



Three new species of *Gyroporus* (Boletales, Basidiomycota) from Australia

Naveed Davoodian¹, Neale L. Bougher², Nigel A. Fechner³, Sarah E. Bergemann⁴ and Roy E. Halling⁵

¹ Royal Botanic Gardens Victoria, Birdwood Avenue, Melbourne, Victoria 3004, Australia; e-mail: Naveed.Davoodian@rbg.vic.gov.au

² Department of Biodiversity, Conservation and Attractions, Western Australian Herbarium, Locked Bag 104, Bentley Delivery Centre, Western Australia 6983, Australia

³ Queensland Herbarium, Mount Coot-tha Road, Toowong, Brisbane, Queensland 4066, Australia

⁴ Department of Biology, Middle Tennessee State University, Murfreesboro, Tennessee 37132, USA

⁵ New York Botanical Garden, 2900 Southern Boulevard, Bronx, New York 10458, USA

Introduction

Gyroporus Quél. is a widely distributed genus of obligately ectomycorrhizal boletes (stipitate-pileate fungi with poroid hymenophores of the order Boletales) that harbours a high level of undescribed diversity (Davoodian *et al.* 2018). A significant portion of this diversity is in Australia, where species of *Gyroporus* are putatively mycorrhizal primarily with Myrtaceae. In addition to its global diversity and ectomycorrhizal trophic mode, *Gyroporus* is notable as being one of few stipitate-pileate genera in the otherwise gasteroid suborder Sclerodermatineae (Wilson *et al.* 2012). Here, we formally describe three new species of *Gyroporus* from Australia that have become apparent after sustained fieldwork, morphological study, and phylogenetic research by the authors. Two of the species described are members of the Australian *cyanescens* complex, a Southern Hemisphere clade sister to the classic European/Northern Hemisphere taxon *Gyroporus cyanescens* (Bull.:Fr.) Quél. (Davoodian *et al.* 2018).

Abstract

Three novel Australian species of *Gyroporus* Quél. are formally described here. *Gyroporus naranjus* Davoodian, Bougher, Fechner & Halling sp. nov. is an orange *Gyroporus* phylogenetically linked with undescribed African *Gyroporus* species. Two Western Australian species, *Gyroporus occidentalis* Davoodian, Bougher & Halling sp. nov. and *Gyroporus robinsonii* Davoodian sp. nov. are dark blue oxidizing and light blue oxidizing (respectively) members of the Australian *cyanescens* complex.

Keywords: ectomycorrhizal fungi, taxonomy, systematics, Australasia, boletes

The Australian *cyanescens* complex is composed of two clades, one of light color oxidising and one of dark color oxidising species (see Davoodian *et al.* 2018). The light-oxidising species are represented by the clade including *Gyroporus australiensis* Davoodian, Fechner & Halling, "*Gyroporus allocyanescens*" nom. prov., and *Gyroporus robinsonii* Davoodian sp. nov. In these species the bluing reaction on injured flesh is gradual and relatively weak, generally not occurring in all tissues. *G. australiensis* is thus far only known from Great Sandy National Park in Queensland and is readily diagnosable by the combination of its brown pileus and gradual cyanescent reaction that is present in the flesh and on the pores but absent from the tubes. *Gyroporus robinsonii* sp. nov., thus far only known from Western Australia, is described below. The dark-oxidising species are represented by the clade including *Gyroporus furvescens* Davoodian & Halling, "*Gyroporus austrocyanescens*" nom. prov., "*Gyroporus neocyaneescens*" nom. prov., *Gyroporus brunnescens* Davoodian, Fechner & Halling, and *Gyroporus occidentalis* Davoodian, Bougher & Halling sp. nov. In these species, the tissues stain immediately and intensely deep blue, with the exception of *G. brunnescens*, which is the only true *Gyroporus* known to have a brown oxidation reaction. *Gyroporus occidentalis* sp. nov., thus far only known from Western Australia, is described and illustrated. Several undescribed species (e.g. "*G. neocyaneescens*") belong to the Australian *cyanescens* complex, however, beyond whether they are members of the light-oxidising or dark-oxidising clades, the boundaries and characteristics of these species cannot be fully ascertained until more collections are acquired.

Gyroporus cyanescens sensu lato (i.e. the Northern Hemisphere *cyanescens* complex) includes several segregate species, such as *Gyroporus pseudolacteus* G. Moreno, Carlavilla, Heykoop, Manjón & Vizzini and *Gyroporus pseudocyaneescens* G. Moreno, Carlavilla, Heykoop, Manjón & Vizzini (Crous, Wingfield, Richardson *et al.* 2016; Crous, Wingfield, Burgess *et al.* 2017). *Gyroporus castaneus* (Bull.:Fr.) Quél., a classic European taxon, has not been reliably documented in Australia; previous Australian collections under this name are now known to be either *Gyroporus mcabbii* Davoodian, Bougher & Halling or *Gyroporus naranjus* Davoodian, Bougher, Fechner & Halling sp. nov.

Taxonomy

Gyroporus naranjus Davoodian, Bougher, Fechner & Halling sp. nov.

Mycobank No.: MB828913

Differs from other species of *Gyroporus* in Australia by its orange colouration throughout the pileus and stipe surfaces.

Type: QUEENSLAND. Wide Bay District, Great Sandy National Park, Fraser Island, 25°28'41"S, 153°03'42"E, 15.ii.2011, Halling 9411 (holo: BRI AQ0797904 photo!, iso: NY 1194004!). GenBank – RPB2: MF818233. ATP6: MF818157.

Pileus 1.5–7 cm broad, convex to planoconvex, dry, brown to pale brownish orange to light orange, sometimes nearly white, finely matted to barely subvelutinous to furfureous to nearly glabrous. *Flesh* white, unchanging, with mild odour and taste. *Tubes* adnexed, unchanging, white then yellow when mature, some parts occasionally discolouring to orange or orange-brown. *Stipe* brown to cinnamon brown to pale brownish orange to faint orange, 3–7 cm long, 0.8–3 cm broad, dry, equal to subclavate, fine matted to glabrous, chambered to hollow. *Spores* (7)7.2–9.7 × 4–5(5.5) µm (Q=1.79), smooth, light yellow-hyaline to yellow-hyaline, subreniform to ellipsoid to subovoid to elongate subovoid, sometimes slightly peanut shaped, sometimes appearing apiculate. *Basidia* 25–30 × 9–10 µm, clavate. *Cheilocystidia* 29–40 × 6–9 µm, versiform (ventricose-acuminate, cylindrical, cylindrical-tapering, or slightly clavate). *Pileipellis* a shortened, tightly-arranged trichoderm with inflated elements. *Clamp connections* present.

Additional specimens examined: QUEENSLAND. Wide Bay District. Great Sandy National Park. Fraser Island. Central Station, 25°28'34.3"S, 153°03'21.6"E, 90m, 07.iii.2011, R.E. Halling 9471 (BRI, NY); W of Central Station (Wanggoolba Creek Road), 25°28'16.3"S, 153°02'09.6"E, 24m, 18.ii.2011, R.E. Halling 9429 (BRI, NY); Road from Eurong to Central Station, 25°28'41.2"S, 153°03'43.2"E, 116m, 15.ii.2011, R.E. Halling 9413 (BRI, NY); Road from Central Station to Lake Birrabeen, 25°29'42.0"S, 153°03'50.4"E, 160m, 13.ii.2009, R.E. Halling 9068 (BRI, NY); Road from Central Station to Lake Birrabeen, 25°29'49.9"S, 153°03'03.6"E, 140m, 08.ii.2009, R.E. Halling 9020 (BRI, NY); Walkamin, south of Mareeba. Along Kennedy Highway, 24.ii.1993, N.L. Bougher E4879 (PERTH).

Distribution and ecology: Thus far known only from Queensland. Gregarious to scattered in sand with Myrtaceae (*Leptospermum* J.R.Forst. & G.Forst., *Eucalyptus* L'Hér., *Syncarpia* Ten., *Lophostemon* Schott) and possibly Casuarinaceae (*Allocasuarina* L.A.S.Johnson) and Fabaceae (*Acacia* Mill.).

Comments: Based on analysis of the protein-coding genes *atp6* (mitochondrial) and *rpb2* (nuclear), *Gyroporus naranjus* sp. nov. is sister to several undescribed species from mainland Africa (Davoodian *et al.* 2018 and unpublished data), which together may represent a Gondwanan lineage. In this context, molecular comparisons with *G. austrobrasiliensis* A.C.Magnago from Brazil and *G. paramjitii* K.Das, D.Chakraborty & Vizzini from India would be illuminating (Das *et al.* 2017; Magnago *et al.* 2018). A similar species that occurs in Australia, *Gyroporus mcnabbii* Davoodian, Bougher & Halling, is distinguishable from *G. naranjus* in that *G. mcnabbii* displays deeper, mottled colours, a more subvelvety pileus texture, and larger spores. A photograph of the holotype of *G. naranjus* taken shortly after collection is provided (Fig. 1).

***Gyroporus occidentalis* Davoodian, Bougher & Halling sp. nov.**

Mycobank No.: MB828914

This is the only species of *Gyroporus* thus far known from Western Australia with a rapidly bluing oxidation reaction. It is also unique for its robust size and stature.

Type: WESTERN AUSTRALIA. Capel Shire, Ludlow State Forest, Tuart Forest National Park, 33°36'51.1"S, 115°27'39.6"E, 20.vi.2006, *Halling* 8821 (holo: PERTH 8019118 photo!, iso: NY 1194024!). GenBank - RPB2: MF818213, FJ536639. ATP6: MF818177. 18S(part)-ITS1-5.8S-ITS2-25S(part): EU718103.

Pileus 4–10 cm broad, irregular (roughly subhemispherical to subconvex to irregular to irregularly planar), dry, floccose to matted woolly to heavily appressed tomentose, yellow-white to yellow buff to dirty yellow, cyanescent, with slightly extended margin. *Flesh* white, rapidly cyanescent, with mild odor and taste. *Tubes* adnexed to subfree, whitish to yellowish white to pale yellow, cyanescent. *Stipe* 5.5–12 cm long, 2.2–4.5 cm broad, irregular (subequal to slightly



Figure 1. *Gyroporus naranjus* (holotype *Halling* 9411). Photo: Roy Halling

ventricose to subclavate to tapering downward), dry, finely appressed lanose, often with annular zone/ridge, subconcolorous with pileus, cyanescent, pithy to chambered (hollowing). *Spores* 7.7–8.4(–9.1) × 3.5–4.2 μm (Q=2.17), smooth, yellow. *Basidia* 28–32 μm long. *Cheilocystidia* clavate to more or less fusoid to tapering, sometimes elongate. *Pileipellis* an elongated, tangled trichodermium; elements yellow-hyaline, septate, clamped, 8–16 μm wide. *Clamp connections* present.

Additional specimens examined: WESTERN AUSTRALIA.

Perth. Floreat. Elphin Road, 31°59'12.1"S, 115°53'16.8"E, 17.vi.2006, R.E. Halling 8819 (PERTH, NY); Perry Lakes, N.L. Bougher E8164 (PERTH).

Distribution and ecology: Thus far known only from Western Australia. On sand in association with Myrtaceae (*Eucalyptus* and possibly *Agonis*).

Comments: This is a quickly dark blue-staining *Gyroporus cyanescens* (a classic Northern Hemisphere taxon) relative from Western Australia, embedded in a clade of other quickly dark blue-staining species from

Eastern Australia (e.g. *G. furvescens* Davoodian & Halling supported with ATP6 and RPB2 data in Davoodian et al. 2018). A photograph of the holotype arranged in the field is provided (Fig. 2), as well as a photograph of the exposed flesh taken indoors during collection processing (Fig. 3).

***Gyroporus robinsonii* Davoodian sp. nov.**

Mycobank No.: MB828915

This is the only species of *Gyroporus* thus far known from Western Australia with a slowly and faintly bluing oxidation reaction.

Type: WESTERN AUSTRALIA. Trent, London Forest Block, edge of Mountain Road, 1.6 km west of Nornalup Road, 34°46'39"S, 116°58'48"E, 8.vi.2010, R.M. Robinson s.n. (holo: NY 1292999!). GenBank - ATP6: MF818178.

Pileus plane to subplanoconvex, margins turning upward or recurving, dry, matted, fibrils sometimes aggregating



Figure 2. *Gyroporus occidentalis* (holotype Halling 8821). Photo: Roy Halling

into small scales, yellow-white to straw yellow to buff to dirty buff. *Flesh* white, slowly and faintly cyanescent. *Tubes* adnexed, whitish to yellowish, not cyanescent, pores likewise. *Stipe* dry, very finely matted, more or less subconcolorous with pileus, pithy to chambered. *Spores* (8.4–)8.8–10.5(–12) × 4.7–5.6(–6) μm (Q=1.75–2.14), smooth, cloudy yellow to yellow to yellow-hyaline, subreniform to ellipsoid to subellipsoid to subovoid to ovoid-elongate, sometimes appearing apiculate. *Basidia* 28–29 × 12–13 μm. *Pileipellis* an elongated, repent, subparallel to tangled trichodermium; elements up to 12–16 μm wide. *Clamp connections* present.

Additional specimen examined: WESTERN AUSTRALIA. Near Scotsdale and Denmark, near Hamilton Road, 34°54'33.1"S, 117°20'27.6"E, 16.vii.2011, N. Davoodian ND13 (NY).

Distribution and ecology: Thus far known only from Western Australia. On sandy soil in association with Myrtaceae (*Eucalyptus marginata* and possibly other species).

Comments: This is a slowly and faintly blue-staining *Gyroporus cyanescens* (a classic Northern Hemisphere taxon) relative from Western Australia, in a clade of other slowly and faintly blue-staining species from Eastern Australia (e.g. *G. australiensis* Davoodian, Fechner & Halling supported with ATP6 data in Davoodian *et al.* 2018). Two photographs of specimen ND13 taken within minutes of being encountered in the field are provided (Figs. 4, 5). The number ND14 was assigned to the holotype (NY 1292999) after acquisition of the



Figure 3. *Gyroporus occidentalis* (holotype Halling 8821). Exposed flesh. Photo: Robert Garvey

specimen by N. Davoodian from R.M. Robinson. This species is primarily distinguished by the combination of molecular data, known distribution, and oxidation reaction; further collection of this species may reveal additional distinguishing characters.

Identity of previous records of *Gyroporus* from Australia

Several *Gyroporus* taxa have previously been reported from Australia, though documentation has generally been insufficient for unambiguous identification. A



Figure 4. *Gyroporus robinsonii* (Davoodian 13). The slow, faint oxidation reaction in the flesh is apparent closest to the edges of the context. Photo: Naveed Davoodian



Figure 5. *Gyroporus robinsonii* (Davoodian 13). Hymenophore view. Photo: Naveed Davoodian

Gyroporus (reported alternately as *Gyroporus* sp. and “*Gyroporus variabilis*” – an invalid name) is treated in Bougher & Syme (1998), and the authors suggest that “The name Variable *Gyroporus* is appropriate because both slowly/weakly blueing and rapidly/intensely blueing varieties occur in south-western Australia.” Nevertheless, the description and illustrations provided on pp 308–309 and the voucher cited on p 378 in Bougher & Syme (1998) are exclusively based on PERTH5507022, which appears to represent *G. robinsonii*. “*Gyroporus* aff. *cyanesces*” in McMullan-Fisher *et al.* (2014) appears to correspond to *Gyroporus furvescens*, based on its swift grey blue to deep blue to blackish oxidation reaction (that can eventually become very dark brown), ivory/yellowish-white tones at the stipe apex, and spore measurements that mostly agree with the original description. Also, *G. furvescens* is recorded from rainforest habitat in eastern Australia (based on collections thus far). *Gyroporus caespitosus* Cleland is not a *Gyroporus*. Cleland (1924) initially described this taxon under *Boletus (Gyroporus) caespitosus* Cleland, which is illegitimate (the earliest homonym is *Boletus caespitosus* Masee 1892). Grgurinovic (1997) synonymised *G. caespitosus* Cleland with *Boletus ovalisporus* Cleland, and treated the latter as *Chalciporus ovalisporus* (Cleland) Grgur. She effectively lectotypified *G. caespitosus* and *B. ovalisporus* by indicating a holotype for each taxon from among the syntypes (AD 10831 [ND !] and AD 10832 [ND !], respectively – neither are true *Gyroporus*). Li and Watling (1999) later combined *G. caespitosus* into *Rubinoboletus* Pilát & Dermek.

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References

- Bougher, N.L. and Syme, K. (1998). *Fungi of Southern Australia*. University of Western Australia Press: Nedlands.
- Cleland, J.B. (1924). Australian fungi: notes and descriptions. No. 5. *Transactions and Proceedings of the Royal Society of South Australia* **48**, 236–252.
- Crous, P.W., Wingfield, M.J., Richardson, D.M., *et al.* (2016). Fungal Planet description sheets. *Persoonia* **37**, 247.
- Crous, P.W., Wingfield, M.J., Burgess, T.I., *et al.* (2017). Fungal Planet description sheets. *Persoonia* **38**, 329.
- Das, K., Chakraborty, D. and Vizzini, A. (2017). Morphological and phylogenetic evidences unveil a novel species of *Gyroporus* (Gyroporaceae, Boletales) from Indian Himalaya. *Nordic Journal of Botany* **35**, 669–675.
- Davoodian, N., Bergemann, S.E., Hosaka, K., Raspé, O., Bougher, N.L., Fechner, N.A., Henkel, T.W., Gelardi, M., Soyong, K., Naseer, A., Ortiz-Santana, B., Baroni, T.J., Nagasawa, E., Smith, M.E. and Halling, R.E. (2018). A global view of *Gyroporus*: molecular phylogenetics, diversity patterns, and new species. *Mycologia* **110**, 985–995.
- Grgurinovic, C.A. (1997). *Larger Fungi of South Australia*. The Botanic Gardens of Adelaide and State Herbarium & The Flora and Fauna of South Australia Handbooks Committee: Adelaide.
- Li, T.H. and Watling, R. (1999). New taxa and combinations of Australian boletes. *Edinburgh Journal of Botany* **56**, 143–148.
- Magnago, A.C., Alves-Silva, G., Neves, M.A. and Borges da Silveira, R.M. (2018). A new species of *Gyroporus* (Gyroporaceae, Boletales) from Atlantic Forest in Southern Brazil. *Nova Hedwigia* **107**, 291–301.
- McMullan-Fisher, S., Leonard, P. and Guard, F. (2014). *Australian Subtropical Fungi*. Suncoast Fungi: Buderim.
- Wilson, A.W., Binder, M. and Hibbett, D.S. (2012). Diversity and evolution of ectomycorrhizal host associations in the Sclerodermatineae (Boletales, Basidiomycota). *New Phytologist* **194**, 1079–1095.

