Sipman et al., 2013; Bawingan et al., 2014; Galinato et al., 2017) with subsequent additions to Philippine lichenology (Bawingan et al., 2022; Gerlach et al., 2023; Taer et al., 2023, 2024, 2025). However, these additions comprise only a fraction of the estimated 20,000 lichenized

fungal species worldwide (Lücking et al., 2017). With its complex geography, diverse habitat heterogeneity, and extensive areas of pristine forest, the country likely harbors a substantial portion of lichen diversity that remains unknown and undocumented. Among these groups are pyrenocarpous lichens, or "pyrenolichens", a primarily microlichen assemblage distinguished by its flask-shaped perithecia (Aptroot, 2021). These lichens act as pioneer colonizers, and provide food resources and microhabitats for small organisms (Haines & Renwick, 2009; Fang et al., 2020). Despite their ecological significance, pyrenocarpous lichens remain poorly known and underrepresented in biodiversity assessments.

Between 2019 and 2024, a series of sampling trips across Mindanao were conducted, and among the material collected were 41 pyrenocarpous lichen species previously not recorded from the country. Here, we report further lichen records to contribute to advancing lichenology in the Philippines.

MATERIALS AND METHODS

Study Sites

A series of major and minor collection trips was conducted in the southern Philippines in collaboration of the team of researchers from Botanical Research Institute of Texas (BRIT), Central Mindanao University (CMU), the University of North Carolina Wilmington (UNCW), other institutions, and local government units as part of the National Science Foundation (NSF)-funded project "*Plants and Lichens of the Southern Philippines*". Among the provinces explored, three were from mainland Mindanao (Bukidnon, Davao del Sur, Misamis Oriental) and one from a satellite island of Mindanao (Dinagat Islands). Field trips were conducted across 17 localities (Fig. 1) and surveyed various habitat types, ranging from tropical lowland to upper montane rainforest, forest over ultramafic rocks, and anthropogenically disturbed habitats (Table 1).

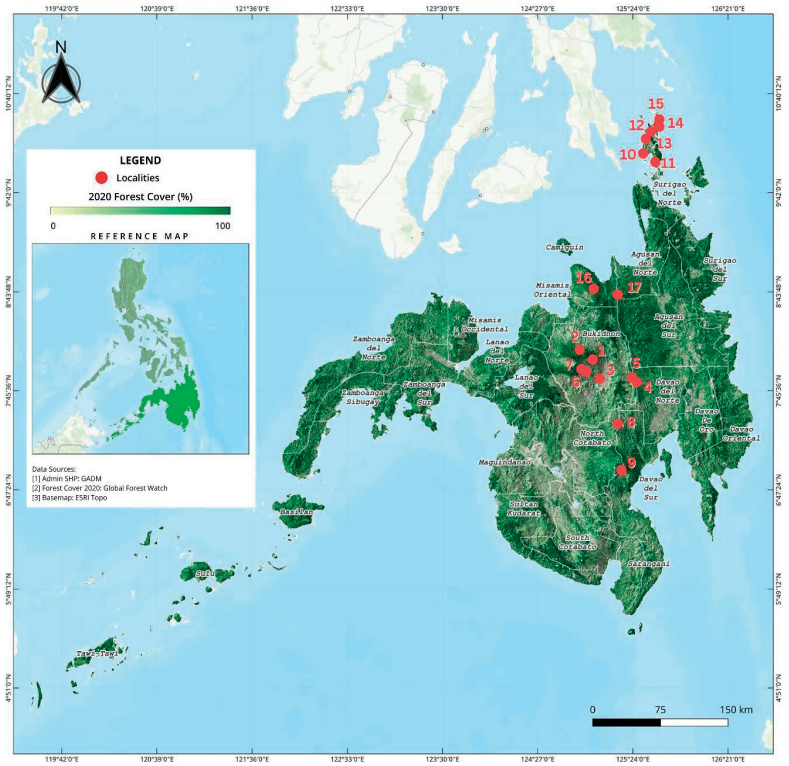

Fig. 1. Location of study sites and map of Mindanao Island, southern Philippines (for information on the localities, refer to Table 1). Prepared by Ariel Dome.

Table 1. Profile of study sites in the Mindanao island group, southern Philippines.

Province	Localities Name	Location	Coordinates	Dates
Bukidnon	1. Cinchona Forest Reserve	Mount Kalatungan Range Natural Park, Lantapan, Bukidnon. Alt.1231 masl, tropical lower montane rainforest, and anthropogenically disturbed habitat	08°03'32.4"N 125°00'16.8"E	13–14 January 2023
	2. Northern slope of Mt. Kitanglad	Barangay Dahilayan, Manolo Fortich, Bukidnon. Alt. 1342 –1755 masl, tropical upper montane rainforest	08°10'30"N 124°51'50"E	4–7 June 2024
	3. Mt. Musuan	Musuan, Maramag, Bukidnon. Alt. 391–508 masl, tropical lower montane forest over lava dome and a tuff.	07°52'46.7"N 125°03'47.1"E	30 July 2022
	4. Mt. Malimumu	Barangay Magkalungay, Pantaron Range, San Fernando, Bukidnon. Alt. 724–778 masl, tropical lower montane rainforest.	07°52'25"N 125°24'12"E	20 July 2022
	5. Mount Natampod	Barangay Namnam, Pantaron Range, San Fernando, Bukidnon. Alt. 977 masl, tropical lower montane rainforest.	07°51'44.3"N 125°24'47.6"E	24 July 2022
	6. Mt. Nebo	Sitio Migtulod, Mt. Kalatungan Range Natural Park, Valencia, Bukidnon. Alt. 1274–1596 masl, tropical upper montane rainforest.	07°56'47.2"N 124°56'30.4"E	4–8 July 2023
	7. Lilingayon	Sitio Tandacol, Valencia, Bukidnon. Alt. 1317 masl, tropical lower montane rainforest.	07°58'08"N 124°56'07"E	12 June 2024
Davao del Sur	8. Marilog Forest Reserve	Baganihan, Arakan, Datu Ladayon, Davao City, Davao del Sur. Alt. 1153 masl, tropical lower montane rainforest.	7°27'23.7"N, 125°14'38.1"E	27 December 2019
	9. Mount Apo	Barangay Santa Cruz, Digos City, Davao Del Sur. Alt. 1599–1748 masl, tropical upper montane rainforest.	06°58'34.1"N 125°17'39.4"E	4–5 August 2022
Dinagat Islands	10. Bababu	Barangay Melgar, Basilisa, Dinagat Islands. Alt. 67 masl, forest over limestone	10°04'09.8"N 125°30'25.9"E	31 January 2023
	11. Cuarenta Watershed	Barangay Cuarenta, San Jose, Dinagat Islands. Alt. 309 masl lowland forest, along the Gleicheniaceae field.	10°01'28.8"N 125°37'16.3"E	28 January 2023
	12. Paragua Forest of Libjo	Barangay San Antonio, Libjo, Dinagat Islands. Alt. 194 masl, tropical lowland evergreen rainforest, anthropogenically disturbed habitat	10°14'10.7"N 125°32'22.7"E	29 January 2023
	13. Paragua Forest of Tubajon	Barangay Navarro, Tubajon, Dinagat Islands. Alt. 78 masl, tropical lowland evergreen rainforest, anthropogenically disturbed habitat.	10°17'28.9"N 125°35'06.1"E	30 January 2023
	14. Mt. Redondo	Barangay Esperanza, Loreto, Dinagat Islands. Alt. 630–930 masl, Upper Montane Dwarf Forest over ultramafic soil (locally known as Bonsai forest).	10°21'05.8"N 125°38'16.6"E	21–22 June 2024
	15. Mt. Kanbinlio	Barangay Esperanza, Loreto, Dinagat Islands. Alt. 782 masl, tropical lower montane forest over ultramafic soil	10°23'16"N 125°38'29"E	23 June 2024
Misamis Oriental	16. Mt. Balatukan,	Scout Camp Campsite, Barangay Kalagonoy, Gingoog City, Misamis Oriental. Alt. 1546–1584 masl, tropical upper montane rainforest	08°44'03.8"N 125°00'02.9"E	18 January 2023
	17. Talangisog Forest Park and View Point	Sitio Talangisog, Barangay Eureka, Gingoog City, Misamis Oriental. Alt. 594–638 masl, tropical lowland evergreen rainforest.	08°41'45.6"N 125°14'12.0"E	19–22 July 2023

Fieldwork

The first set of lichen fieldwork was conducted between 2019 and 2022, composed of a lichen team led by Manuela Dal Forno, Alice Gerlach, and Bibiana Moncada, who collected various lichen taxa. During the subsequent 2023–2024 expeditions, the first author joined the team and collected additional specimens, especially focusing on pyrenolichens. Voucher specimens will be deposited according to the following priority order: Philippine National Herbarium (PNH) and/or Central Mindanao University (CMUH) (in accordance with the Philippine national law), with duplicates in the Botanical Research Institute of Texas (BRIT), Fort Worth Botanic Garden, Texas, USA.

Prior to each trip, an approved Wildlife Gratuitous Permits (WGPs) from the Department of Environment and Natural Resources (DENR) Regions 10, 11, and 13 in compliance with RA 9147 for the collection of the specimens, were obtained and utilized throughout the fieldwork duration. Subsequently, a series of transect walks and opportunistic sampling was carried out at each locality. The specimens included in this study are mainly corticolous, with occasional saxicolous materials. All foliicolous specimens will be treated in a forthcoming paper. Collected specimens were placed in individual paper bags labeled with corresponding field information for further analysis in the laboratory.

Examination and Identification

Identification and descriptive work was carried out at the Botanical Research Institute of Texas, Fort Worth Botanic Garden, Fort Worth, Texas, United States, using a LEICA M165 FC Fluorescent Stereo Microscope and a Leica DM500 compound microscope, with macroscopic images captured using a Leica DMC2900 microscope camera with a 3.1 Megapixel CMOS sensor. The chemistry was investigated using long-wave UV light and spot tests with 10% KOH on sections and the thallus surface. Furthermore, the chemistry of critical specimens was examined by thin-layer chromatography (TLC) using solvent A (Orange et al., 2010).

Taxonomic keys from various scientific articles and journals were used to confirm species-level identities (Aptroot et al., 2008; Aptroot & Lücking, 2016; Hongsanan et al., 2020; Aptroot, 2021). Short notes are provided for selected species, particularly those newly reported for Asia and Southeast Asia.

RESULTS

New records for the Philippines

The majority of the species reported in the current study have a pantropical distribution. Fourteen species are new for Southeast Asia (marked with *), and four are new records for Asia (marked with •); three of the latter were previously considered as neotropical. For all 41 listed species that are new reports for the Philippines, the pertinent vouchers and locality are indicated.

Monoblastiaceae Walt. Watson, New Phytol. 28: 106 (1929)

Anisomeridium subprostans (Nyl.) R.C. Harris

Specimens examined: Dinagat Islands, Mt. Redondo, 10°21’6”N, 125°38’12”E, 791 masl, upper montane dwarf forest over ultramafic soil (locally known as Bonsai forest), corticolous, 22 June 2024, *M. Dal Forno 10492*; 10°21’7”N, 125°38’29”E, 938 masl, upper montane dwarf forest over ultramafic soil, corticolous, 22 June 2024, *M. Dal Forno 10576*.

Porinaceae Rchb., Consp. Regni Veget. (Lipsiae): 20 (1828)

Myeloconis erumpens P.M. McCarthy & Elix

Specimens examined: Dinagat Islands, Paragua Forest, Libjo, 10°14’10.7”N, 125°32’22.7”E, 194 masl, tropical lowland evergreen rainforest, anthropogenically disturbed habitat, corticolous, 29 January 2023, *M. Dal Forno 6240, 6249*; Paragua Forest, Tubajon, 10°17’28.9”N, 125°35’06.1”E, 78 masl, tropical lowland evergreen rainforest, anthropogenically disturbed habitat, corticolous, 30 January 2023, *M. Dal Forno 6303*. — Misamis Oriental, Talangisog Forest Park and View Point, 08°42’00.6”N, 125°14’12.2”E, 594 masl, tropical lowland evergreen rainforest, corticolous, 19 July 2023, *M. Dal Forno 8509*; 08°41’33.4”N, 125°14’18.8”E, 636 masl, tropical lowland evergreen rainforest, corticolous, 20 July 2023, *M. Dal Forno 8617*; 08°41’21.7”N, 125°14’18.6”E, 610 masl, tropical lowland evergreen rainforest, corticolous, 22 July 2023, *M. Dal Forno 8808, 8809, 8810, 8838*.

*Porina africana Müll.Arg. (Fig. 2A & G)
Specimens examined: Bukidnon, Lilingayon, 07°58’08’’N, 124°56’07’’E, 1317 masl, tropical lower montane forest, mixed with anthropogenically disturbed habitat, corticolous, 12 June 2024, *M. Dal Forno 9910;* Mt. Musuan, 07°52’57.4”N, 125°03’57.4”E, 391 masl, tropical lower montane rainforest, corticolous, 06 February 2023, *M. Dal Forno 6502;* Mt. Nebo, 07°56’47.2’’N, 124°56’30.4’’E, 1596 masl, tropical upper montane rainforest, corticolous, 04 July 2023, *M. Dal Forno 6902*.

A scattered paleotropical species, also known from Taiwan, India and Australia (McCarthy, 2013). It differs from the morphologically similar species *P. tetracerae* (Ach.) Müll. Arg. in having larger perithecial verrucae 0.4–1 mm diam, inconsistently 7-septate, longer ascospores 42–55 × 5–7 µm (vs. *P. tetracerae* with perithecial verrucae 0.36–0.8 mm diam., 7-septate, 24–44 × 3.5–7 µm).

*Porina cestrensis (Tuck. ex Michener) Müll.Arg. (Fig. 2B & H)
Specimen examined: Misamis Oriental, Talangisog Forest Park and View Point, 08°41’33.4”N, 125°14’18.8”E, 636 masl, tropical lowland evergreen rainforest, corticolous, 20 July 2023, *M. Dal Forno 8530*.

This species was previously known from temperate countries and was later reported from Brazil and Taiwan (Aptroot, 2003). The Philippine material fits closely with the description provided by Aptroot (2001), with hyaline, long–fusiform ascospores, 7–9 (–11) eusepta, 72–90 × 2–4 µm, not ornamented, without a gelatinous sheath. It only deviates from the description of Aptroot (2001; “perithecia hemispherical, black, semi-immersed in the thallus) by its perithecia being often violet-black.

*Porina subinterstes (Nyl.) Müll.Arg. (Fig. 2C & I)
Specimen examined: Dinagat Islands, Bababu, 10°04’09.8”N, 125°30’25.9”E, 67 masl, forest over limestone, trunk of *Dracaena* sp. (Asparagaceae), corticolous, 31 January 2023, *M. Dal Forno 6355.*

A relatively rare pantropical species, also known from the Andaman Islands, Rarotonga, Brazil, Paraguay, and India (McCarthy, 2013). It differs from the morphologically similar species *P. papuensis* P. M. McCarthy in having smaller perithecial verrucae, 0.24 – 0.45 mm diam. (vs. *P. papuensis*, perithecial verrucae (0.38–)0.55(–0.7) mm diam).

Pyrenulaceae Rabenh., Krypt. Fl. Sachsen, Abth. 2 (Breslau): 42 (1870)
*Lithothelium grossum Aptroot (Fig. 2D & J)
Specimen examined: Bukidnon, Mt. Musuan, 07°52’57.4”N, 125°03’57.4”E, 391 masl, tropical lower montane rainforest, corticolous, 06 February 2023, *M. Dal Forno 6522*.

Pyrenula acutalis R.C. Harris
Specimen examined: Davao del Sur, Marilog Forest Reserve, 7°27’23.7”N, 125°14’38.1”E, 1153 masl, tropical lower montane rainforest, 27 December 2019, *M. Dal Forno 3823*.

*Pyrenula acutispora Kalb & Hafellner (Fig. 2E & K)
Specimens examined: Bukidnon, Mt. Malimumu, 07°51’59.3”N, 125°24’04.2”E, 778 masl, tropical lower montane rainforest, corticolous, 20 July 2022, *M. Dal Forno 4536*; Northern slope of Mt. Kitanglad, 8°10’32.7”N, 124°51’50.2”E, 1755 masl, tropical upper montane rainforest, corticolous, 04 June 2024, *M. Dal Forno 9127*. — Davao del Sur, Mt. Apo, 06°58’14.4’’N, 125°18’02.1’’E, 1599 masl, tropical upper montane rainforest, corticolous, 04 August 2022, *M. Dal Forno 5270*. — Dinagat Islands, Mt. Redondo, 10º 21’6”N, 125º 38’12”E, 791 masl, upper montane dwarf forest over ultramafic soil (locally known as Bonsai forest), corticolous, 22 June 2024, *M. Dal Forno 10642.*

The species is known from the temperate Northern Hemisphere, extending into the tropics (Aptroot, 2012); also reported in China growing on bark of trees in subtropical virgin forest (Xie et al., 2021). It fits well with the concept of *P. acutispora* by having simple to occasionally aggregated perithecia with ostioles pointing in various directions, mostly apical or lateral. In addition, the ascospores are 20–25 × 7–10 µm, the lumina are angular, the terminal lumina separated from the exospore wall by endospore thickening and the ascospores have at least one pointed end.

Pyrenula bispora Aptroot & M. Cáceres
Specimens examined: Bukidnon, Mt. Musuan, 07°52’46.7”N, 125°03’47.1”E, 508 masl, tropical lower montane rainforest, corticolous, 30 July 2022, *M. Dal Forno 4968;* 07°52’56.5’’N,

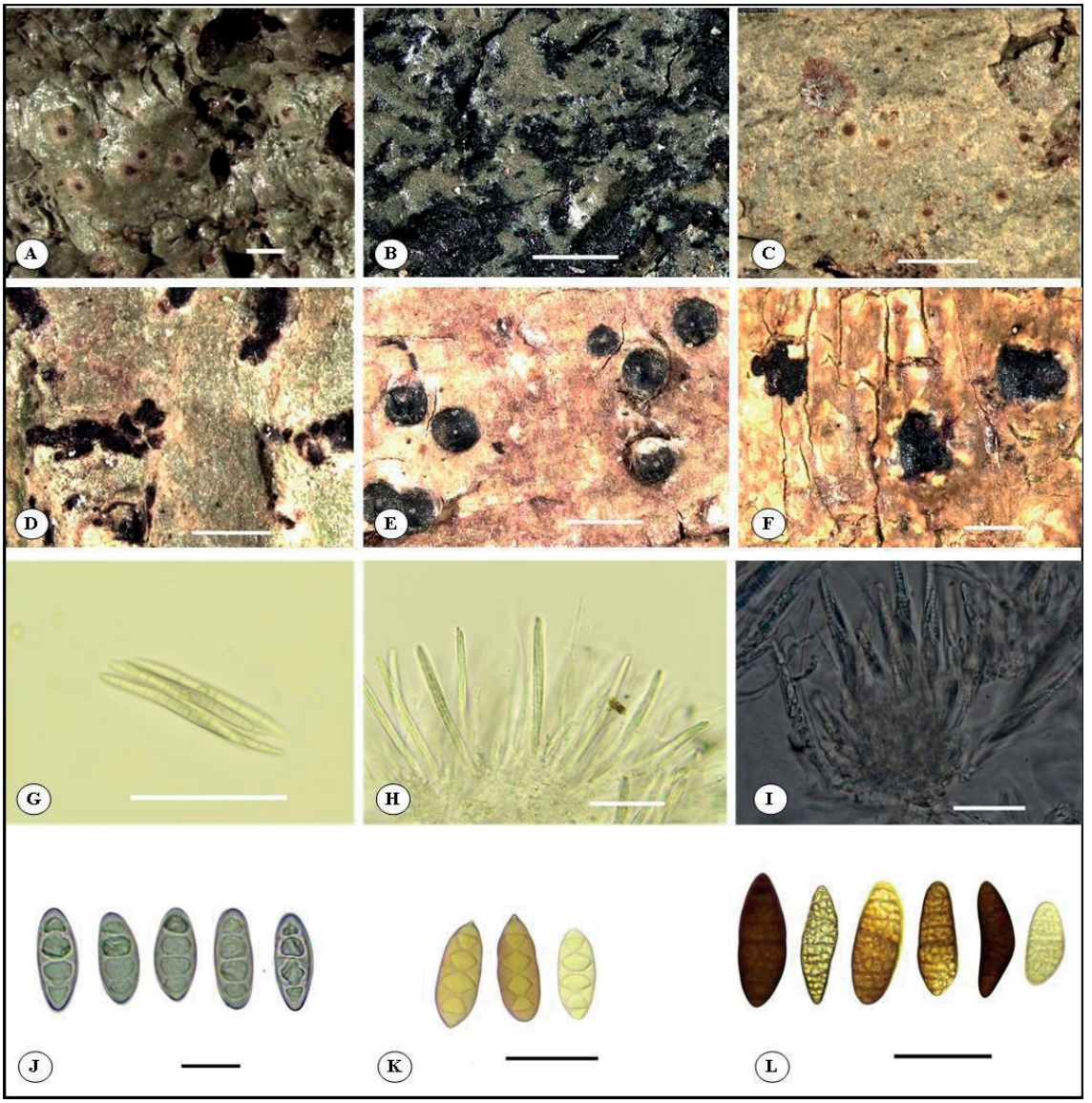

Fig. 2. A–F, thallus with ascomata, and G–L, ascospores. A & G, *Porina africana;* B & H, *P. cestrensis;* C & I, *P. subinterstes;* D & J, *Lithothelium grossum;* E & K, *Pyrenula acutispora;* F & L, *P. ceylonensis.* Scales: A–F = 1mm; G–I & L = 50 µm; J–K = 20 µm.

125°03'50.6''E, 508 masl, tropical lower montane rainforest, corticolous, 06 February 2023, *M. Dal Forno 6540.*

*Pyrenula ceylonensis (Ajay Singh & Upreti) Aptroot (Fig. 2F & L)

Specimens examined: Bukidnon, Northern slope of Mt. Kitanglad, 08°10'57''N, 124°51'48''E, 1650 masl, tropical upper montane rainforest, corticolous, 06 June 2024, *M. Dal Forno 9594;* 08°11'02"N, 124°52'13"E, 1478 masl, tropical upper montane rainforest, corticolous, 07 June 2024, *M. Dal Forno 9721.*

A pantropical species, previously known only from El Salvador and India (Aptroot, 2021).

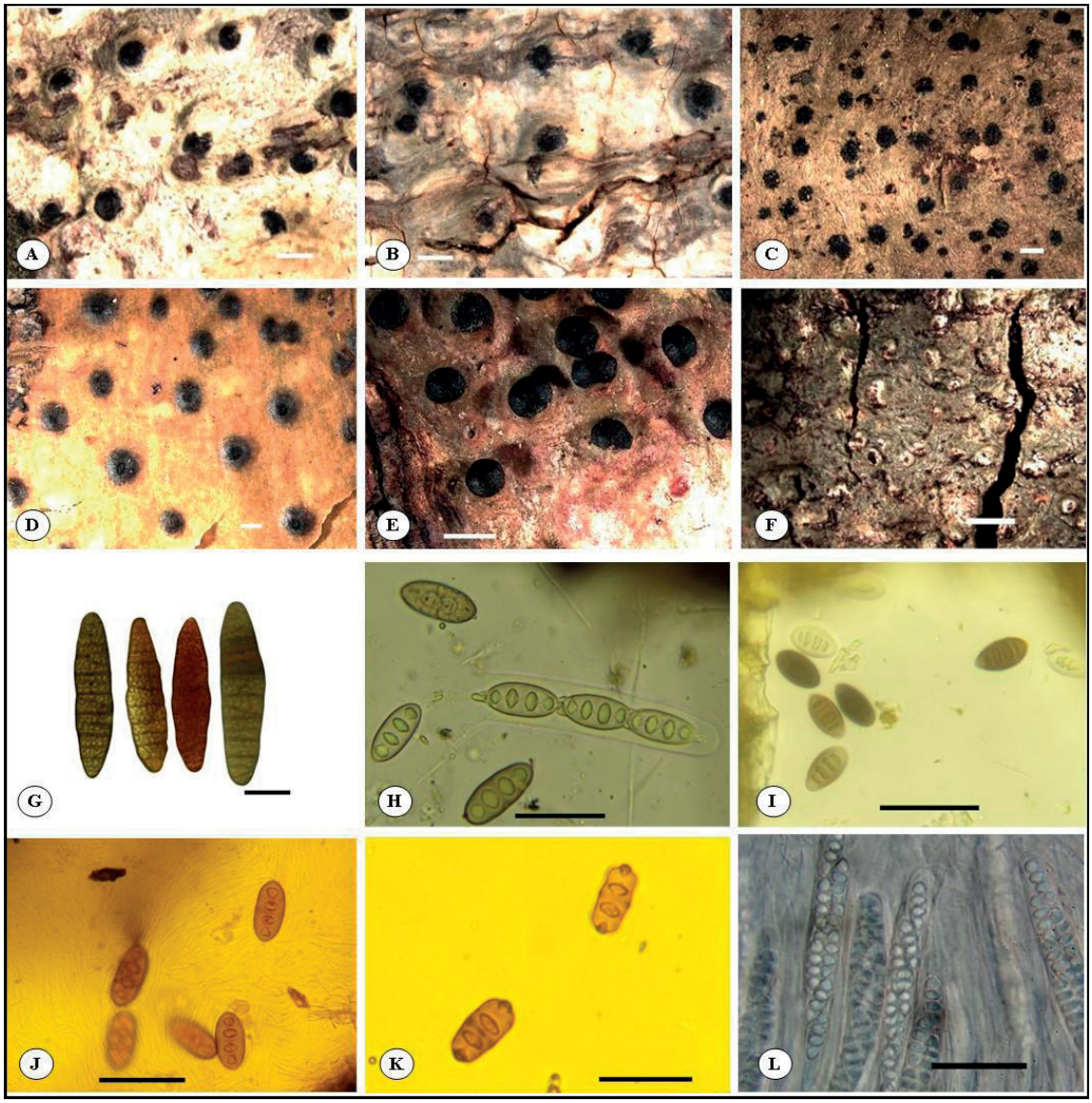

Fig. 3. A–F, thallus with ascomata, and G–L, ascospores. A & G, *Pyrenula duplicans;* B & H, *P. mastophoroides;* C & I, *P. pyrgillospora;* D & J, *P. subducta;* E & K, *P. subgregantula;* F & L, *Astrothelium fallax.* Scales: A–F = 1mm; G–L = 50 µm.

It is characterized by perithecia with lateral ostioles, muriform ascospores, 50–90 µm, either septation only or mostly distoseptate, with notably thickened endospore. The Philippine material fits well with the description of *P. ceylonensis* by the lateral ostioles, muriform ascospores, 57–91 × 24–34 µm, with a distinctly thickened endospore.

*Pyrenula duplicans (Nyl.) Aptroot (Fig. 3A & G)
Specimen examined: Bukidnon, Northern slope of Mt. Kitanglad, 08°10'30"N, 124°51'50"E, 1784 masl, tropical upper montane rainforest, corticolous, 04 June 2024, *M. Dal Forno 9033.*

The Philippine material fits closely with the description from Aptroot et al. (2008), having a pseudocyphellate thallus, not inspersed

hamathecium, densely muriform ascospores with 9–15 primary septa, ellipsoid with rounded ends, 112–205 × 30–41 µm (vs. Aptroot et al., 2008, with 110–180 × 30–45 µm).

Pyrenula immissa (Stirt.) Zahlbr.
Specimens examined: Bukidnon, Cinchona Forest Reserve, 08°03'34.8"N, 125°00'25.6"E, 1231 masl, tropical lower montane rainforest, corticolous, 13 July 2023, *M. Dal Forno 8132;* Mt. Nebo, 07°56'15.0"N, 124°57'22.6"E, 1274 masl, tropical lower montane rainforest, corticolous, 08 July 2023, *M. Dal Forno 7903.*

Pyrenula laetior Müll.Arg.
Specimens examined: Bukidnon, Cinchona Forest Reserve, 08°03'29.2"N, 125°00'20.4"E, 1262 masl, tropical upper montane rainforest, corticolous, 14 July 2023, *M. Dal Forno 8361;* Mt. Nebo, 07°56'18.0"N, 124°57'13.3"E, 1274 masl, tropical lower montane rainforest, corticolous, 08 July 2023, *M. Dal Forno 7790.* — Misamis Oriental, Talangisog Forest Park and View Point, 08°41'21.7"N, 125°14'18.6"E, 610 masl, tropical lowland evergreen rainforest, corticolous, 22 July 2023, *M. Dal Forno 8836.*

Pyrenula lineatostroma Aptroot
Specimen examined: Misamis Oriental, Talangisog Forest Park and View Point, 08°41'21.7"N, 125°14'18.6"E, 610 masl, tropical lowland evergreen rainforest, corticolous, 22 July 2023, *M. Dal Forno 8837.*

*Pyrenula mastophoroides (Nyl.) Zahlbr.
(Fig. 3B & H)
Specimens examined: Bukidnon, Northern slope of Mt. Kitanglad, 08°11'02"N, 124°52'13"E, 1478 masl, tropical upper montane rainforest, corticolous, 07 June 2024, *M. Dal Forno 9687, 9818.*

A species previously known from the Neotropics but also reported in India (Ram and Sinha 2010). It is anatomically similar with the species *P. interducta* (Nyl.) Zahlbr., having an inspersed hamathecium, same ascospore type and size, but differs morphologically as the ascomata of *P. mastophoroides* are globose, not spreading laterally, whereas *P. interducta* is conical and laterally spreading (Aptroot, 2021).

Pyrenula platystoma (Müll. Arg.) Aptroot
Specimen examined: Bukidnon, Northern slope of Mt. Kitanglad, 08°10'39''N, 124°51'49''E, 1637 masl, tropical upper montane rainforest, corticolous, 06 June 2024, *M. Dal Forno 9468.*

Pyrenula pseudobufonia (Rehm) R.C., Harris
Specimen examined: Dinagat Islands, Mt. Redondo, 10°21'44"N, 125°37'45"E, 630 masl, forest over ultramafic soil, corticolous, 21 June 2024, *M. Dal Forno 10424.*

• Pyrenula pyrgillospora Aptroot (Fig. 3C & I)
Specimen examined: Davao del Sur, Mt. Apo, 06°58'29.0''N, 125°17'50.0''E, 1748 masl, tropical upper montane forest, corticolous, 05 August 2022, *M. Dal Forno 5193.*

A pantropical species, characterized by ascospores with rounded to quadrangular locules, with bands of dark granules between the locules, and with more or less endospore thickening between the outer lumina and the wall (Aptroot, 2021).

Pyrenula rinodinospora Aptroot
Specimens examined: Bukidnon, Mt. Nebo, 07°56'18.0''N, 124°57'13.3''E, 1274 masl, tropical lower montane rainforest, corticolous, 08 July 2023, *M. Dal Forno, 7780, 7788;* Northern slope of Mt. Kitanglad, 08°11'02"N, 124°52'13"E, 1478 masl, tropical upper montane rainforest, 07 June 2024, *M. Dal Forno 9804.* — Dinagat Islands, Mt. Redondo, 10°21'7"N, 125°38'29"E, 938 masl, upper montane dwarf forest over ultramafic soil (locally known as Bonsai forest), corticolous, 22 June 2024, *M. Dal Forno 10606.*

*Pyrenula subducta (Nyl.) Müll.Arg. (Fig. 3D & J)
Specimens examined: Bukidnon, Northern slope of Mt. Kitanglad, 08°11'02"N, 124°52'13"E, 1478 masl, tropical upper montane rainforest, corticolous, 07 June 2024, *M. Dal Forno 9720, 9722, 9808, 9814.*

A pantropical species, characterized by 3-septate, oblong ellipsoid ascospores with rounded central lumina, and with all lumina developing papillae at the sides facing the adjacent lumina (Upreti, 1990).

*Pyrenula subgregantula Müll.Arg. (Fig. 3E & K)
Specimen examined**:** Dinagat Islands, Mt. Kanbinlio, 10°22'42" N, 125°38'9"E, 782 masl, tropical lower montane forest over ultramafic soil, corticolous, 23 June 2024, *M. Dal Forno 10737.*

A species previously known from the neotropics but also reported from India (Ingle et al., 2018). This species is characterized by ascomata at least partly with joint ostioles, and ascospores

with rather pointed ends, 17–21 × 7–8 µm, lumina angular, end lumina elongated, directly against the exospore wall. The Philippine material fits rather closely to the description of Aptroot et al. (2008).

Pyrenula supracongruens Aptroot & Schumm
Specimens examined: Misamis Oriental, Mt. Balatukan, 08°44'02.6''N, 125°00'04.2''E, 1546 masl, tropical upper montane rainforest, corticolous, 18 January 2023, *M. Dal Forno 5728;* Talangisog Forest Park and View Point, 08°41'39.4"N, 125°14'01.6"E, 628 masl, tropical lowland evergreen rainforest, corticolous, 21 July 2023, *M. Dal Forno 8690;* 08°41'33.4"N, 125°14'18.8''E, 636 masl, tropical lowland evergreen rainforest, corticolous, 20 July 2023, *M. Dal Forno 8577*.

Trypetheliaceae Eschw., Syst. Lich.: 17 (1824)
*Astrothelium fallax Müll.Arg. (Fig. 3F & L)
Specimen examined: Misamis Oriental, Mt. Balatukan, 08°44'05.4''N, 125°00'01.6''E, 1584 masl, tropical upper montane rainforest, corticolous, 18 January 2023, *M. Dal Forno 5699*.

A pantropical species, characterized by distinctly pseudostromatic ascomata, distinctly prominent to sessile, uneven-verrucose, covered with thallus, with whitish ring around dark the ostiolar zone, and with 3-septate, fusiform–ellipsoid, 30–39 × 10–13 µm ascospores (Aptroot & Lücking, 2016).

Astrothelium meiophorum (Nyl.) Aptroot & Lücking
Specimen examined: Misamis Oriental, Talangisog Forest Park and View Point, 08°41'51.6"N, 125°14'12.8"E, 589 masl, tropical lowland evergreen rainforest, corticolous, 19 July 2023, *M. Dal Forno 8419*.

Astrothelium neglectum Luangsuph., Aptroot & Sangvichien
Specimen examined: Bukidnon, Mt. Natampod, 07°51'52.0"N, 125°24'45.8"E, 977 masl, tropical lower montane rainforest, corticolous, 24 July 2022, *M. Dal Forno 4786*.

*Astrothelium nigratum (Müll. Arg.) Aptroot & Lücking (Fig. 4A & G)
Specimen examined: Davao del Sur, Mt. Apo, 06°54'27"N, 125°20'37"E, 1144 masl, tropical lower montane rainforest, anthropogenically disturbed habitat, corticolous, 01 August 2022, *M. Dal Forno 5077*.

A species previously reported only from the neotropics (Aptroot & Lücking, 2016), but records were later reported also in New Zealand and Sri Lanka, with verified preserved specimens deposited at the Natural History Museum in London (NHM-UK). The Philippine material fits well with the description from Aptroot & Lücking (2016), having an olive-brown, corticate thallus, smooth to uneven; trypethelioid ascomata, diffusely pseudostromatic, 0.2–0.3 mm in diam., immersed-erumpent, exposed and brown-black; hamathecium clear; ascospores 8 per ascus, 3-septate, fusiform-ellipsoid, 20–27 × 7–10 µm, hyaline, and IKI −.

*Astrothelium nitidulum Weerakoon & Aptroot (Fig. 4B & H)
Specimen examined: Bukidnon, Northern slope of Mt. Kitanglad, 08°11'17"N, 124°52'10"E, 1342 masl, tropical upper montane rainforest, corticolous, 07 June 2024, *M. Dal Forno 9856*.

An eastern paleotropical species, previously known only from Sri Lanka, and characterized by having a trypethelioid ascomata, solitary to confluent, with erumpent to prominent pseudostromata, 7-septate ascospores, fusiform, 40–49 × 12–15 µm with diamond-shaped lumina, and an inspersed hamathecium (Weerakoon & Aptroot, 2014). It only deviates from the original description by having 5–7-septate ascospores.

Astrothelium scoria (Fée) Aptroot & Lücking
Specimen examined: Dinagat Islands, Cuarenta Watershed, 10°01'35.9"N, 125°37'28.2"E, 292, lowland forest, along the Gleicheniaceae field, corticolous, 28 January 2023, *M. Dal Forno 6200*.

Bathelium albidoporum (Makhija & Patw.) R.C. Harris
Specimen examined: Bukidnon, Northern slope of Mt. Kitanglad, 08°11'42"N, 124°51'33"E, 1427 masl, tropical upper montane rainforest, corticolous, 06 June 2024, *M. Dal Forno 9429*.

Bathelium nigroporum (Makhija & Patw.) Aptroot & Lücking
Specimen examined: Bukidnon, Mt. Nebo, 07°56'15.0''N, 124°57'22.6"E, 1274 masl, tropical lower montane rainforest, corticolous, 08 July 2023, *M. Dal Forno 7909*.

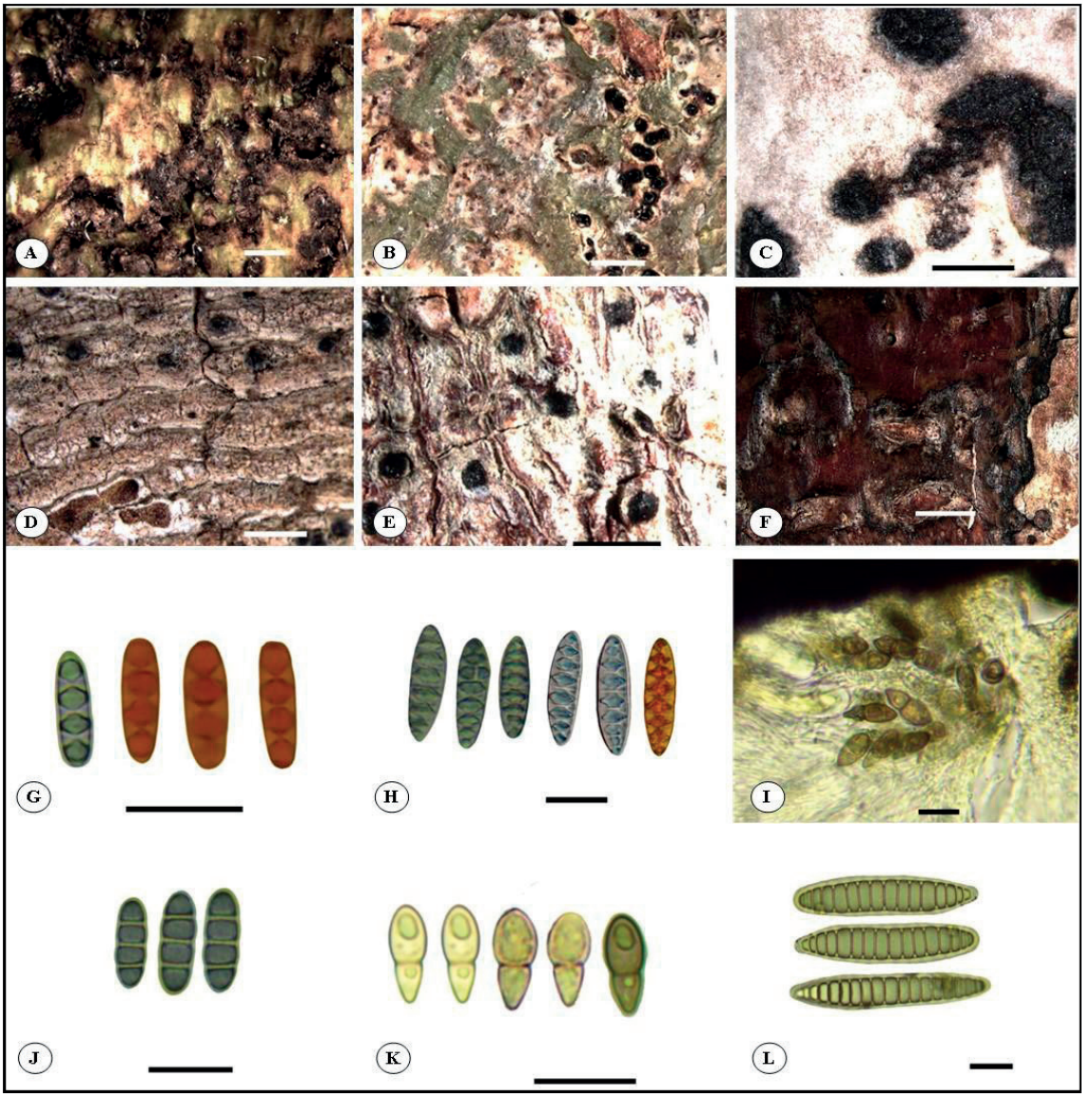

Fig. 4. A–F, thallus with ascomata, and G–L, ascospores. A & G, *Astrothelium nigratum;* B & H, *A. nitidulum;* C & I, *Bogoriella confluens;* D & J, *Polymeridium suffusum;* E & K, *Pseudobogoriella captiosa;* F & L, *Viridothelium cinereoglaucescens.* Scales: A–F = 1mm; G–L = 20 µm.

•Bogoriella confluens (Müll. Arg.) Aptroot & Lücking (Fig. 4C & I)
Specimen examined: Dinagat Islands, Mt. Redondo, 10°21'44"N, 125°37'45"E, 630 masl, forest over ultramafic soil, corticolous, 21 June 2024, *M. Dal Forno 10460*.

A relatively common cosmopolitan species, characterized by ascospores under 9 µm wide, with more or less equal locules and ascomata with a 200–400 µm wide fringe (Aptroot & Lücking, 2016).

Macroconstrictolumina lyrata (R.C. Harris) Lücking, R. Miranda & Aptroot
Specimen examined: Dinagat Islands, Paragua Forest, Libjo, 10°14'10.7"N, 125°32'22.7"E, 194 masl, lowland evergreen rainforest, anthro-

pogenically disturbed habitat, corticolous, 29 January 2023, *M. Dal Forno 6239.*

Macroconstrictolumina malaccitula (Nyl.) Lücking, R. Miranda & Aptroot
Specimens examined: Dinagat Islands, Mt. Redondo, 10°21'05.8"N, 125°37'57.3''E, 802 masl, upper montane dwarf forest over ultramafic soil (locally known as Bonsai forest), corticolous, 01 February 2023, *M. Dal Forno 6409, 10418*; 10°21'44"N, 125°37'45"E, 630 masl, forest over ultramafic soil, corticolous, 21 June 2024, *M. Dal Forno 10418.*

•Polymeridium suffusum (Knight) Aptroot (Fig. 4D & J)
Specimens examined: Bukidnon, Mt. Malimumu, 07°52'25"N, 125°24'12"E, 903 masl, tropical lower montane rainforest, along the road, corticolous, 18 July 2022, *M. Dal Forno 4320.* — Dinagat Islands, Cuarenta Watershed, 10°01'35.9"N, 125°37'28.2"E, 292 masl, lowland forest, along the Gleicheniaceae field, corticolous, 28 January 2023, *M. Dal Forno 6205.*

A pantropical species, characterized by an ecorticate, white thallus, ascomata with apical or partly lateral, separate ostioles, solitary, erumpent to mostly covered by thallus, inspersed hamathecium, ascospores 3-septate, fusiform, 24–30 × 6–9 µm, hyaline. It fits well with the description of *P. suffusum* (Aptroot & Cáceres, 2014) by the thallus, ascomata, hamathecium characters, as well as the ascospores size of 25–30 × 7–9 µm.

•Pseudobogoriella captiosa (Kremp.) Lücking, R. Miranda & Aptroot (Fig. 4E & K)
Specimens examined: Dinagat Islands, Mt. Redondo, 10°21'44"N, 125°37'45"E, 630 masl, forest over ultramafic soil, corticolous, 21 June 2024, *M. Dal Forno 10428*;10° 21'6" N, 125° 38'12" E, 791 masl, upper montane dwarf forest over ultramafic soil (locally known as Bonsai forest), corticolous, 22 June 2024, *M. Dal Forno 10485.*

A possibly cosmopolitan species reported from Brazil, Costa Rica, Colombia, Guyana, and the United States of America (including Hawai'i, Aptroot & Lücking, 2016). It is characterized by a whitish rose thallus with black prothallus lines, ascomata conical, without distinct fringe; ascospores (13.5–)17– 19(–21) × (5.5–) 6.5–7.5(–8.5) µm, with equal locules or larger upper locule, with rounded (–attenuate) ends, verruculose (Aptroot & Lücking, 2016). It fits rather well with the description of *P. captiosa* by the thallus, ascomata and ascospore characters, 13–22 × 7–9 µm.

Pseudobogoriella fumosula (Zahlbr.) Lücking, R. Miranda & Aptroot
Specimen examined: Bukidnon, Mt. Nebo, 07°56'27.3''N, 124°57'14.6''E, 1274 masl, tropical lower montane rainforest, corticolous, 06 July 2023, *M. Dal Forno 7084*.

Pseudopyrenula endoxanthoides Vain.
Specimens examined: Bukidnon, Mt. Nebo, 07°56'49.8''N, 124°57'00.1''E, 1295 masl, tropical lower montane rainforest, corticolous, 06 July 2023, *M. Dal Forno 7325*. — Dinagat Islands, Mt. Redondo, 10°22'45.4"N, 125°36'31.2"E, 57 masl, lowland rainforest over ultramafic soil, corticolous, 02 February 2023, *M. Dal Forno 6489;* 10°21'44''N, 125°37'45''E, 630 masl, forest over ultramafic soil, corticolous, 21 June 2024, *M. Dal Forno 10419*. — Misamis Oriental, Talangisog Forest Park and View Point, 08°41'33.4"N, 125°14'18.8"E, 636, tropical lowland evergreen rainforest, corticolous, 20 July 2023, *M. Dal Forno 8526.*

Trypethelium platystomum Mont.
Specimen examined: Bukidnon, Mt. Musuan, 07°52'49.9"N, 125°04'02.7"E, 489 masl, tropical lower montane rainforest, corticolous, 30 July 2022, *M. Dal Forno 5010*.

*Viridothelium cinereoglaucescens (Vain.) Lücking, M. P. Nelsen & Aptroot (Fig. 4F & L)
Specimen examined: Dinagat Islands, Cuarenta Watershed, 10°01'28.8"N, 125°37'16.3"E, 309 masl, lowland forest, anthropogenically disturbed habitat, corticolous, 28 January 2023, *M. Dal Forno 6187*.

Previously known only from temperate and subtropical Asia, mainly from Japan and South Korea (Harris, 1998) and also reported in India (Aptroot & Lücking, 2016), *V. cinereoglaucescens* is characterized by 11–18-septate, fusiform ascospores, 50–80 × 8–15 µm, with thin septation. The Philippine material fits rather well with the description of *V. cinereoglaucescens* based on the ascomata, hamathecium and ascospore characters, 11–17-septate, 62–78(–80) × 12–15 µm. It only deviates from the

description of Aptroot & Lücking (2016; "thallus olive green to yellowish brown") by the red-brown thallus, though this might be an environmental variation since the specimen was collected from an anthropogenically disturbed habitat with increased light exposure.

Verrucariaceae Eschw., Syst. Lich.: 15 (1824)
Flakea papillata O. E. Erikss.
Specimen examined: Dinagat Islands, Cinchona Forest Reserve, 08°03'15.5"N, 125°00'19.5"E, 1234 masl, tropical lower montane rainforest, on tree trunk, 14 July 2023, *M. Dal Forno 8340*.

Verrucaria muralis Ach.
Specimen examined: Dinagat Islands, Bababu, 10°04'09.8"N, 125°30'25.9"E, 67 masl, forest over limestone, saxicolous, 31 January 2023, *M. Dal Forno 6373*.

DISCUSSION

The discovery of forty-one species as new distribution records for the Philippines highlights the extent to which pyrenocarpous lichens have been previously overlooked. This number may increase as more localities are explored. The country is now represented by the occurrence of the 224 species of pyrenocarpous lichens belonging to 39 genera and 12 families, and surpasses the total species reported from Thailand (151 species; Buaruang et al., 2017), Vietnam (ca. 100 species; Aptroot & Sparrius, 2006; Santoshi et al., 2019), and Taiwan (101 species; Aptroot, 2003), although it remains below the 382 species documented for India (Mishra et al., 2020). Nevertheless, the Philippines still emerge as one of the pyrenolichen hotspots in the Southeast Asian region.

Most of the newly recorded species exhibit pantropical distributions, while a few show either paleotropical or cosmopolitan patterns. Notably, fourteen species represent new records for Southeast Asia, whereas four lichen species are new for Asia. Three from the new Asian records: viz. *Pyrenula mastophoroides, P. subgregantula, Pseudoborgoriella captiosa*, were previously known only from the neotropics, but subsequently recorded in Asia and the Pacific region (Aptroot & Lücking, 2016). The presence of Neotropical taxa now recorded in Asia may reflect previously overlooked pantropical distributions (and the possibility of long-distance dispersal) due to limited sampling (Buschbom, 2007; Garrido-Benavent et al., 2018). Although specific dispersal mechanisms remain uncertain, similar patterns have been observed in other lichenized and lichenicolous fungi, for instance *Microxyphiomyces similis* (Vězda) Xavier-Leite, M. Cáceres & Lücking (basionym: *Tricharia similis* Vězda) was originally described from the Neotropics, but was later documented in Malaysia and Papua New Guinea as well (Meise Botanic Garden Herbarium, 2024; Botanic Garden and Botanical Museum Berlin, 2016), illustrating an emerging pattern of taxa with wider pantropical affinities than once assumed.

Although the discovery of numerous new country records further highlights the exceptional biological significance of Mindanao, the long-term persistence of its forest ecosystems is increasingly jeopardized by intensive deforestation, mining operations, and agricultural expansion (Agduma et al., 2023). Many pyrenolichens are microhabitat-specific, with several groups particularly sensitive to changes in canopy structure and moisture stability (Rivas Plata et al., 2008; Aptroot et al., 2013). Given these vulnerabilities, continued exploration efforts, improved national capacity in lichen taxonomy, and strengthened collaborations with various institutions are urgently needed, not only to exhaustively document the lichen biota in Mindanao but also to integrate these often-overlooked organisms into a broader conservation planning aimed at safeguarding the ecological integrity of the Philippine forests.

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Declaration of Competing Interest

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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