**Cantharellus violaceovinosus**, a new species from tropical Quercus forests in eastern Mexico

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**Abstract**

During explorations of tropical oak forests in central Veracruz (eastern Mexico), the authors discovered a *Cantharellus* species that produces basidiomes with strikingly violet pileus and a hymenium with yellow, raised gill-like folds. It is harvested locally and valued as a prized edible wild mushroom. Systematic multiyear sampling of basidiomes allowed the recording of the morphological variation exhibited by fresh fruit bodies in different growth stages, which supports the recognition of this *Cantharellus* species from others in the genus. Two molecular phylogenetic analyses based on a set of sequences of species of all major clades in *Cantharellus*, one including sequences of the transcription elongation factor 1-alpha (tef-1α) and a combined tef-1α and nLSU region (the large subunit of the ribosome), confirm the isolated position of the new species in a clade close to *C. lewisii* from USA, in the subgenus *Cantharellus*. Detailed macroscopic and microscopic descriptions, accompanied by illustrations and a taxonomic discussion are presented.

**Keywords**

Cantharellales, ectomycorrhizal fungi, Neotropical fungi, oak forest, wild edible mushrooms

**Introduction**

The diversity of species in *Cantharellus* Adans.: Fr., in combination with their ectomycorrhizal nature (mycobionts of several plant lineages), as well as their highly prized value as edible wild mushrooms, have attracted the attention of specialists from different fields worldwide (Smith and Morse 1947, Trappe 1962, Chandra 1989, Molina et al. 1992, Homola 1993, Thoen 1993, Watling 1997, Danell 1999, Pilz et al.
Cantharellus encompasses fungi with long-lived, gymnocarpic, fleshy, variedly coloured, trumpet-shaped basidiomes with nearly smooth, veined, gill-like folded to distinctly lamellate hymenophore, pileipellis poorly differentiated, cystidia lacking, smooth and thin-walled spores, with or without clamps (Wilson et al. 2012, Buyck et al. 2014). In many cases, basidiomes of members of closely related species or inclusive, unrelated look-alike species are difficult to identify in a strict sense, especially if there is not an accurate record of the variation of morpho-anatomical characters and colours in fresh condition. Few microscopic features in the genus had been considered discriminative, especially clamps (presence or absence), wall thickness of the terminal elements of the pileipellis hyphae and the basidiospore features (size and form).

The two former features are considered amongst the most taxonomically informative at subgeneric level and the latter used to distinguish species (Eyssartier and Buyck 2001, Buyck et al. 2014). Additionally, it has been hypothesized that there are cryptic species still undefined taxonomically, even amongst the best known Cantharellus species, especially from tropical regions but also from temperate regions (Smith and Morse 1947, Corner 1966, Heinemann 1958, 1966, Smith 1968, Petersen and Ryvarden 1971, Petersen 1976, Bigelow 1978, Petersen and Mueller 1992, Buyck and Hofstetter 2011, Buyck et al. 2012, Eyssartier et al. 2003, De Kesel et al. 2011, Tian et al. 2012, Wartchow et al. 2012, Buyck and Randrianjohany 2013, Foltz et al. 2013, Buyck et al. 2014, 2016a, c, Leacock et al. 2016).

Taxonomic research on Cantharellus has increased substantially in the last decade, especially by combining DNA and morphological information to support the definition of early recognised species and others recently discovered (Buyck and Hofstetter 2011, Buyck et al. 2011, Tibuhwa et al. 2012, Wilson et al. 2012, Buyck et al. 2012, 2013, 2014, 2015, 2016a, 2016b, Foltz et al. 2013, Shao et al. 2014, Shao et al. 2016, Leacock et al. 2016).

The earliest description of Cantharellus in Mexico dates from Fries (1855), who proposed *C. mexicanus* based on a specimen with “… pileo carnoso turbinato-infundibuliformi glabro griseofusco… lamellis augustissimis longe decurrentibus”. It was collected by F.M. Liebmann at El Mirador, Veracruz and, years later, considered by Corner (1966) as “… incert. sed. (? Gomphus)…” no longer recorded in the literature. From the same region (Orizaba, relatively near to the current study site), *Craterellus confluens* Berk. & M.A. Curtis was described by Berkeley (1867). This species is characterised by its yellow basidiomes, it is closely related to Cantharellus lateritius (Berk.) Singer, with which it has been confused or even with other yellow chanterelles, such as *C. cibarius* Fr. and *Craterellus odoratus* (Schwein.) Fr. (Heim 1954, Corner 1966, Petersen 1979, Guzmán and Sampieri 1984, Buyck and Hofstetter 2011). After such descriptions of new Cantharellus species from Mexico, only some additional records of about ten species described from other latitudes have been mentioned to occur in different forest ecosystems in the country, including Quercus forests (Guzmán and Sampieri 1984, Guzmán 1985, Guevara et al. 2004, Perez-Moreno et al. 2008, Garibay-Orijel et al. 2009). The identity of these records, however, has not been confirmed with molecular evidence. Recently, *C. coccolobae* Buyck,
Moreau & Courtecuisse was described from the Caribbean (Guadeloupe), including two collections from Yucatán, Mexico (Buyck et al. 2016c).

During the authors’ long term explorations in tropical oak forests in central Veracruz, a *Cantharellus* species was found with a striking habit, distinctive when compared to the previous records from Mexico. In fact, this fungus is unique because the fresh basidiomes in different growth stages possess a strikingly violet pileus and yellow, raised gill-like folded hymenophore, in combination with ellipsoid basidiopores and terminal elements of pileipellis slightly thick-walled. The macro- and micromorphological features depicted in this fungus, as well as its distinct position in two phylogenetic analyses, one of tef-1α and other of a combined tef-1α+nLSU sequences datasets, allowed its recognition as a new species. This *Cantharellus* species is locally considered a prized edible mushroom.

**Materials and methods**

**Sampling and morphological study**

*Cantharellus* basidiomes were collected during June-October, through six consecutive years (2012–2017) including some collections in 2009 and 2011, in tropical oak forests from Zentla (837–850 m a.s.l.) and Alto Lucero (400–500 m a.s.l.) counties in central Veracruz (eastern Mexico). In these oak forests, *Quercus oleoides* is dominant and even forms pure stands. In the Zentla locality, however, *Q. glaucescens* and *Q. sapotifolia* are also present and, at times, also form monodominant small patches. Descriptions of morpho-anatomical features were achieved based on fresh samples and following Largent (1973). The colour notations indicated in the descriptions follow Kornerup and Wanscher (1978) and Munsell colour chart (1994). Basidiomes were dried in a hot air dehydrator (45 °C). Microscopic features were observed and measured after tissues were rehydrated in 3 % potassium hydroxide (KOH) and stained with 1 % Congo red or analysed in Melzer’s solution. At least thirty-five basidiospores per collection were measured in length and width. Mean ranges denoted as $\bar{X}$ and the length/width ratio ($Q$) of basidiospores, in side view, are given as an interval of mean values per collection (n=15 collections). The form of the basidiospores was interpreted after calculating the Q values, following Bas (1969). Line drawings were made with the aid of a drawing tube. Collections are part of XAL Herbarium (Thiers B. [continuously updated] Index Herbariorum: a global directory of public herbaria and associate staff. New York Botanical Garden’s Virtual Herbarium. http://sweetgum.nybg.org/science/ih/).

**DNA extraction, PCR and sequencing**

DNA was isolated from fresh material using DNAeasy Plant Mini Kit (QIAGEN, Hilden, Germany) following the manufacturer’s recommendations. The transcription elongation factor 1-alpha (tef-1α) was amplified using the primers tef1F and tef1R
(Morehouse et al. 2003) and the large subunit of ribosome (nLSU) using the primers LR0R and LR7 (Vilgalys and Hesler 1990). PCR conditions were performed with an initial denaturation at 94 °C for 3 min; 35 cycles of 1 min 94 °C, 1 min at 55 °C and 2 min at 72 °C; and final elongation at 72 °C for 7 min. Amplified PCR products were purified with the DNA Clean & Concentrator Kit (Zymo Research, USA) following the manufacturer’s instructions. Cycle sequencing reactions were made using BigDye Terminator 3.1 Cycle Sequencing kit (Applied Biosaystems, USA); reactions were purified with ZR DNA Sequencing Clean-up Kit (Zymo Research, USA) and run in a sequencer, ABIPrism 310 Genetic Analyzer (Applied Biosystems). Sequences obtained were assembled and edited in BioEdit (Hall 1999) and deposited at GenBank database (Benson et al. 2017) (Table 1).

Table 1. Cantharellus species included in this study: samples, location and accession number for tef-1α and nLSU sequences.

| Taxon               | Voucher Specimen | Location     | GenBank   |
|---------------------|------------------|--------------|-----------|
|                     |                  |              | tef-1α    | nLSU      |
| C. addatiensis      | BB 98.033        | Tanzania     | JX192992  | KF294667  |
| C. afrocbiarus      | BB 96.236        | Zambia       | JX192993  | KF294668  |
| C. alboidolutescens | BB 08.057        | Madagascar   | KF294752  | KF294645  |
| C. alboidolutescens | BB 08.080        | Madagascar   | JX192982  | –         |
| C. ambobitanelyensis| BB 08.336        | Madagascar   | JX192989  | –         |
| C. amethysteus      | BB 07.284        | Slovakia     | GQ914953  | KF294639  |
| C. amethysteus      | BB 07.309        | Slovakia     | GQ914954  | KF294642  |
| C. appalachiensis   | BB 07.123        | USA          | GQ914979  | KF294565  |
| C. cascadensis      | BB 13.251        | USA          | KX857044  | –         |
| C. chichaogenensis  | JJ/MO-CANT1      | USA          | KX857025  | –         |
| C. cibarius         | BB 07.300        | Slovakia     | GQ914950  | KF294641  |
| C. cibarius         | GE 07.025        | France       | GQ914949  | –         |
| C. cinnabarinus     | BB 07.053        | USA          | GQ914984  | KF294630  |
| C. cinnabarinus     | BB 07.001        | USA          | GQ914985  | KF294624  |
| C. congolensis      | BB 98.039        | Tanzania     | JX193015  | KF294609  |
| C. congolensis      | BB 98.058        | Tanzania     | JX192996  | KF294673  |
| C. corallinus       | JJ/MO-CANT2      | USA          | KX857031  | –         |
| C. corallinus       | JJ/MO-CANT5      | USA          | KX857034  | –         |
| C. deceptions       | JJ/NC-CANT5      | USA          | KX857029  | –         |
| C. decolorans       | BB 08.278        | Madagascar   | GQ914968  | –         |
| C. decolorans       | BB 08.243        | Madagascar   | JX192987  | –         |
| C. densifolius      | BB 98.013        | Tanzania     | JX193014  | KF294616  |
| C. ferruginascens   | BB 07.283        | Slovakia     | GQ914952  | KF294638  |
| C. fistulosus       | DT 43            | Tanzania     | JX192997  | KF294674  |
| C. flavolateritius  | VH 1076          | USA          | KX857027  | –         |
| C. flavolateritius  | VH1078           | USA          | KX857029  | –         |
| C. gracilis         | BB 98.234        | Tanzania     | JX192970  | –         |
| C. humidicolus      | BB 98.036        | Tanzania     | JX193005  | KF294666  |
| C. ibityensis       | BB 08.203        | Madagascar   | JX192985  | KF294651  |
| C. isabellinus var. parvisporus | BB 98.020 | Tanzania     | JX192972  | KF294614  |
| Taxon                              | Voucher Specimen | Location | GenBank  | GenBank  |
|-----------------------------------|------------------|----------|----------|----------|
|                                   |                  |          | tef-1x   | nLSU     |
| C. iuventateviridis               | SH13/7/2012      | USA      | KX857063 | –        |
| C. iuventateviridis               | SH14/7/2012      | USA      | KX857064 | –        |
| C. lateritius                     | BB 07.025        | USA      | GQ914957 | KF294628 |
| C. lateritius                     | BB 07.058        | USA      | GQ914959 | KF294633 |
| C. lewisii                        | BB 02.197        | USA      | GQ914961 | KF294623 |
| C. lewisii                        | BB 07.003        | USA      | GQ914962 | –        |
| C. lilacinopruinatus              | BB 07.221        | Slovakia | GQ914951 | KF294637 |
| C. minor                          | BB 07.002        | USA      | JX192978 | KF294625 |
| C. minor                          | BB 07.057        | USA      | JX192979 | KF294632 |
| C. pallens                        | BB 09.441        | Italy    | KX857013 | –        |
| C. pallens                        | BB 12.082        | Italy    | KX857035 | –        |
| C. paucifurcatus                  | BB 08.320        | Madagascar | KF294655 | JK192988 |
| C. persicus                       | MH 15.001        | USA      | KX857080 | –        |
| C. phasmas                        | CO57             | USA      | JX030417 | –        |
| C. phasmas                        | CO74             | USA      | JX030418 | –        |
| C. platyphyllus                   | BB 98.012        | Tanzania | GQ914969 | KF294617 |
| C. platyphyllus subsp. bojeriensis| BB 08.160        | Madagascar | JX192984 | KF294648 |
| C. pseudominimus                  | JV 00.663        | Portugal | JX192991 | KF294657 |
| C. quercophilus                   | BB 07.097        | USA      | JX192981 | KF294644 |
| C. sebosus                        | BB 08.234        | Madagascar | JX192986 | KF294652 |
| C. spectaculatus                  | C081             | USA      | JX030414 | –        |
| C. cf subamethysteus              | AV 12.003        | Thailand | KX857062 | –        |
| C. subcyanoxanthus                | BB 00.1137       | Madagascar | JX192990 | –        |
| C. subincarnatus subsp. rubrosalmineus | BB 06.080       | Madagascar | JX192962 | KF294601 |
| C. subincarnatus subsp. rubrosalmineus | BB 06.096       | Madagascar | JX192963 | KF294602 |
| C. symoensii                      | BB 98.011        | Tanzania | GQ914970 | KF294618 |
| C. symoensii                      | BB 98.113        | Tanzania | JX192974 | KF294619 |
| C. tabernensis                    | BB 07.119        | USA      | GQ914976 | KF294634 |
| C. tabernensis                    | BB 07.020        | USA      | GQ914971 | –        |
| C. tanzanicus                     | BB 98.040        | Tanzania | JX192977 | KF294622 |
| C. tenuithrix                     | BB 14.008        | USA      | KX857045 | –        |
| C. tenuithrix                     | BB 14.009        | USA      | KX857045 | –        |
| C. tomentosus                     | BB 98.038        | Tanzania | GQ914965 | KF294610 |
| C. vellutinus                     | VH 1583          | USA      | KX857070 | –        |
| C. vellutinus                     | WR WV 07.074     | USA      | KX857068 | –        |
| C. versicolor                     | Tian 160         | China    | KM893857 | –        |
| C. versicolor                     | Yu 24            | China    | KM893856 | –        |
| C. violaceovinosus*               | Bandala 4513     | Mexico   | MF616520 | MF616524 |
| C. violaceovinosus*               | Corona 648       | Mexico   | MF616521 | MF616525 |
| C. violaceovinosus*               | Herrera125       | Mexico   | MF616522 | MF616526 |
| Craterellus tubaeformis           | BB 07.293        | Slovakia | GQ914989 | KF294640 |
| Hydnum repandum                   | BB 07.341        | Slovakia | JX192980 | KF294643 |

*samples and sequences obtained here
Phylogenetic analysis

Six tef-1α and nLSU sequences obtained in this study, together with 113 sequences of *Cantharellus* species from all major clades across the genus (after Buyck et al. 2014) and with the highest similarity scores from the results of BLAST (Altschul et al. 1997) were downloaded from GenBank (http://www.ncbi.nlm.nih.gov/) and used to construct two datasets. One dataset consisted of tef-1α and other combined tef-1α+nLSU sequences. *Craterellus tubaeformis* and *Hydnum repandum* were included as outgroup taxa (Table 1 and alignment in TreeBASE S21920). Both datasets were assembled in the data editor PhyDE v.0.995 programme (Müller et al. 2010). They were aligned using Muscle (Edgar 2004) with inconsistencies corrected manually. A phylogeny of each dataset was constructed under maximum likelihood (ML) and Bayesian Inference (BI) methods. The best evolutionary model for both datasets was calculated with Mega 6.06 (Tamura et al. 2013). ML analyses were also performed using Mega 6.06 with 500 replicates of bootstrap. BI analyses were implemented with MrBayes on XSEDE (3.2.6) on CIPRES portal (Miller et al. 2010) with settings as described in Montoya et al. (2014). The phylogenies from ML and BI analyses were displayed using Mega 6.06 and FigTree v 1.3.1 (Rambaut 2009), respectively.

Results

Sixty fresh collections were obtained of the violet *Cantharellus* species, including basidiomes in different growth stages, most of them detected between August-October, in both localities explored. Six new tef-1α and nLSU sequences from three collections were generated in this study (Table 1). In the inferred molecular phylogenies (from tef-1α and tef-1α+nLSU sequences datasets) (Figs 1–2), the generated sequences from the Mexican specimens, clustered in a terminal clade, strongly supported only bootstrap values ≥70 and posterior probabilities ≥0.90 were considered and indicated (BS/BPP) on the branches of each tree. Both trees were congruent and the sequences of the Mexican *Cantharellus* cluster in a sister clade to *C. lewisii* from USA, in the subgenus *Cantharellus* (Buyck et al. 2014). Based on the distinctive morphological features and colour variation of the studied *Cantharellus* specimens, as well as the isolated position of the samples in the phylogenies obtained, it was concluded that this should be proposed as a new *Cantharellus* species, which inhabits the tropical *Quercus* forests in eastern Mexico.

Description of the new species

*Cantharellus violaceovinosus* M. Herrera, Bandala & Montoya, sp. nov.
MycoBank: MB823600
Figs 3–5

Holotype. MEXICO. Veracruz: Municipality of Zentla, around town of Zentla, 850 m a.s.l., gregarious in soil, under *Quercus oleoides* Schltdl. & Cham., 5 July 2012, Corona 648 (XAL).
Cantharellus violaceovinosus, a new species from Mexico

Figure 1. Molecular phylogenetic analysis by maximum likelihood of tef-1 α sequences dataset of Cantharellus species. Posterior probabilities and Bootstrap values (BPP/BS) are indicated on the tree branches.
Figure 2. Molecular phylogenetic analysis by maximum likelihood of tef-1α+nLSU sequences dataset of Cantharellus species. Posterior probabilities and Bootstrap values (BPP/BS) are indicated on the tree branches.

Diagnosis. Differing from other Cantharellus species by: uniformly dark violet, violet-grey to violet-wine or violet-reddish pileus; yellow, gill-like folded hymenophore and ellipsoid basidiospores 7–10 (–11) × (4.5–) 5–6.5 (–7) µm. $\bar{X}m = 7.8–9× 5.1–6.3$ µm, $Q = 1.31–1.66$, basidia (40–) 45–114 (–125) × (6–) 7–11 (–12) µm, with (1–) 2–5 sterigmata, and terminal elements of the pileipellis 4–6 µm diam, slightly thick-walled.

Gene sequences ex-holotype. MF616521 (tef-1α), MF616525 (nLSU).

Etymology. Referring to the dark violaceous, becoming wine to reddish pileus.
Cantharellus violaceovinosus, a new species from Mexico

Pileus (15–) 25–113 mm diam, convex to broadly-convex with margin incurved when young, expanding to plane or subplane, often shallowly depressed or finally broadly infundibuliform, surface dry, not hygrophanous, dull, smooth, glabrescent, surface at times breaking in faintly tesselate-rimose-like pattern, then appearing appressed fibrillose with age and not forming scales; surface uniformly dark violet (15D4, 15F2–7, 16D3–4, 16D6, 16F4–5) to pale violet with age (15DE5–7) or violet-grey (16D3–4, 16D6), lilac or greyish-lilac (15A3, 15C3–4, 16C2–3), becoming violet-wine or violet-reddish (14E5–8, 14EF4–5), wine (12D4), fading with age and sun exposure, developing pinkish, lilac and reddish tints, especially towards the margin (13A3–4, 13D3–4, 15A4–5), naked parts showing the yellow context (4A2–3); margin incurved or straight, entire or slightly crenate, undulate or irregular, often incised, rarely lobed, not striated. Hymenophore with well-defined gill-like folds, up to 3 mm deep, decurrent, subdistant, in some specimens almost straight and inclusive thin, in other materials with faintly sinuous or irregular thicker folds, frequently forking at different levels or only towards the pileus margin, with lower irregular anastomosis amongst the folds, in some specimens the anastomosis occur practically in the whole hymenophore, while in others only at some areas, especially at pileus margin, some specimens (specially towards the stipe) with irregular low veins amongst the folds or the folds become as low and sinuous vein-like; butter-yellow or yellow (2.5Y 8/4, 10YR...
Figure 4. *Cantharellus violaceovinosus* (Corona 648, holotype): a basidiospores b terminal elements of the pileipellis c basidia d pileipellis. Scale bars: 5 µm (a); 10 µm (b, c); 25 µm (d).

8/6; 4A3–4). *Stipe* (20–) 25–75 × 5–18 mm, equal and only slightly swollen at base or widening above and tapering gradually downwards, solid, surface glabrous, concolorous with hymenophore, often staining ochraceous or rusty orange colour when handled, occasionally with whitish, small rhizomorphs at base. *Context* whitish to yellow (4A2–3), at times wax-like, odour mild, agreeable, at time fruity somewhat to apricot; taste mild, agreeable.

*Basidiospores* 7–10 (–11) × (4.5–) 5–6.5 (–7) µm, [\(\bar{X}m = 7.8–9 \times 5.1–6.3 \mu m, Q=1.31–1.66, (n=13)\)], ellipsoid, smooth, thin-walled, hyaline, inamylloid, devoid of gran-
Cantharellus violaceovinosus, a new species from Mexico

Figure 5. Cantharellus violaceovinosus: a basidiospores b basidia (Gutiérrez 23) c pileipellis (Herrera 61). Scale bars: 5 µm (a); 10 µm (b); 25 µm (c).

ular contents or refractive droplets. Basidia (40–) 45–114 (–125) × (6–) 7–11(–12) µm, narrowly clavate to subcylindrical, with (1–) 2–5 sterigmata 8–10 µm long, thin-walled, hyaline; subhymenium composed of cylindrical hyphae 4–5 µm diam. Cystidia absent. Pileipellis a cutis composed of hyphae 4–6 µm diam, intermingled in a compact arrangement, cylindrical, hyaline to yellowish, inamyloid, often some of them with pale brownish contents, these decidedly brown coloured in group; distinctive terminal elements 4–6 µm broad, slightly thick-walled (<1 µm thick), smooth, hyaline, some pale brownish, scattered on the surface. Pileus trama composed of cylindrical to inflated hyphae, 3–12 µm diam, slightly thick-walled (<1 µm thick), hyaline, yellowish in mass, some
of the hyphal segments completely filled with darker contents. *Hymenophoral trama* composed of hyphae 3–5 µm diam, thin-walled, some with weakly refringent contents. *Clamp connections* present on hyphae in all tissues.

**Habitat.** Solitary to gregarious, in soil, at tropical oak forest, under *Quercus oleoides*, less frequently also under both *Q. glaucescens* Bonpl. and *Q. sapotifolia* Liebm. June-October, known in the coastal plain of central Veracruz State, east coast of Mexico.

**Specimen examined.** MEXICO. Veracruz, Zentla Co., Road Puentecilla-La Piña, 837 m a.s.l., 2 Jul 2009, Del Moral 427, Ramos 216; 27 Oct 2009, García 20, García 22; 16 Jun 2011, Bandala 4490; 21 Jul 2012, Herrera 25; 31 Jul 2012, Bandala 4513; 20 Sep 2012, Bandala 4550, Corona 743; 4 Oct 2012, Bandala 4569, 4573; 4 Jul 2013, Gutiérrez 23; 12 Jul 2013, Bandala 4671; 20 Sep 2013, Herrera 67; 15 Sep 2015, Herrera 135. Around town of Zentla, 850 m a.s.l., 5 Jul 2012, Corona 648; 25 Jun 2013, Herrera 60, 61; 15 Sep 2015, Herrera 137, Santillan 16; 1 Oct 2015, Herrera 151; 30 Jun 2016, Herrera 172; 6 Jul 2016, Herrera 184; 12 Jul 2016, Herrera 187; 22 Sep 2016, Herrera 200, 201, 202, 203; 5 Oct 2016, De la Cruz 14,15; 13 Oct 2016, De la Cruz 42; 27 Oct 2016, Herrera 210, 211; 6 Jul 2017, Garay 350; 3 Aug 2017, Garay 364; 31 Aug 17, Garrido 79; 7 Sep 2017, Herrera 214, 215, 216; 15 Sep 17, Montoya 5403; 21 Sep 17, Corona 1420; 5 Oct 17, Mateo 5. Alto Lucero Co., NE Mesa de Venticuatro, 450–500 m a.s.l., 2 Jul 15, Herrera 125, Herrera 126; 17 Sep 2015, Herrera 138; 2 Aug 2016, Herrera 191; 10 Aug 2016, Herrera 192; 20 Sep 2016, Herrera 195, 196, 197, 198; 27 Sep 2016, Herrera 205, 206, 207; 4 Oct 2016, Herrera 208, 209; 22 Aug 17, Herrera 214; 12 Sep 2017, Garay 375; 19 Sep 2017, Garay 392; 2 Oct 17, Mateo 1 (all at XAL).

**Discussion**

Distinctive features of this species include the medium to large size basidiomes, with pileus practically homogeneously violet pigmented (only fading with age), smooth, with surface free of scales, at times with disrupted pileus surfaces due to age, hymenophore bearing yellow gill-like folds, ellipsoid, medium-sized basidiospores [7–10 (–11) × (4.5–) 5– 6.5 (–7) µm], medium to large basidia [(40–) 45–114 (–125) × (6–) 7–11(–12) µm] and terminal elements of pileipellis 4–6 µm diam, slightly thick-walled (<1 µm thick). Molecular phylogenetic analyses support that the species is genetically distinct from other *Cantharellus* taxa, in both analyses, *C. violaceovinosus* was nested in an isolated and well-supported clade (95–99/1) (Figs 1–2).

*Cantharellus* species with basidiomata having violet pileus are rare but occur in various regions worldwide (Eyssartier et al. 2009; Buyck et al. 2012). Amongst about 45 species of the genus known from USA, Mexico, Central and South America (Guzmán and Sampieri 1984, Guzmán 1985, Eyssartier et al. 2003, Guevara et al. 2004, Henkel et al. 2006, Wartchow et al. 2012, Wilson et al. 2012, Pinheiro and Wartchow 2013, Wartchow et al. 2013, Nascimento et al. 2014, Buyck et al. 2016c), *C. lewissi* Buyck & V. Hofst., *C. atrolilacinus* Eyssart., Buyck & Halling and the new
Cantharellus violaceovinosus are, up to now, the species known to produce basidiomes with violet tints in the Americas.

Cantharellus lewisii grows in floodplain hardwoods, in Water Oak plots next to a *Taxodium* swamp, in beech-magnolia-loblolly pine forests and also under beech-white oak-loblolly pine-magnolia forests in the south of USA (Buyck and Hofstetter 2011). In the inferred phylogeny, it appears as sister of *C. violaceovinosus*, but differs because its pileus is pale yellow, dull to greyish-yellow or ochre to pale brownish-orange, sometimes reddish-brown near the margin, with a surface covered with dark purplish-lilac appressed fibrils (in young stages, *C. lewisii* is often entirely dark lilac-purple) and with terminal elements of pileipellis conspicuously thick-walled (mostly 1–1.5 µm thick) (Buyck and Hofstetter 2011). According to the original description, *C. lewisii* also differs by its ellipsoid or often somewhat reniform and narrower basidiospores [(7.08–) 7.16–7.62–8.07 (–8.96) × (4.17–) 4.24–4.58–4.93 (–5.21) µm; Q= (1.42–) 1.45–1.57–1.70 (–1.80)] and by 5–6-spored and shorter basidia (60–75 × 7–8 µm) (Buyck and Hofstetter 2011). Two Texan collections of *C. lewisii* (holotype BB 07.003 and BB 02.197, both at PC) were studied. Based on observations, it was confirmed that this later species differs from the Mexican *C. violaceovinosus*, because of its markedly reniform, narrower basidiospores, then tending to be “more ellipsoid” [BB 07.003, holotype: 7.5–9.5 × (4–) 4.5–5.5 µm, $\bar{X} m = 8.4 \times 5$ µm, $\bar{Q} = 1.68$; BB 02.197: 7.5–10 (–11) × 4–5.5 µm, $\bar{X} m = 9 \times 4.8$ µm, $\bar{Q} = 1.87$).

*Cantharellus atrolilacinus* was described from Costa Rica, growing under *Quercus corrugata* Hook.) and Q. sp. (Eyssartier et al. 2003). According to the data on this species (R. Halling, www.nybg.org/bsci/res/hall/canlilac.html; Eyssartier et al. 2003), it differs from *C. violaceovinosus* because its pileus colours tend to be darker, even blackish, dark lilac-grey or brown-lilac, with tomentose surface at the disc, with strong radial, adnate fibrils at the margin, and the stipe whitish with lilac tints. Microscopically, *C. atrolilacinus* has basidiospores (7–) 7.5–8–8.5 (–9) × 4.5–5–5.5 (–6) µm, tending to be more ellipsoid (Eyssartier et al. 2003, fig. 1:2) and having wider pileipellis hyphae [(4–) 5–10 (–15) µm] with a very thick wall (“...très nettement épaissies...”).

Although *Cantharellus amethysteus* (Quél.) Sacc. (subg. *Cantharellus*) from Europe, may appear superficially similar to some forms of *C. violaceovinosus*, the former however, especially has a pileus surface covered with vinous or lilac, small scales. The authors studied two specimens of *C. amethysteus* from France (BB 07.284 and BB 07.309 at PC) displaying elongate basidiospores, 9.5–12 (–12.5) × 5–7 µm ($\bar{X} m = 11–11.2 \times 5.9–6.4$ µm; $\bar{Q} = 1.76–1.86$), as Eyssartier and Buyck (2000) reported [(9–) 9.5–10.37–11.5 (–12.5) × 6–6.5–7 µm], resulting in being larger and more elongate than in the Mexican species. Also, it is interesting that one sequence of tef-1a of a specimen from Thailand (GB coded KX857062, Table 1) identified as “*C. cf. subamethysteus*”, appeared close to *C. violaceovinosus* (Fig. 1). *Cantharellus subamethysteus* indeed is phylogenetically related to *C. lewisii* (Buyck et al. 2014) and differs from *C. violaceovinosus* in the shorter basidiomes (pileus 20–65 mm; stipe 42–57 × 5–11 mm), deep and bright yellow pileus surface, covered with squamules even with rather brown to dark brown tinges, shorter basidiospores [7–8 (8.75) × (4.75) 5–6 µm] and
wider pileipellis elements (8–15 µm width) (Eyssartier et al. 2009). Additionally, the hymenophore of this species is rugose to faintly veined (as depicted in the picture accompanying the description).

*Cantharellus goossensiae* (Beeli) Heinem., *C. cyanoxanthus* R. Heim ex Heinem., *C. subcyanoxanthus* Buyck, Randrianjohany & Eyssart. and *C. longisporus* Heinem. represent African species with basidiomes displaying violaceous tinges (Buyck et al. 2012) therefore, at some stages their basidiomes could resemble those of *C. violaceovinosus*. However, the three former species have the pileipellis with thin-walled hyphal extremities, thus differing from members of subgenus *Cantharellus*, including the new species here described. Moreover, the four African taxa have basidiospores distinctly narrowly ellipsoid to elongate (Q>1.70) and often slightly reniform, curved or even somewhat peanut-shaped (Beeli 1928, Heinemann 1958, 1959, Buyck et al. 2012).

*Cantharellus violaceovinosus* was recorded as a common fleshy mushroom, during the multiyear sampling developed in the tropical *Quercus* forests studied. It was found in ectomycorrhizal association with native trees of *Quercus* species. This mushroom was very often recorded in pure stands of *Q. oleoides* and less frequently in *Q. glaucescens* and *Q. sapotifolia* patches. This violet pigmented chanterelle shares the same habit preferences as *C. lateritius*, also found in the study sites. A similar co-occurrence has been reported between *C. lewissi* (the sister relative of *C. violaceovinosus*) and *C. lateritius* in the State of Texas in the USA (Buyck et al. 2011). Basidiomes of *C. violaceovinosus* and *C. lateritius* are abundant in the local oak forests studied and both are considered choice wild mushrooms although the latter is more highly prized. They are even more appreciated than species of *Amanita* or *Lactarius*, representing an income source for wild mushroom collectors. Benefits from mushrooms harvesting, as well as other ecosystemic services, are motivating some owners to conserve relicts of the tropical *Quercus* forest of the region.

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**References**

Agerer R (2006) Fungal relationships and structural identity of their ectomycorrhizae. Mycological Progress 5: 67–107. https://doi.org/10.1007/s11557-006-0505-x
Cantharellus violaceovinosus, a new species from Mexico

Altschul SF, Madden TL, Schäffer AA, Zhang J, Zhang Z, Miller W, Lipman DJ (1997) Gapped BLAST and PSI-BLAST: a new generation of protein database search programs. Nucleic Acids Research 25: 3389–3402. https://doi.org/10.1093/nar/25.17.3389

Arora D, Dunham SM (2008) A new, commercially valuable chantharelle species, Cantharellus californicus sp. nov., associated with Live Oak in California. Economic Botany 62: 376–391. https://doi.org/10.1007/s12231-008-9042-7

Bas C (1969) Morphology and subdivision of Amanita and a monograph of its section Lepidella. Persoonia 5(4):285–579.

Beeli M (1928) Contribution a l’étude de la Flore mycologique du Congo: VI: Fungi Goossensianii. Bulletin de la Société Royale de Botanique de Belgique 61: 78–107.

Benson DA, Cavanaugh M, Clark K, Karsch-Mizrachi I, Lipman DJ, Ostell J, Sayers EW (2017) GenBank. Nucleic Acids Research 45: D37–D42. https://doi.org/10.1093/nar/gkw1070

Berkeley MJ (1867) On some new fungi from Mexico. The Journal of the Linnean Society of Botany 9: 423–425. https://doi.org/10.1111/j.1095-8339.1867.tb01307.x

Boa E (2005) Los hongos silvestres comestibles. Perspectiva global de su uso e importancia para la población. Productos forestales no madereros 17. Organización de las Naciones Unidas para la Agricultura y la Alimentación, 1–161.

Buyck B, Hofstetter V (2011) The contribution of tef-1 sequences to species delimitation in the Cantharellus cibarius complex in the southeastern USA. Fungal Diversity 49(1): 35–46. https://doi.org/10.1007/s13225-011-0095-z

Buyck B, Cruaud C, Couloux A, Hofstetter V (2011) Cantharellus texensis sp. nov. from Texas, a Southern lookalike of C. cinnabarinus revealed by tef-1 sequence data. Mycologia 103(5): 1037–1046. https://doi.org/10.3852/10-261

Buyck B, Randrianjohany E, Eyssartier G (2012) Observations on some enigmatic Cantharellus (Chantarellales, Basidiomycota) with Lilac-Violaceus Tints from Africa and Madagascar. Cryptogamie, Mycologie 33(2): 167–179. https://doi.org/10.7872/crym.v33.iss2.2012.167

Buyck B, Randrianjohany E (2013) Cantharellus eyssartierii sp. nov. (Cantharellales, Basidiomycota) from monospecific Uapaca ferruginea stands near Ranomafana (eastern escarpment, Madagascar). Cryptogamie, Mycologie 34(1): 29–34. https://doi.org/10.7872/crym.v34.iss1.2013.29

Buyck B, Kauff F, Cruaud C, Hofstetter V (2013) Molecular evidence for novel Cantharellus (Cantharellales, Basidiomycota) from tropical African miombo woodland and a key to all tropical African chanterelles. Fungal Diversity 58: 281–291. https://doi.org/10.1007/s13225-012-0215-4

Buyck B, Kauff F, Eyssartier G, Couloux A, Hofstetter V (2014) A multilocus phylogeny for worldwide Cantharellus (Cantharellales, Agaricomycetidae). Fungal Diversity 64(1): 101–121. https://doi.org/10.1007/s13225-013-0272-3

Buyck B, Kauff F, Randrianjohany E, Hofstetter V (2015) Sequence data reveal a high diversity of Cantharellus associated with endemic vegetation in Madagascar. Fungal Diversity 70(1): 189–208. https://doi.org/10.1007/s13225-014-0314-5

Buyck B, Olariaga I, Justice J, Lewis D, Roody W, Hofstetter V (2016a) The dilemma of species recognition in the field when sequence data are not in phase with phenotypic variability. Cryptogamie, Mycologie 37(3): 367–389. https://doi.org/10.7872/crym.v37.iss3.2016.367

Buyck B, Olariaga I, Looney B, Justice J, Hofstetter V (2016b) Wisconsin chanterelles revisited and first indications for very wide distributions of Cantharellus species in the United States East
of the Rocky Mountains. Cryptogamie, Mycologie 37(3): 345–366. https://doi.org/10.7872/crym/v37.iss3.2016.345
Buyck B, Moreau PA, Courtecuisse R, Kong A, Roy M, Hofstetter V (2016c) Cantharellus coccolobae sp. nov. and Cantharellus garnieri, two tropical members of Cantharellus subg. Cinabarinus. Cryptogamie, Mycologie 37(3): 391–403. https://doi.org/10.7872/crym/v37.iss3.2016.391
Bigelow, H (1978) The cantharelloid fungi of New England and adjacent areas. Mycologia 70(4): 706–756. https://doi.org/10.2307/3759354
Chandra A (1989) Elsevier's dictionary of edible mushrooms. Botanical and common names in various languages of the world. Elsevier Science Publishing Co., 1–259.
Corner EJH (1966) A monograph of cantharelloid fungi. Oxford University Press, 1–255.
Danell E (1999) Cantharellus. In: Cairney JWG, et al. (Eds) Ectomycorrhizal Fungi Key Genera in Profile. Springer-Verlag, Berlin, 253–267. https://doi.org/10.1007/978-3-662-06827-4_10
De Kesel A, Yorou NS, Buyck B (2011) Cantharellus solidus, a new species from Benin (West-Africa) with a smooth hymenium. Cryptogamie, Mycologie 32(3): 277–283. https://doi.org/10.7872/crym.v32.iss3.2011.277
Edgar RC (2004) MUSCLE: multiple sequence alignment with high accuracy and high throughput. Nucleic Acids Research 32(5): 1792–1797. https://doi.org/10.1093/nar/gkh340
Eyssartier G, B Buyck (2000) Le Genre Cantharellus in: Europe nomenclature et taxonomie. Bulletin de la Société mycologique de France 116(2): 91–137.
Eyssartier G, Buyck B (2001) Note Nomenclaturale et Systmatique sur le genre Cantharellus. Documents mycologiques 121: 55–56.
Eyssartier G, Buyck B, Halling RE (2003) Une nouvelle chantarelle du Costa Rica: Cantharellus atrolilacinus sp. nov. Cryptogamie, Mycologie 24(1): 21–25.
Eyssartier G, Stubbe D, Walleyn R, Verbeken A (2009) New records of Cantharellus species (Basidiomycota, Cantharellaceae) from Malaysian dipterocarp rainforest. Fungal Diversity 36: 57–67.
Foltz MJ, Perez KE, Volk TJ (2013) Molecular phylogeny and morphology reveal three new species of Cantharellus within 20m of one another in western Wisconsin, USA. Mycologia 105(2): 447–461. https://doi.org/10.3852/12-181
Fries E (1855) Novarum symbolarum mycologicarum mantiss. Nova Acta Regiae Societatis Scientiarum Upsaliensis 3(1): 225–231.
Garibay-Orijel R, Córdova J, Cifuentes J, Valenzuela R, Estrada-Torres A, Kong A (2009) Integrating wild mushrooms use into a model of sustainable management for indigenous community forest. Forest Ecology and Management 258(2): 122–131. https://doi.org/10.1016/j.foreco.2009.03.051
GenBank (1997) Nucleic Acids Research 45: D37–D42. https://doi.org/10.1093/nar/gkw1070
Guzmán G, Sampieri A (1984) Nuevos datos sobre el hongo comestible Cantharellus odoratus en México. Boletín de la Sociedad Mexicana de Micología 19: 201–205.
Guzmán G (1985) Estudios sobre los Cantarelaceos de México (Fungi, Aphyllophorales). Biótica 5(10): 395–402.
Guevara G, Ocaña F, Cázares E (2004) Estudio del ITS nuclear en algunas especies del género Cantharellus en México. Ciencia UANL 7: 371–378.
Cantharellus violaceovinosus, a new species from Mexico

Eyssartier G, Buyck B (2001) Note Nomenclaturale et Systematique sur le genre Cantharellus. Documents mycologiques 121: 55–56.

Hall T (1999) BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. Nucleic Acids Symposium Series 41: 95–98.

Henkel T, Aime MC, Mehl H, Miller SL (2006) Cantharellus pleurotoides, a new and unusual basidiomycete from Guyana. Mycological Research 110: 1409–1412. https://doi.org/10.1016/j.mycres.2006.09.010

Heim R (1954) A propos de trois Chanterelles américaines. Revue Mycologique 19: 47–56.

Heinemann P (1958) Champignons récoltés au Congo Belge par madame M. Goossens-Fontana III. Cantharellineae. Bulletin du Jardin botanique de l’État a Bruxelles 28: 385–438. https://doi.org/10.2307/3667153

Heinemann P (1959) Cantharellineae. Flore Iconographique des Champignons du Congo, 8° Fascicule 153–165, 3 pl.

Heinemann P (1966) Cantharellineae du Katanga. Bulletin du Jardin Botanique de l’État a Bruxelles 36: 335–352. https://doi.org/10.2307/3667194

Homola RL (1993) Cantharelloid fungi of Maine. Maine Naturalist 1(2): 5–12. https://doi.org/10.2307/3858219

Kornerup A, Wanscher JH (1967) Methuen Handbook of Colour (2nd edn). Methuen, London.

Kumari D, RC Upadhyay, Reddy MS (2011) Cantharellus pseudoformosus, a new species associated with Cedrus odorata form India. Mycoscience 52: 147–151. https://doi.org/10.1007/S10267-010-0080-5

Largent D (1973) How to identify mushrooms to genus I. Macroscopic features. Mad River Press, Eureka.

Leacock PR, Riddell J, Wilson AW, Zhang R, Ning Ch, Mueller GM (2016) Cantharellus chicagensis sp. nov. is supported by molecular and morphological analysis as a new yellow chanterelle in midwestern United States. Mycologia 108(4): 765–772. https://doi.org/10.3852/15-230

Lee SS, Watling R, Turnbull E (2003) Diversity of putative ectomycorrhizal fungi in Pasoh Forest Reserve. In: Okuda et al. (Eds) Pasoh. Ecology of a lowland rainforest in Southeast Asia. Springer-Verlag, Tokyo, 149–159.

Miller MA, Pfeiffer W, Schwart ZT (2010) Creating the CIPRES Science Gateway for inference of large phylogenetic trees. Proceedings of the 1st Conference on Extreme Science and Engineering Discovery Environment, 1–8. https://doi.org/10.1109/GCE.2010.5676129

Molina R, Massicotte H, Trappe J (1992) Specificity phenomena in mycorrhizal symbioses: Community ecological consequences and practical implications. In: Allen M (Ed.) Mycorrhizal functioning, an integrative plant-fungal process. Chapman and Hall, London, 357–423.

Montoya L, Bandala VM, Garay E (2014) Two new species of Lactarius associated with Alnus acuminata subsp. arguta in Mexico based on morphological and molecular evidence. Mycologia 106(5): 949–962. https://doi.org/10.3852/14-006

Morehouse EA, James TY, Ganley ARD, Vilgalys R, Berger L, Murphy PJ, Longcore JE (2003) Multilocus sequence typing suggests the chytrid pathogen of amphibians is a recently emerged clone. Molecular Ecology 12: 395–403. https://doi.org/10.1046/j.1365-294X.2003.01732.x

Munsell soil Color Charts (1994) Macbeth, New Windsor, 10 pp.
Müller J, Müller K, Neinhuis C, Quandt D (2010) PhyDE* – Phylogenetic Data Editor, version 0.9971. Program distributed by the authors. Available to: http://www.phyde.de

Nascimento C, Pinheiro FGB, Wartchow F, Alves MA (2014) *Cantharellus rubescens*, a new chanterelle from the Brazilian semi-arid. Cryptogamie, Mycologie 35(4): 369–375. https://doi.org/10.7872/crym.v35.iss4.2014.369

New York Botanical Garden (2017) Staff Research Projects and Project Web Pages. https://www.nybg.org/bsci/res/hall/canlilac.html

Pérez-Moreno J, Martínez-Reyes M, Yescas-Pérez A, Delgado-Alvarado A, Xoconostle-Cázares B (2008) Wild mushroom markets in Central Mexico and a case study at Ozumba. Economic Botany 62(3): 425–436. https://doi.org/10.1007/s12231-008-9043-6

Petersen RH, Ryvarden L (1971) Notes on cantharelloid fungi IV. Two new species of *Cantharellus*. Svensk Botanisk Tidskrift 65: 399–405.

Petersen RH (1976) Notes on Chanterellloid Fungi. VII. The taxa described by Charles H. Peck. Mycologia 68: 304–326. https://doi.org/10.2307/3759002

Petersen RH (1979) Notes on chanterellloid fungi X. *Cantharellus confluens* and *C. lateritius, Craterellus odoratus* and *C. aureus*. Sydowia 32: 198–208.

Petersen RH, Mueller GM (1992) New south American taxa of *Cantharellus, C. nothofagorum*, *C. xanthoscyphus* and *C. lateritius var. colombianus*. Boletín de la Sociedad Argentina de Botánica 28: 195–200.

Pinheiro FGB, Wartchow F (2013) *Cantharellus protectus*, a new species from Paraíba, Brazil, Sydowia 65(1): 27–31.

Pilz D, Norvell L, Danell E, Molina R (2002) Ecology and management of commercially harvested chanterelle mushrooms. Gen. Tech.Rep. GTR-576. Department of Agriculture, Forest Service, Northwest Research Station, Oregon, 1–83.

Smith AH, Morse E (1947) The genus *Cantharellus* in the Western United. Mycologia 39(8): 497–534. https://doi.org/10.2307/3755192

Smith AH (1968) The Chantharellaceae of Michigan. The Michigan Botanist 7: 143–183.

Shao SC, Buyck B, Hofstetter V, Tian XF, Geng YH, Yu FQ, Liu PG (2014) *Cantharellus hygrophorus*, a new species in subgenus *Afrocantharellus* from tropical southwestern China. Cryptogamie, Mycologie 35(3): 283–291. https://doi.org/10.7872/crym.v35.iss3.2014.283

Shao SC, Buyck B, Tian XF, Liu PG, Geng YH (2016) *Cantharellus phloginus*, a new pink-colored species from southwestern China. Mycoscience 57(2): 144–149. https://doi.org/10.1016/j.myc.2015.12.004

Rambaut A (2009) FigTree. Tree figure drawing tool version 1.3.1. Institute of Evolutionary biology, University of Edinburgh. http://tree.bio.ed.ac.uk/

Tamura K, Stecher G, Peterson D, Filipski A, Kumar S (2013) MEGA6: molecular evolutionary genetics analysis version 6. Molecular Biology and Evolution 30: 2725–2729. https://doi.org/10.1093/molbev/mst197

Thoen D (1993) Looking for ectomycorrhizal trees and ectomycorrhizal fungi in tropical Africa. In: Isaac S, Frankland JC, Watling R, Whalley AJS (Eds) Aspects of tropical mycology. Cambridge University Press, New York, 193–205.

Tian XF, Buyck B, Shao SCh, Liu PG, Fang Y (2012) *Cantharellus zangii*, a new subalpine basidiomycete from southwestern China. Mycotaxon 120(1): 99–103. https://doi.org/10.5248/120.99
Cantharellus violaceovinosus, a new species from Mexico

Tibuhwa DD, Savic J, Tibell L, Kivaisi A (2012) Afrocantharellus gen. stat. nov. is part of a rich diversity of African Cantharellaceae. IMA Fungus 3(1): 25–38. https://doi.org/10.5598/imafungus.2012.03.01.04

Trappe J (1962) Fungus Associates of Ectotrophic Mycorrhizae. Botanical Review 28(4): 538–606. https://doi.org/10.1007/BF02868758

Vilgalys R, Hesler M (1990) Rapid Genetic Identification and Mapping of Enzymatically Amplified Ribosomal DNA from Several Cryptococcus Species. Journal of Bacteriology 172(8): 4238–4246. https://doi.org/10.1128/jb.172.8.4238-4246.1990

Wartchow F, Buyck B, Maia LC (2012) Cantharellus aurantiocspicuus (Cantharellales). A new species from Pernambuco, Brazil. Nova Hedwigia 94(1): 129–137. https://doi.org/10.1127/0029-5035/2012/0094-0129

Wartchow F, Santos JC, Fonseca MDP (2013) Cantharellus amazonensis, a new species from Amazon. Mycosphere 3(4): 414–418. https://doi.org/10.5943/mycosphere/3/4/4

Watling R (1997) The business of fructification. Nature 385: 229–300. https://doi.org/10.1038/385299a0

Wilson AW, Aime MC, Dierks J, Muler GM, Henkel TW (2012) Cantharellaceae of Guyana I: new species, combinations and distribution records of Craterellus and synopsis of known taxa. Mycologia 104(6): 1466–1477. https://doi.org/10.3852/11-412

Yun W, Hall IR (2004) Edible ectomycorrhizal mushrooms: challenges and achievements. Canadian Journal of Botany 82(8): 1063–1073. https://doi.org/10.1139/b04-051