Tomophagus cattienensis sp. Nov., A NEW SPECIES AND THE GENERIC SPECIATIONS OF THE GANODERMATACEAE

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Ganoderma Karsten and allies (Ganodermataceae Donk, Polyporales, Agaricomycetidae) are a group of polypore fungi of significant economic importance. Several species cause severe losses to perennial crops in many tropical countries (Flood *et al.* 2000) and some are of great interest for medicinal and pharmaceutical purposes particularly in eastern Asia (Jong & Birmingham 1992, Lin & Zang 2004). Members of the Ganodermataceae are characterized and easily recognized by the unique presence of double-walled basidospores. The monophyly of the group was confirmed in molecular phylogenetic analyses (Hibbett *et al.* 1997, Moncalvo *et al.* 2002). However, both generic and specific circumscription within the family has been difficult and controversial (Furtado 1965, Steyaert 1972, 1980, Corner 1983, Zhao 1989, Zhao & Zhang, 2000, Moncalvo & Ryvarden 1997, Moncalvo 2000). Murrill (1905a,b) created the genus *Tomophagus* to segregate *G. colossum* (Fr.) C.F. Baker from *Ganoderma* based on its unusually thick and pale context that becomes soft and light when dry. *Tomophagus* was not accepted by Furtado (1965), Steyaert (1972,1980), Corner (1983), Ryvarden (1991), and many other authors. Steyaert (1980) even suggested that *G. colossum* could be a tropical variant of the temperate western North American species *G. oregonense* Murrill that also has a soft and pale context. However, recent molecular phylogenetic studies that used sequence data from the internal transcribed spacers of the nuclear ribosomal DNA repeats (ITS rDNA; Moncalvo *et al.* 1995, Moncalvo 2000) and nearly complete mitochondrial small-subunit ribosomal DNA sequences (Hong & Jung 2004) indicate that *G. colossum* and *G. oregonense* are distantly related, supporting the recognition of *Tomophagus* as a distinct genus.

Tomophagus colossus was described by Fries (1851) from Costa Rica as *Polyporus colossus* and later transferred to *Ganoderma* by Baker (1918). It is a rare species but it has been reported throughout the tropics, except from East Africa (Ryvarden & Johansen 1980, Ofodile *et al.* 2005). In Vietnam, *T. colossus* was first recorded by Patouillard (1897) as *G. obokense* Pat., a species described from Somalia and later synonymized with *G. colossum* (Furtado 1965, Steyaert 1972, Ryvarden & Johansen 1980, Ryvarden 2004). This rare species was only recently rediscovered in Vietnam (Ngo Anh *et al.* 2001). In this paper we report a second species of *Tomophagus* from Cat Tien National Park in southern Vietnam (Cat Tien is a designated UNESCO Biosphere Reserve; The MAB Programme 2007). The new species reported here is distinguished from *T. colossus* on the basis of combined evidence from morphology, cultural characteristics, and ITS rDNA barcodes.

I. MATERIALS AND METHODS

Organisms studied and morphological examination

Four *Tomophagus* collections were obtained from Vietnam between 2000 and 2008 (Table 1). Macroscopic and anatomical examinations of basidiomata were made as described in Le Xuan Tham (1998). Basidiospore structure was described according to Pegler & Young (1973) and Perreau (1973). Data were compared with the detailed description of the type specimen of *T. colossus* in Steyaert (1972), Ryvarden & Johansen (1980), and Ryvarden (2004). Descriptions of this species in Corner (1983), Gilbertson & Ryvarden (1986), and Wu & Zhang (2003) were also consulted.

Cultivation

Context tissues from fresh collection of strains CT99, CT119, HCMC10 and ANH s.n. were used for isolation in pure culture in a homemade broth of Potato-Glucose-Agar (PGA: Le Xuan Tham *et al.* 1999). Mycelial characteristics were observed on that medium, particularly for the presence/absence of chlamydospores as reported in Peng (1990). *In vitro* basidioma induction was conducted at room temperature on rubber tree sawdust supplemented with 5% rice bran in 2.5 L plastic bags (Le Xuan Tham *et al.* 1999), and many other species also fruitfully cultured (Le Xuan Tham 2005, Le Xuan Tham *et al.*, 2009, 2010).

DNA analyses

ITS sequences from collections ANH and HCMC10 were produced at the Royal Ontario Museum. Sequences from CT99 and CT119 were produced at the DNA sequencing facility of the Institute for Microorganism and Biotechnology, National Hanoi University. A sequence of *T. colossus* CBS 216.36 (Philippines) was retrieved from Moncalvo *et al.* (1995). A BLAST search in the NCBI database using TRTC157076 as the query sequence was used to identify additional sequences from closely related taxa to include in our dataset. Taxa used for DNA analyses are listed along with their source and GenBank accession numbers, incl. in previous papers. Sequences were aligned manually and analyzed in PAUP* (Swofford 2003) using maximumparsimony and 1,000 nonparametric bootstrap replicates, with 100 heuristic searches of random addition sequence and TBR branch-swapping (MP). All gaps in the alignment consisted of single deletion/insertion and were treated as a "fifth base" in our analyses. Trees were midpointrooted.

II. RESULTS AND DISCUSSION

DNA analyses

BLAST searches returned 99% similarity to *Ganoderma* sp. kk-02 (AJ749970) from India (Sharma *et al.* 2005), and < 92% similarity to other *Ganoderma* sequences in the database. Therefore, we only included AJ749970 in our molecular analyses. After removal of residual SSU and LSU sequences at the 3'- and 5'- end, respectively, ITS sequences were aligned in 558 positions. Thirty-five characters were variable, of which 27 were parsimony-informative. Maximum-parsimony analysis returned a single tree of length 35 (CI=1.000, RI=1.000). Nonparametric bootstrapping strongly supported (100%) the reciprocal monophyly of *T. cattienensis* sp. nov. and *T. colossus* (Fig. 1).

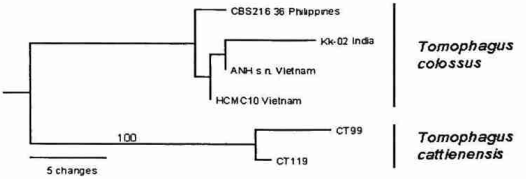


Fig. 1. Phylogenetic relationship between T. cattienensis and T. colossus races, based on rDNA

Taxonomy

Tomophagus cattienensis Le Xuan Tham & J.M. Moncalvo, *spec. nov.* (Fig. 2)

MycoBank no. MB 561806

Etymology: Named after the locality of the original collections: Cat Tien National Park, Vietnam.

Holotype: Pham Ngoc Duong & Le Xuan Tham, collection CT99; 6 June 2007; on the trunk of a broad leaf tree, Cat Tien National Park, Dong Nai Province, Vietnam; voucher deposited in the mycology herbarium of the Cat Tien National Park; fragments (*isotypes*) in the Royal Ontario Museum, Toronto, Canada (TRTC 161191), and in the National Museum of Natural Science, Taichung, Taiwan (China).

Distinctus ex Polyporus colossus Fr. quo lux lucis rutilus frons superficies, leviter congelo crusta, contextu frons si quando siccus, quod amplus basidiosporae. Ordines genorum ITS competentes ordinum depositorum NCBI (GenBank) JN184397.

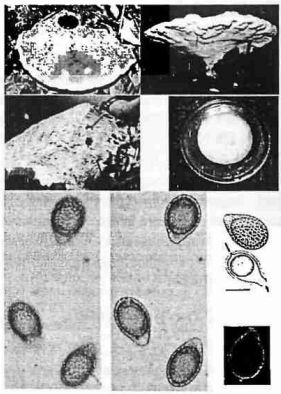


Fig. 2. Holotypus of T. cattienensis (fruitbody, basidiospores and cultured mycelia)
Nguồn ảnh: *Nhóm nghiên cứu*

Pileus bulky, thick, flabelliform, dimidiate (~29cm in diameter and ~16cm long) with a very short cylindrical stipe, perennial, occurring singly on rotting trunks of hardwood trees. Crust red-brown or red-coffeate, laccate at first, but later becoming dull brown by a dusty covering of basidiospores, thin, easily broken when cracking or pressing with fingernails. Margin obtuse, rugose, very thick (~3-4cm), white creamy or pale yellow brown. The crust of the stipe is thicker, more laccate, glossy red-brown. *Context* thick ~3.7-7.7cm, up to 11cm at the base, homogeneous (without stratifications), soft, light,

creamy white becoming pale brown upon drying, somewhat cheesy and powdery, slightly striate above the tubes, composed of dimitic hyphae. *Tube layer* thin (0.8-1.4cm), grey brown to cinnamon brown, unstratified. *Pores* round or angular, small (2-3/mm) with the surface creamy turning pale grey or dark grey when touched. Trimitic, generative hyphae hyaline, branched, thick wall with clamps, 2.5-3.5 µm, skeletal hyphae 2-3.5 µm and binding branched 1,7-2,8 µm diam *Basidiospores* typically ganodermoid, honey yellow, 17.5-21.5 × 11 5-14.5 µm, truncate-ovate with a yellow round guttule in the center. Basidiospore surface coarse verrucose, pits connected with each other or not completely reticulate (labyrinthine) with thin pillar layer from inner wall. Apex (= germpore aperture) hyaline, very thick, concave (truncate) or convex, opposite to the hilum (= the attachment of spore to sterigma). ITS sequence accession number of the type specimen in the NCBI (GenBank) database: JN184397.

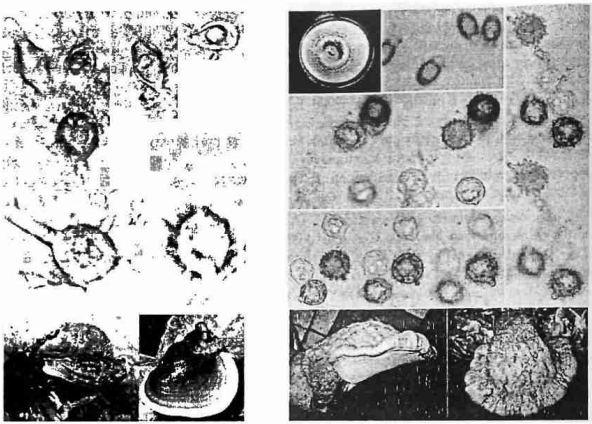
Additional specimens examined: VIETNAM: Dong Nai Province, Cat Tien National Park, on the trunk of broad leaf tree. 2 August 2008, Pham Ngoc Duong & Le Xuan Tham, coll. CT119; deposited in the mycology herbarium of the Cat Tien National Park. ITS sequence accession number in the NCBI (GenBank) database: JN184398.

Tomophagus colossus (Fr.) Murrill

The two Vietnamese collections of *T. colossus* examined in this study (Fig. 1) fully correspond to the morphological descriptions of the type specimen in Steyaert (1972), Ryvarden & Johansen (1980), and Ryvarden (2004). In addition. the collection ANH s.n. was described in detail in Ngo Anh *et al.* (2001). This species is easy to recognize from its thin yellow crust and a pale and chalky context. It is rarely found but widespread in the tropics. It was reported in the Neotropics including Mexico, Florida, and Brazil (Steyaert 1972, Gilbertson & Ryvarden 1986, Gomes-Silva *et al.* 2011), tropical Africa (Steyaert 1972, Ryvarden & Johansen1980), the Arabian Peninsula (Al Bahry *et al.* 2005), India, Pakistan and Sri Lanka (Steyaert 1972), Malaysia and Indonesia (Corner 1983), and South China and Taiwan (Wu & Zhang 2003). Our ITS analyses also indicate that the strain *Ganoderma* sp. kk-02 reported from India by Sharma *et al.* (2005) corresponds to *T. colossus*. Based on the literature cited above, *T. colossus* has a wide host range on woody angiosperms and monocotyledons. Wide host range and pantropical distribution of a fungal morphotype is uncommon. Future comprehensive studies of this species using mating and molecular data from a broad geographic sampling may reveal the existence of cryptic species within this unique pantropical morphotype.

Distinction between *T. cattienensis* and *T. colossus*

Wild collections of *T. cattienensis* clearly differ morphologically from *T. colossus* by having glossy light red-brown basidomata (rather than yellow), a slightly harder crust, a context that turns pale brown upon drying (instead of remaining creamy white), and slightly larger basidiospores (17.5-21.5 × 11.5-14.5 µm *versus* 14-20 × 9-14 µm). These characteristics are retained in basidiomata produced in artificial cultivation. In artificial culture, basidiomata of *T. cattienensis* isolates develop and mature in 60-75 days, which is 20-25 days longer than for our *T. colossus* strains. We also observed remarkable differences between the two species in the shape and types of chlamydospores with spines or ridges, produced in cultures grown on PGA medium. *Tomophagus cattienensis* also grows more slowly than *T. colossus* on PGA medium.



(a) (b)

Fig. 3. Chlamydospores and cultured fruitbodies of T. cattienensis (a) and T. colossus (b)

Nguồn ảnh: Nhóm nghiên cứu

Phylogenetic analysis of ITS rDNA barcodes clearly distinguishes between the two species (Fig.1). MP analyses yielded a single tree and indicated 100% bootstrap support for the distinction between *T. cattienensis* and *T. colossus*. Pairwise inter-specific difference was observed in 27- 33 nucleotide positions (4.83-5.91%), whereas intra-specific divergence was much lower: the two *T. cattienensis* collections from Vietnam differ in only 6 nucleotide positions (1.08%), and our four Asian samples of *T. colossus* differ in 1-10 positions (0.18-1.8%). These values for intra- and inter-specific variation in fungal ITS sequences are in agreement with the study by Nilsson *et al.* (2008). The present work therefore confirms the view that ITS can be a good molecular marker (DNA barcode) for species identification in fungi (Seifert 2009), although it may not work in all taxa (Seifert *et al.* 2007, Nilsson *et al.* 2008), but so interesting for taxa at generic and species levels in the Ganodermataceae Donk as shown in Figs. 4, 5.

Tomophagus Murr. nd *Amauroderma* Murr. differentiating as distinctive genera in clades quite naturally, however, *Ganoderma* Karst. is under speciations to form various relative groups of species, incl. *Magoderna* Stey., *Haddowia* Stey. and *Humphreya* Stey. that are quite conspecific in basidiospore structures and other morphological characters (Le Xuan Tham, 1998, 2005).

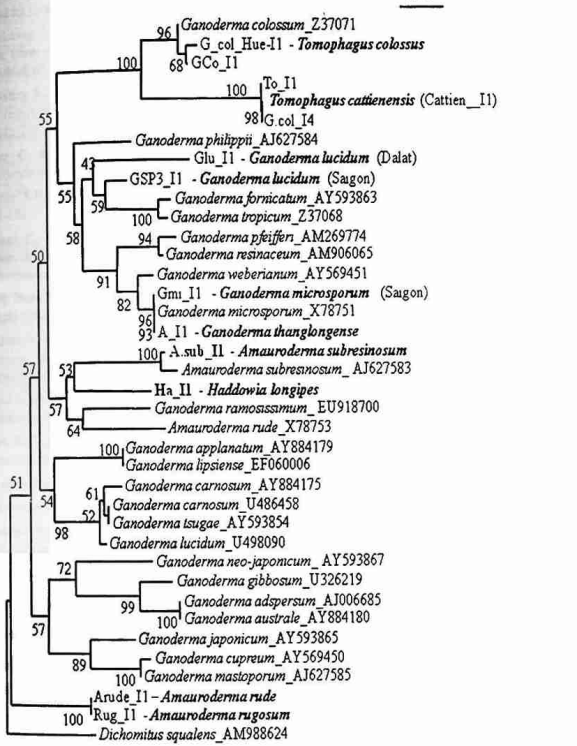


Fig. 4. Phylogenetic speciations of taxa in main genera of the Ganodermataceae Donk based on ITS1 data

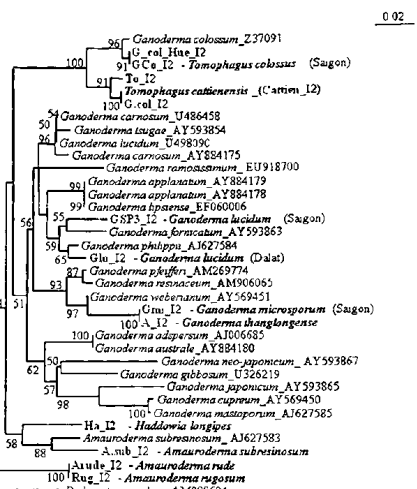


Fig. 5. *Phylogenetic speciations of taxa in main genera of the Ganodermataceae Donk based on ITS2 data*

Practical implications of the discovery of *T. cattienensis*

Members of the Ganodermataceae have been shown to be pharmacologically active and their therapeutic use is being investigated (Dzubak *et al.* 2006, Liby *et al.* 2007). Recent studies have reported several new lanostane triterpene lactones ("colossolactones") from the cultivated *T. in idiosporebascolossus* strain ANH s.n. from Vietnam (Kleinwachter *et al.* 2001, El Dine *et al.* 2008). Colossactones were also present in a Nigerian strain of that species (Ofodile *et al.* 2005). *Tomophagus colossus* is also known for its excellent delignification activity (Adaskaveg *et al.* 1990, 1995). Therefore, the discovery of a novel species of *Tomophagus*, *T. cattienensis*, may have implications for the discovery of novel bioactive compounds for pharmaceutical use and/or the pulp and biofuel industries as so many other *Ganoderma* species.

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REFERENCES

1. **Adaskaveg J. E., R. L. Gilbertson, R. A. Blanchette**, 1990. Comparative studies of delignifications caused by *Ganoderma* species. Appl Environ Microbiol, 56: 1932-1943.
2. **Adaskaveg J. E., R. L. Gilbertson,m. R. Dunlap**, 1995. Effects of incubation time and temperature on in vitro selective delignification of silver leaf oak by Ganoderma colossum. Appl Environ Microbiol, 61: 138-144.
3. **Al-Bahry S., A. E. Elshafie, M. Deadman, A. Al Sa'di, A. Al Raeesi, Y. Al Maqbali**, 2005. First report of *Ganoderma colossum* on *Ficus altissima* and *Delonix regia* in Oman. Plant Pathol, 54: 245-245.
4. **Baker C. F.**, 1918. *Ganoderma colossus* (Fr.) C. F. Baker, Brotéria 425. Index Fungorum http://www.indexfungorum.org/Names/NamesRecord.asp?RecordID=251520 (accessed June 26, 2011).
5. **Corner EJH.**, 1983. Ad Polyporaceas I. *Amauroderma* and *Ganoderma*. Beih Nova Hedwigia, 75: 1-182.
6. **Dzubak P., M. Hajduch, D. Vydra, A. Hustova, M. Kvasnica, D. Biedermann, L. Markova, M. Urban, J. Sarek**, 2006. Pharmacological activities of natural triterpenoids and their therapeutic implications. Nat. Prod Rep., 23: 394-411.
7. **Dang Ngoc Quang, T.T. Nga, Le Xuan Tham**, 2011. Chemical Composition of Vietnam Black Lingzhi *Amauroderma subresinosum* Murr. Research Journal of Phytochemistry, 5(4): 216-221, 2011.
8. **El Dine S. R., M. A. El Halawany, N. Nakamura, C.M. Ma, M. Hattori**, 2008. New lanostane triterpene lactones from Vietnamese mushroom *Ganoderma colossum* (Fr.) C.F Baker. Chem Pharm. Bull., 56: 642-646
9. **Flood J., P. D. Bridge, M. Holderness, eds**, 2000. *Ganoderma* Diseases of Perennial Crops. CABI Publishing, Wallingford, UK.
10. **Fries E.M.**, 1851. Novae symbolae mycologicae, in peregrinis terris a botanicis Danicis collectae. Nova Acta Regiae Societatis Scientiarum Upsaliensis Series 3:17-136
11. **Furtado J. S.**, 1965. *Ganoderma colossum* and the status of *Tomophagus*. Mycologia, 57: 979-984
12. **Gilbertson R. L., L. Ryvarden**, 1986. North American Polypores, Fungiflora, Oslo, Norway, vol. I.
13. **Gomes-Silva A. C., L. Ryvarden, T. B. Gibertoni**, 2011. New records of Ganodermataceae (Basidiomycota) from Brazil. Nova Hedwigia, 92: 83-89.
14. **Hibbett D. S.,M. P. Pine, E. Langer, G. Langer, J. D. Donoghue**, 1997. Evolution of gilled mushrooms and puffballs inferred from ribosomal DNA sequences. Proc. Natl Acad. Sci U.S.A., 94: 12002-12006.
15. **Hong S. G., H. S. Jung**, 2004. Phylogenetic analysis of *Ganoderma* based on nearly complete mitochondrial small-subunit ribosomal DNA sequences. Mycologia, 96: 742-755
16. **Jong S. C., J.M. Birmingham**, 1992. Medicinal benefits of the mushroom *Ganoderma*. Adv Appl Microbiol, 37: 101-134.
17. **Kleinwachter P., Ngo Anh, Trinh Tam Kiet, B. Schlegel, H.M. Dahse, A. Hartl, U. Grafe**, 2001. Colossolactones, new triterpenoid metabolites from a Vietnamese mushroom *Ganoderma colossum*. J. Nat. Prod., 64: 236-239.
18. **Le Xuan Tham**, 1998. A phylogenetic hypothesis of the Ganodermataceae based on a possible mode of basidiospore evolution. Mycotaxon, 69: 1-12
19. **Le Xuan Tham, S. Matsuhashi, T. Kume**, 1999. Growth and fruitbody formation of *Ganoderma lucidum* on media supplemented with vanadium, selenium and germanium. Mycoscience, 40: 87-92

20. **Lê Xuân Thám**, 2005. Nấm Linh chi Ganodermataceae-Tài nguyên dược liệu quí ở Việt Nam. NXB Khoa học Kỹ thuật, Hà Nội, 404 trang.

21. **Lê Xuân Thám, Nguyễn Lê Quốc Hùng, Phạm Ngọc Dương, J.M. Moncalvo**, 2009. Phát hiện đại diện đầu tiên của chi mới *Humphreya* Stey. của họ Linh chi Ganodermataceae ở Vườn Quốc gia Cát Tiên: Linh chi Endert *Humphreya endertii*. Tạp chí Sinh học, số 1: 39-45.

22. **Lê Xuân Thám, Nguyễn Lê Quốc Hùng, Phạm Ngọc Dương, Đặng Ngọc Quang, Đào Thị Lương**, 2009. Nghiên cứu nuôi trồng loài nấm Linh chi đen *Amauroderma subresinosum*, mới phát hiện ở Nam Việt Nam. Tạp chí Sinh học, số 3: 55-64.

23. **Lê Xuân Thám, Bùi Thị Minh Hải, Mai Thị Việt Hằng, Phạm Ngọc Dương**, 2010. Dẫn liệu sinh học và quan hệ chủng loại phát sinh của đại diện chi nấm *Haddowia* thuộc họ Linh chi Ganodermataceae. Tạp chí Công nghệ sinh học, số 8 (3A): 955-966.

24. **Le Xuan Tham, Nguyen Le Quoc Hung, Pham Ngoc Duong, Duong Van Hop, T.M. Bryn Dentinger and Jean-Marc Moncalvo**, 2012. *Tomophagus cattienensis* sp. nov., a new Ganodermataceae species from Vietnam: Evidence from morphology and ITS DNA barcodes. Mycological Progress, 11(3): 775-780.

25. **Liby K. T., m.m. Yore, m. B. Sporn**, 2007. Triterpenoids and rexinoids as multifunctional agents for the prevention and treatment of cancer. Nat. Rev. Cancer, 7: 357-369

26. **Lin Z. B., H. N. Zang**, 2004. Anti-tumor and immunoregulatory activities of *Ganoderma lucidum* and its possible mechanisms. Acta Pharmacologia Sinica, 25: 1387-1395.

27. **Moncalvo J.M., H. H. Wang, R. S. Hseu**, 1995. The use of ribosomal DNA sequence data for species identification and phylogeny in the Ganodermataceae. In: P. K. Buchanan, R. S. Hseu, J.M. Moncalvo (eds) *Ganoderma:* Systematics, Phytopathology and Pharmacology, Taipei, Taiwan, p. 31-44.

28. **Moncalvo J.M., L. Ryvarden**, 1997. Nomenclatural study of the Ganodermataceae Donk. Synopsis Fungorum 11. Fungiflora, Oslo, Norway.

29. **Moncalvo J.M.**, 2000. Systematics of *Ganoderma*. In: Flood P. Bridge D, Holdernessm (eds) *Ganoderma* Diseases of Perennial Crops, CABI Publishing, Wallingford, UK, p. 23-45.

30. **Moncalvo J.M., R. Vilgalys, S. A. Redhead, J. E. Johnson, T. Y. James, M. C. Aime, V. Hofstetter, S. J. W. Verduin, E. Larsson, T. J. Baroni, R. G. Thorn, S. Jacobsson, H. Clémençon, O. K. Miller**, 2002. One Hundred and Seventeen Clades of Euagarics. Mol Phylogenet Evol, 23: 357-400.

31. **Murrill W. A.**, 1905a. The Polyporaceae of North America: XII. A synopsis of the white and brightcolored pileate species. Bull. Torrey Bot. Club, 32: 469-493.

32. **Murrill W. A.** 1905b. *Tomophagus* for *Dendrophagus*. Torreya, 5: 197.

33. **Ngo Anh, Trinh Tam Kiet, Nguyen Thi Duc Hue**, 2001. Some scarce taxa of the family Ganodermataceae Donk in Vietnam. Journal of Genetics and Applications, Special Issue: Biotechnology, Genetics Society of Vietnam, Hanoi, Vietnam, pp 52-56.

34. **Nilsson R. H., E. Kristiansson, N. Ryberg, N. Hallenberg, K. H. Larsson**, 2008. Intraspecific *ITS* variability in the kingdom fungi as expressed in the international sequence databases and its implications for molecular species identification. Evol Bioinf Online, 4: 193-201.

35. **Ofodile L. N., N. U. Uma, T. Kokubun, R. J. Grayer, O. T. Ogundipe, M. S. J. Simmond**, 2005. Antimicrobial colossolactones from a Nigerian polypore *Ganoderma colossum* (Fr.) C.F. Baker. Int. J. Med Mushrooms, 7: 437.

36. **Patouillard N.**, 1897. Contribution a la flore mycologique du Tonkin (3e serie). Journal de Botanique 11: 335-374.

37. **Peng J. T.**, 1990. Identification and Culture Conservation of the Wild *Ganoderma* species in Taiwan. Publication of the Taiwan Agriculture Research Institute.

38. **Pegler D. N., T. W. K. Young,** 1973. Basidiospore form in the British species of *Ganoderma* Karst. Kew Bull, 28: 351-370.

39. **Perreau J.,** 1973. Contribution à l'étude des ornaments sporaux chez les Ganodermes. Rev. Mycol. Paris, 37: 241-252.

40. **Ryvarden L.,** 1991. Genera of Polypores: Nomenclature and Taxonomy. Fungiflora, Oslo, Norway.

41. **Ryvarden L., I. Johansen,** 1980. Preliminary polypore flora of East Africa. Fungiflora, Oslo, Norway.

42. **Ryvarden L.,** 2004. Neotropical Polypores, Part 1, Introduction, Hymenochaetaceae and Ganodermataceae. Synopsis Fungorum 19. Fungiflora, Oslo, Norway.

43. **Seifert K. A., R. A. Samson, J. R. deWaard, J. Houbraken, C. A. Lévesque, J.M. Moncalvo, G. Louis-Seize, P. D. N. Hebert,** 2007. Prospects for fungus identification using *CO1* DNA barcodes, with *Penicillium* as a test case. Proc. Natl. Acad. Sci. USA, 104: 3901-3906.

44. **Seifert K. A.** 2009. Progress towards DNA barcoding of fungi. Mol. Ecol. Resour., 9: 83-89.

45. **Sharma K. K., M. Kapoor, R. C. Kuhad,** 2005. *In vivo* enzymatic digestion, *in vitro* xylanase digestion, metabolic analogues, surfactants and polyethylene glycol ameliorate laccase production from *Ganoderma* sp. kk-02. Lett Appl Microbiol, 41: 24-31.

46. **Steyaert R. L.,** 1972. Species of *Ganoderma* and related genera mainly of the Bogor and Leiden Herbaria. Persoonia, 7: 55-118.

47. **Steyaert R. L.,** 1980. Study of some *Ganoderma* species. Bull. J. Bot. Nat. Belgique, 50: 135-186.

48. **Swofford D. L.,** 2003. PAUP*: Phylogenetic analysis using parsimony (and other methods), version 4.0b 10. Sinauer Associates, Sunderland, Massachusetts The MAB Programme, 2007. http://www.unesco.org/mabdb/br/brdir/directory/biores.asp?mode=all & code=VIE+02.

49. **Wu S. H., X. Q. Zhang,** 2003. The findings of three Ganodermataceae species in Taiwan. Collection and Research, 16: 61-66.

50. **Zhao J. D.,** 1989. The Ganodermataceae in China. Bibl Mycol, 132: 1-176.

51. **Zhao J. D., X. Q. Zhang,** 2000. The Ganodermataceae in China.

Tomophagus cattienensis sp.nov., MỘT LOÀI NẤM LINH CHI VÀNG MỚI VÀ SỰ PHÂN HÓA CỦA CÁC CHI THUỘC HỌ Ganodermataceae

LÊ XUÂN THÁM, NGUYỄN LÊ QUỐC HÙNG, PHẠN QUỐC CHÍNH, NGUYỄN NHƯ CHƯƠNG, PHẠM NGỌC DƯƠNG, DƯƠNG VĂN HỢP, BRYN T.M. DENTINGER VÀ JEAN-MARC MONCALVO

TÓM TẮT

Chi *Tomophagus* được xác lập tách biệt với một loài đặc sắc, *Ganoderma colossum*, với chi *Ganoderma*. Các dẫn liệu sinh học phân tử gần đây xác nhận tính hữu hiệu của chi đơn loài này. Chúng tôi báo các phát hiện một loài thứ hai của *Tomophagus*, *T. cattienensis* sp.nov., ở Vườn Quốc gia Cát Tiên, Nam Việt Nam, một vùng rừng thấp-Khu Dự trữ sinh quyển của UNESCO. Việc công nhận loài mới này dựa trên bằng chứng hình thái học, phân tử, các đặc trưng nuôi cấy và ITS rDNA barcodes. Việc phát hiện loài mới này có triển vọng tìm được các hoạt chất mới cho ứng dụng dược học và/hoặc cho công nghiệp giấy. Những phân hóa đặc sắc của các chi *Ganoderma*, *Amauroderma*, *Humphreya*, *Haddowia* với các nhóm chuyển tiếp trung gian được ghi nhận nghiên cứu khá phong phú và là nguồn dược liệu quí ở Việt Nam