Fungal Biotec 5(1): 1–15 (2025) ISSN 2774-0323

www.fungalbiotec.org

Article

Doi 10.5943/FunBiotec/5/1/1

Scleroderma: A review of the known species in Thailand

Gonkhom D[1,2], Sysouphanthong P[2], Niego AGT[3], Thongklang N [1, 2*] and Hyde KD[1,2*]

[1] School of Science, Mae Fah Luang University, Chiang Rai 57100, Thailand
[2] Center of Excellence in Fungal Research, Mae Fah Luang University, Chiang Rai 57100, Thailand
[3] Natural Science Department, College of Arts and Sciences, Iloilo Science and Technology University, La Paz, Iloilo, 5000, Philippines

Gonkhom D, Sysouphanthong P, Niego AGT, Thongklang N and Hyde KD 2024 – *Scleroderma*: A review of the known species in Thailand. Fungal Biotec 5(1), 1–15, Doi 10.5943/FunBiotec/5/1/1

Abstract

Scleroderma species belong to Gasteromycetes (Basidiomycota), characterised by their basidiospores maturing within the basidioma without forcible discharge from the basidia. Commonly known as earth balls, *Scleroderma* has been identified as suitable for human consumption. Additionally, these fungi exhibit medicinal properties through the production of bioactive compounds. However, there have been some concerns about the edibility and potential toxicity of this mushroom. In Asia, twenty-five species of *Scleroderma* have been documented, with eleven species identified in Thailand based on morphological evidence. This review aims to provide insights into the taxonomy, distribution, life cycle, and cultivation of *Scleroderma* species found in Thailand. Furthermore, we report the bioactive compounds produced by this genus and their economic significance.

Keywords – edible mushroom – Gasteromycetes – poisonous – puffball – taxonomy

Introduction

Scleroderma Pers. belongs to Sclerodermataceae with *Scleroderma verrucosum* (Bull.) Pers. as the type species (He et al. 2019). This genus is distributed worldwide in temperate, subtropical, and tropical regions (Sims et al. 1997, He et al. 2019). Several morphological and molecular studies have confirmed the systematic position of *Scleroderma*, placing it in the suborder Sclerodermatineae within Boletales (Binder & Bresinsky 2002, Hughey et al. 2000, Louzan et al. 2007). Most lineages within this suborder are recognised as ectomycorrhizal taxa (Binder & Hibbett 2006, Watling 2006). The taxonomy of *Scleroderma* is understudied particularly in tropical Africa (Sanon et al. 1997) and in Asia (Farmer & Sylvia 1998, Sims et al. 1999). There are 202 records with 121 species of *Scleroderma* in Index Fungorum 2025 (www.indexfungorum.org). However, only 46 species have been accepted by He et al. (2019).

A revised key of the genus *Scleroderma* was considered for the identification of 25 species in Asia (Sim et al. 1995, Sanon et al. 2009). In Thailand, only eleven species of *Scleroderma* based on morphology have been reported, namely *S. areolatum* Ehrenb., *S. bovista* Fr., *S. cepa* Pers., *S. citrinum* Pers., *S. dictyosporum* Pat., *S. flavidum* Ellis & Everh., *S. lycoperdoides* Schwein., *S. polyrhizum* (J.F. Gmel.) Pers., *S. sinnamariense* Mont., *S. verrucosum* (Bull.) Pers. (Chandrasrikul et al. 2011) and *S. suthepense* Kumla, Suwannar. & Lumyong (Kumla et al. 2013).

Scleroderma species are good candidates as symbionts for inoculation in afforestation initiatives involving pine and eucalyptus trees (Dell et al. 2002, Chen 2006). Typically, the well-

Submitted 7 October 2024, Accepted 13 March 2025, Published 31 March 2025
Corresponding Author: Thongklang N– e-mail – naritsada.t@gmail.com; Hyde KD – kdhyde3@gmail.com

known species are *S. citrinum* and *S. verrucosum,* which are found in tropical areas (Cortez et al. 2011). This review focuses on the *Scleroderma* species, emphasizing their economic significance due to their edible nature, ease of cultivation, production of bioactive substances, and traditional medicinal applications. Moreover, it also tackles the taxonomy and distribution of *Scleroderma* species that have been reported in Thailand.

Economic Importance of *Scleroderma*

Scleroderma species have numerous ecological and economic significance. Mycorrhizal interactions exist between a number of *Scleroderma* species and plants and trees (Jeffries 1999). They are essential for nutrient intake and can enhance the development and health of plants (Bradshaw 2000). They also help increase the productivity of crops, forests, and the overall ecosystem (Wu et al. 2023).

Certain species of *Scleroderma* have been reported to be edible and used in medicinal development (Guzmán et al. 2013). Some metabolites derived from *Scleroderma* species have therapeutic uses, although not extensively explored (Menezes Filho et al. 2022). Research on their bioactive ingredients could lead to the development of new drugs or supplements (Kour et al. 2022). Although *Scleroderma* species possess economic significance due to their edibility, cultivation potential, and bioactive compounds, their utilization for consumption or broader applications remains limited.

Although the *Scleroderma* mushroom has yet to dominate Thailand's economy, there are niches where its economic significance might increase, especially in traditional medicine, wild collection, and potential market cultivation as more research becomes available on *Scleroderma* mushrooms in Thailand (Kumla et al. 2013, Somrithipol et al. 2022).

Edibility

Scleroderma does not have much food value. Although in the early years, McIlvaine & Macadam (1902) claimed that all species were edible when young, this has been proven to be wrong. Many species of *Scleroderma* are poisonous (Hall et al. 2003, Schmid et al. 1992, Sims et al. 1995). Symptoms of poisoning can occur within an hour after eating such as loss of consciousness, nausea, severe abdominal pain, vomiting, perspiration, generalised tingling sensations, spasms, cramps, paralysis, and anaphylactic shock (Hall et al. 2003, Schmid et al. 1992, Sims et al. 1995). Among the 25 species described worldwide, four were documented to be highly poisonous, namely *S. albidum*, *S. areolatum*, and *S. cepa* (Van Der Sar et al. 2005, Rasalanavho et al. 2019). However, other authors claimed that some species of *Scleroderma* are safe to consume. *Scleroderma sinnamariense*, *S. polyrhizum,* and *S. verrucosum* are considered edible in Nepal (Christensen et al. 2008). Moreover, the edibility of *S. flavidum* was also verified (Wang et al. 2004, Li et al. 2021). *Scleroderma citrinum*, has been reported as edible in Thailand when they are still young and fresh (Soytong et al. 2014, Puengpholpool et al. 2023), however, proper identification, preparation techniques and cooking are crucial for safety. It is always advisable to consult an expert or mycologist before consuming wild mushrooms (Kaaronen 2020).

Cultivation

There is limited literature on the cultivation of this genus, as most species are considered to be poisonous. To date, only five species have been documented to grow under laboratory conditions to extract bioactive compounds (Table 1). *Scleroderma citrinum* was found to grow well in an axenic culture at 30 °C (Ingleby et al. 1985). *Scleroderma* sp. was found to have fast growth at 28 ºC and pH 7.5 on modified Melin-Norkrans (MMN) media with xylose. It was also found to grow rapidly in nutrient medium with NH_4^+ as an organic nitrogen source (Lazarević & Keča 2013).

Scleroderma sinnamariense can also be grown under laboratory conditions. In the study of Siri-In et al. (2014), among the different culture media tested, fungal host agar was the best medium for optimal mycelium growth and high biomass yield. *Scleroderma sinnamariense* was able to grow at 30 °C. The optimal pH for mycelial growth was 5.0. Additionally, this strain produced indole-3-

acetic acid and siderophore in pure culture (Siri-In et al. 2014). Siri-In et al. (2014) provided valuable information for mycelial cultivation in Thailand.

Mycelial growth of *S. verrucosum* was also observed in the laboratory (Putra et al. 1999). The three-week-old culture was placed on a synthetic agar medium covered with cellophane and incubated at 24 °C in the dark. The growth in the plates was found to range from 0.9 to 36 mm after 4 weeks of incubation. For experiments with non-stirred liquid medium, the inoculum was grown on the surface of 100 ml of MMN medium in 250 ml Erlenmeyer flasks at pH 5-6 and maintained at 24 °C, shaken gently for 20 s at least once every 3 days, and then daily to ensure oxygenation during exponential growth (Putra et al. 1999). *Scleroderma* is an important source of bioactive compounds, but, field cultivation has not been documented in Thailand, thus, further studies are necessary.

Bioactive compounds

Some species of *Scleroderma* have medicinal properties. They possess secondary metabolites with bioactivities. *Scleroderma nitidum* and *S. cepa* for instance, can be used as an anti-inflammatory and hemostatic agent (Nascimento et al. 2011, Guzmán et al. 2013). *Scleroderma polyrhizum* has been found to have anti-inflammatory and hemostatic properties. It can also be used to stop the bleeding of external wounds by applying the spore dust to wounds (Guzmán et al. 2013). In addition, *S. nitidum* has anti-inflammatory and immunomodulatory activities (Nascimento et al. 2011).

Among the species of *Scleroderma*, *S. citrinum* is the most studied for its bioactivities (Entwistle & Pratt 1968, 1969). The methanol extract of *S. citrinum* showed potential antiviral activity against *Herpes simplex* virus type 1 (IC_{50} = 15 µg/mL) and weak activity against *Mycobacterium tuberculosis* H37Ra (MIC = 100 µg/mL) (Guzmán & Ovrebo 2000, Liu 1984).

Many bioactive compounds have been isolated from *Scleroderma* species. Various pigments such as xerocomic acid, badione A, norbadione A, and sclerocitrin have bioactivities such as antioxidant, anticarcinogenic, antiviral, antibacterial, and immunomodulatory properties (Velíšek & Cejpek 2011, Winner et al. 2004) (Fig. 1).

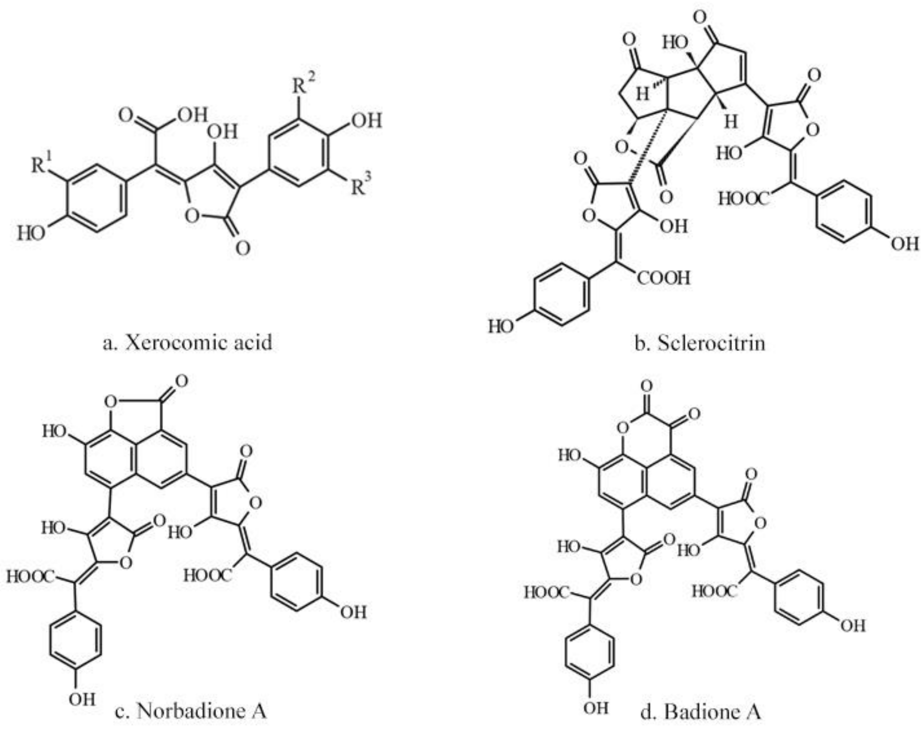
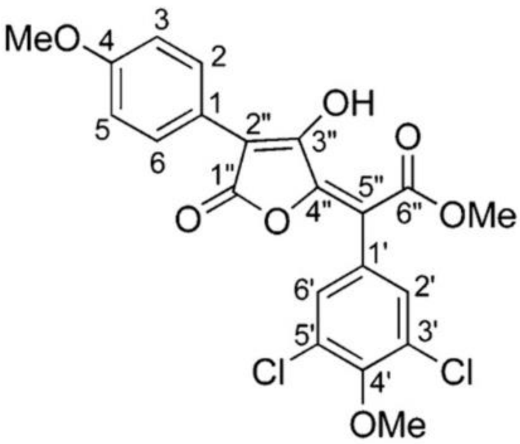


Fig. 1 – Structures of various pigments isolated from *Scleroderma* species

Pulvinic acid dimers have also been isolated from *Scleroderma citrinum* (Winner et al. 2004) (Fig. 2). It is another natural chemical pigment. The purification of this extract resulted in the isolation of a new pulvinic acid derivative, as well as three known pulvinic acid derivatives (Van Der Sar et al. 2005).

Table 1 *Scleroderma* species grown under laboratory conditions.

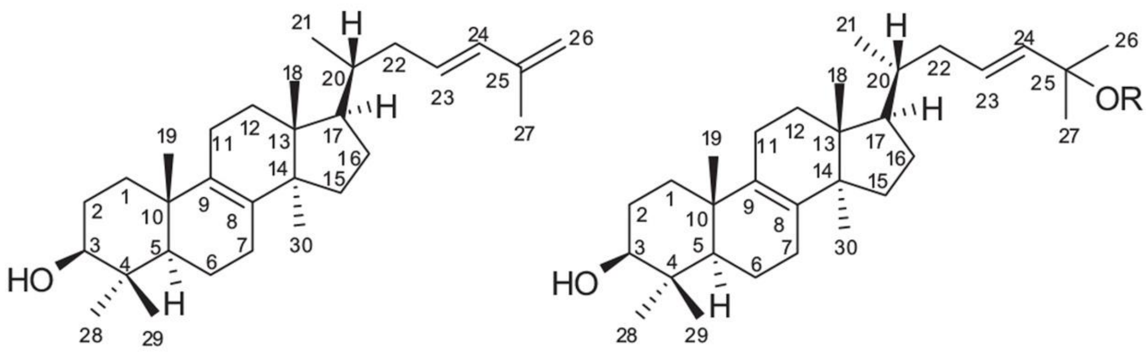
Species of *Scleroderma*	**Media for mycelial growth**	**Reference**
Scleroderma sp.	MMN medium with xylose	Lazarević & Keča (2013)
(JQ685726)	MMN medium with NH_4^+	Lazarević & Keča (2013)
S. sinnamariense	MMN medium	Siri-In et al. (2014)
(CMUS01)	MMN liquid medium	Siri-In et al. (2014)
S. verrucosum (MH13)	MMN medium	Putra et al. (1999)



methyl-3¢,5¢-dichloro-4,4¢-di-O-methylatromentate

Fig. 2 – Structure of pulvinic acid

Scleroderma nitidum has also been reported to produce polysaccharides and glucans with anti-inflammatory potential (Nascimento et al. 2011). Two new lanostane triterpenoids were also isolated from *Scleroderma* UFSMSc1, namely sclerodol A and B (Fig. 3). Lanostanes are a relevant group of lanosterol-derived tetracyclic triterpenoids that possess important biological and pharmacological properties, such as potential anticancer, antimicrobial, anti-inflammatory, and antiviral activities (Morandini et al. 2016).



(1)

(2) R = CH_3
(3) R = H

Fig. 3 – Structures of lanostane-type triterpenes compounds. 1 Sclerodol A. 2 Sclerodol B. and 3 lanostane tripenoid

In general, *Scleroderma* play a significant role in enhancing human well-being and promoting environmental sustainability, despite their economic importance not being firmly established. This is attributed to their ecological functions and potential applications in areas such as bioremediation, agriculture, and medicine.

Ecology and Distribution

Scleroderma is ectomycorrhizal, and establish symbiotic partnerships with plant roots. *Scleroderma* has a worldwide distribution in tropical, subtropical, temperate regions (Siri-In et al. 2014), and boreal areas (Wang et al. 2020), often in association with both deciduous and coniferous trees. However, *Scleroderma* are commonly found from temperate regions in East Asia like Japan, China, and Korea (Wang et al. 2020, Cho et al. 2022) to tropical areas in Southeast Asia, including Thailand, Malaysia, Indonesia, and Vietnam (Naksuwankul et al. 2022, Amira 2018, Turjaman 2018, Truyen & Patacsil 2017). They are also found in South Asia like India, Nepal, and Sri Lanka (Pradhan et al. 2011, Kathmandu 2020) to the Central Asia in Kazakhstan and Uzbekistan (Temreshev 2019, Zoirjon et al. 2023) (Fig. 4).

Fig. 4 – Distribution of *Scleroderma* in Asia

Scleroderma species grow on the soil, forming ectomycorrhizal associations with several trees or shrubs such as Pinaceae (*Abies* and *Pinus*), Betulaceae (*Betula*), Polygonaceae (*Coccoloba*), Myrtaceae (*Eucalyptus*), Nothofagaceae (*Nothofagus*), Salicaceae (*Populus*), and Fagaceae (*Quercus*) (Morris et al. 2008). *Scleroderma* basidiomata are communal in all species, but sometimes they are caespitose or fasciculose and hypogeous or subhypogeous to epigeous in immature stages, such as *S. areolatum*, *S. cepa*, *S. citrinum* and *S. bovista*. However, some species such as *S. columnare*, *S. hypogaeum*, *S. mexicana* and *S. sinnamariense* are associated with Caesalpinaceae, Dipterocarpaceae, or Phyllanthaceae trees (Guzmán et al. 2013).

Several *Scleroderma* species have been recorded in Thailand, some of which are indigenous or were discovered through research (Somrithipol et al. 2022, Sutthikhampa 2023). *Scleroderma* species have been found in various provinces of Thailand including Mukdahan (Yuwa-Amornpitak & Yeunyaw 2020), Chaiyaphum (Chaimongkol & Hanbungkl 2025), especially in Chiang Mai and the Northern regions of Thailand. A total of 11 confirmed *Scleroderma* species have been recorded in Thailand (Chandrasrikul et al. 2011, Kumla et al. 2013) (Table 2).

Table 2 *Scleroderma* species in Thailand.

Species	Province	Reference
Scleroderma areolatum Ehrenb.	Songkhla	Vasun et al. (1998)
Scleroderma bovista Fr.	Chanthaburi	Teerawat et al. (2007), Utis (1999)
Scleroderma cepa Pers.	Unknown	Dissing (1963)
Scleroderma citrinum Pers.	Mae Hong Son, and Songkhla	Anong et al. (2008), Dissing (1963), Ellingsen (1982), Niwat (2010), Teerawat (2002), Utis (1999), Vasun et al. (1998)
Scleroderma dictyosporum Pat.	Chanthaburi	Teerawat et al. (2007)
Scleroderma flavidum Ellis & Everh.	Chanthaburi	Anong et al. (2008), Teerawat et al. (2007)
Scleroderma lycoperdoides Schwein.	Sisaket	Chalermpongs (1992)
Scleroderma polyrhizum (J.F. Gmel.) Pers.	Phetchabun	Anong et al. (2008), Niwat (2010)
Scleroderma sinnamariense Mont.	Chiang Mai	Ellingsen (1982), Kittima et al. (2008), Niwat (2010), Ruksawong (2001), Wanida (1999)
Scleroderma suthepense Kumla, Suwannar. & Lumyong	Chiang Mai	Kumla et al. (2013)
Scleroderma verrucosum (Bull.) Pers.	Songkhla, and Chiang Mai	Anong et al. (2008), Teerawat et al. (2007)

Taxonomy

Scleroderma has received many other common names, such as ‘earthball’ and ‘poison pigskin puffball’. Numerous *Scleroderma* species have been proposed, based on the physical traits of their basidiomes and basidiospores (Sims et al. 1995, Guzmán et al. 2013, Kumla et al. 2013). The listed taxa are documented in Thailand, with their descriptions drawn from various sources.

Scleroderma Pers., Syn. meth. fung. (Göttingen) 1: xiv, 150 (1801)
Synonymy:
=*Actigea* Raf., Précis Découv. Trav. Somiologiques Palermo: 52 (1814)
=*Actinodermium* Nees, Syst. Pilze (Würzburg): 135 (1816) [1816-17]
=*Caloderma* Petri, Malpighia 14: 136 (1900)
=*Goupilia* Mérat, Nouv. Fl. Environs Paris, Edn 3 1: 91 (1834)
=*Lycoperdastrum* P. Micheli, Nov. pl. gen. (Florentiae): 219, tab. 99 (1729)
=*Mycastrum* Raf., Ann. Bot. (Desvaux) 1: 236 (1813)
=*Neosaccardia* Mattir., Annali Fac. Med. vet. Torino 56: 32 (1921)
=*Nepotatus* Lloyd, Mycol. Writ. 7(Letter 75): 1355 (1925)
=*Phlyctospora* Corda, in Sturm, Deutschl. Fl., 3 Abt. (Pilze Deutschl.) [7](19-20): 51 (1841)
=*Pirogaster* Henn., Hedwigia 40(Beibl.): (27) (1901)
=*Pompholyx* Corda, in Sturm, Deutschl. Fl., 3 Abt. (Pilze Deutschl.) 3(12): 51 (1834)
=*Sclerangium* Lév., Annls Sci. Nat., Bot., sér. 3 9: 130 (1848)
=*Stella* Massee, J. Mycol. 5(4): 185 (1889)
=*Sterrebekia* Link, Mag. Gesell. naturf. Freunde, Berlin 8: 44 (1816) [1815]
=*Veligaster* Guzmán, Mycologia 61(6): 1117 (1970) [1969]

The following description is from Guzmán et al. (2013), with few adaptations to modern terminology.

Basidiome with a massive, compact basal mass of mycelium, globose, subglobose, pyriform, sessile, pseudostipitate, or with a well-developed stipe, leathery to very hard when dry. Exoperidium, which develops by the basidiome growth that tears and digests hyphae, has dry, thin, silky smooth cracked, scaly, or wrapped with small to large scales, constantly with a membranaceous wrap on the base of the globose basidiome or in the upper portion of the stipe, and occasionally at/on the apex of the basidiome. The endoperidium is thin and the gleba is protected by a membrane. Frequently rufescent exoperidium and endoperidium both. White, soon purple or dark greyish-brown or reddish-brown, at first with tramal plates, later with thin whitish or yellowish filaments, Gleba subfleshy to leathery, compact, ultimately dusty. Dehiscence through an irregularly lacerated apical pore or by breaking the apical portion of the basidiome. Hymenium undeveloped. Absent of capillitium. When immature, basidiospores are subglobose, seamless, with a visible apiculus, echinulated or subreticulated to reticulated, and have a thick wall. Basidia are pyriform, 4-6(-8) spored, thin- or thick-walled, hyaline, and release their basidiospores early when they are still juvenile. Taste and smell are generally harsh and rubbery.

Habitat – On soil, ectomycorrhizal, epigeous or hypogeous fern stipes, and occasionally rotting wood. tropical, subtropical, and temperate species.

Scleroderma areolatum Ehrenb., Sylv. mycol. berol. (Berlin): 27 (1818) Fig. 5a

The following description is from Nouhra et al. (2012), with few adaptations to modern terminology.

Basidiome 2-4 cm diam, subglobose to pyriform, rounded on the top, sessile, or with a short pseudostipe, rhizomorphs accumulate at of the base basidiocarp. Surface smooth, and the apical section of the brown polygonal scales are clearly dark. When peridium is stretchy at immature, it becomes yellowish white and then becomes paler as it ages. Some specimens are clearly yellow. Dehiscence occurs when the top section ruptures or an uneven apical whole form. Fresh peridium is 800-1000 mm thick, divided into two layers; exoperideium is thin and discontinuous. With KOH, the thin-walled, intertwined, brownish to hyaline hyphae in the upper layer change colour from yellow to reddish brown. The endoperidium is an 8 m wide, thick-walled, pseudoparenchymatic structure made of hyaline hyphae. Basidia none observed. At maturity, gleba becomes powdery, brownish violet to dark olivaceous, and has many trama veins that are yellowish. Basidiospore globose, yellowish brown in KOH, echinulate, densely packed, (10–)11–16(–17) μm diam ornamentation.

Habitat – On soil, growing under *Pinus radiata*, *P. elliottii*, *Cedrus* sp., *Quercus* sp. and *Betula* sp.

Scleroderma bovista Fr., Syst. Mycol. (Lundae) 3(1): 48 (1829) Fig. 5b

Synonymy:

= *Scleroderma verrucosum* subsp. *bovista* (Fr.) Šebek, Sydowia 7(1-4): 177 (1953)

= *Scleroderma verrucosum* var. *bovista* (Fr.) Šebek, Fl. ČSR, B-1, Gasteromycetes: 570 (1958)

= *Tuber fuscum* Corda, Icon. fung. (Prague) 1: 25 (1837)

= *Scleroderma fuscum* (Corda) E. Fisch., in Engler & Prantl, Nat. Pflanzenfam., Teil. I (Leipzig) 1(1**): 336 (1898)

= *Scleroderma lycoperdoides* var. *reticulatum* Coker & Couch, Gasteromycetes E. U.S. Canada (Chapel Hill): 170 (1928)

= *Scleroderma citrinum* var. *reticulatum* (Coker & Couch) Guzmán, Ciencia Méx. 25: 204 (1967)

The following description is from Nouhra et al. (2012) and Siri-In et al. (2014), with few adaptations to modern terminology.

Basidiome 2–7 cm globose to subglobose, accumulating soil particles in a brief basal cluster. Near the top, the surface is smooth, scaly, or finely fractured; the scales are up to 3 mm large and uneven in shape. The peridium is rather stretchy when fresh, whitish to light brown or pale yellowish brown, with cracking of the upper surface. Gleba greyish green with yellowish trama veins that become powdery at maturity constituted by spores, nurse cells, and clamped hyphae. Basidia none observed. Basidiospore globose, dark yellowish brown in KOH, reticulate with spines, (11–)12–14(–16) mm diam, including ornamentation.

Habitat – On soil, growing under *Pinus radiata*, *P. elliottii*, *Cedrus* sp., *Quercus* sp. and *Betula* sp.

Scleroderma cepa Pers., Syn. meth. fung. (Göttingen) 1: 155 (1801) Fig. 5c

Synonymy:
=*Scleroderma cepa* var. *erythraeum* Sacc., Malpighia 23: 233 (1916)
=*Scleroderma cepioides* Gray, Nat. Arr. Brit. Pl. (London) 1: 582 (1821)
=*Scleroderma verrucosum* var. *cepa* (Pers.) Maire, Treb. Mus. Ciènc. nat. Barcelona, sér. bot. 15(no. 2): 112 (1933)
=*Scleroderma vulgare* var. *cepa* (Pers.) W.G. Sm., Syn. Brit. Basidiomyc.: 480 (1908)

The following description is from Guzmán et al. (2013), with few adaptations to modern terminology.

Basidiomes 2–3 cm in diam, globose or subpyriform, sessile, or pseudostipitate. Exoperidium 1–2 mm thick white, whitish or yellowish to orangish-yellow, smooth to coarsely cracked. Endoperidium is whitish to yellowish. Stellate dehiscence with 6–8 lobes or through an unpredictably shaped fissure in the upper peridium. Gleba white to violaceous brown, typically rubescent in context. Occasionally has a rubbery smell and flavour. Clamp connections absent. Basidia 18–25 x 8.5–10 μm, with 4 sterigmata, pyriform, and hyaline. Basidiospores (7–) 8-13 (–14) μm diam., echinulated, spines 1–2 μm high. Hyphae of the endoperidium 3–7 (–10) μm wide, thin-walled.

Habitat – On the ground, in gardens and parks as well as in *Quercus*, Pinus-*Quercus*, or mesophytic forests.

Scleroderma citrinum Pers., Syn. meth. fung. (Göttingen) 1: 153 (1801) Fig. 5d

Synonymy:
= *Scleroderma aurantiacum* sensu Carleton Rea (1922), Ramsbottom (1953), non-Linnaeus (Sp. Pl., 1753); fide Checklist of Basidiomycota of Great Britain and Ireland (2005)
= *Scleroderma aurantium* sensu auct.; fide Checklist of Basidiomycota of Great Britain and Ireland (2005)
= *Lycoperdon aurantium* sensu auct.; fide Checklist of Basidiomycota of Great Britain and Ireland (2005)
= *Scleroderma vulgare* Hornem., Fl. Danic. 10: tab. 1969, fig. 2 (1819)
= *Scleroderma vulgare* var. *macrorhizum* Fr., Syst. mycol. (Lundae) 3(1): 47 (1829)
= *Scleroderma macrorhizum* (Fr.) Wallr., Fl. crypt. Germ. (Norimbergae) 2: 404 (1833)
Scleroderma aurantium var. *macrorhizum* (Fr.) Šebek [as 'macrorrhizum'], Sydowia 7(1-4): 170 (1953)
= *Scleroderma vulgare* subsp. macrorrhizon (Wallr.) Sacc. [as 'macrorhizon'], in Berlese, De Toni & Fischer, Syll. fung. (Abellini) 7(1): 135 (1888)
= *Scleroderma vulgare* var. *novoguineense* Henn., Bot. Jb. 18(4 (Beibl. 44)): 37 (1894)
= *Scleroderma vulgare* var. bogoriense Henn. & E. Nyman, in Hennings in Warburg, Monsunia 1: 159 (1899)
= *Scleroderma vulgare* var. *aurantiacum* Bull. ex W.G. Sm., Syn. Brit. Basidiomyc.: 480 (1908)
= *Scleroderma aurantium* var. *aurantiacum* (Bull. ex W.G. Sm.) Rea, Brit. basidiomyc. (Cambridge): 49 (1922)

Common name:
= Pigskin poison puffball

The following description is from Anong et al. (2008) and Soytong et al. (2014), with few adaptations to modern terminology.

Basidiomes approximately 2−6 cm across, high 2−3 cm, nearly round when young, depressed at maturity, yellow brown, covered with tough raised warts which may have centre darker brown, thick rind, white, spitted into irregular lobes in age, the mass of the spore white, solid and firm, soon becoming marble and publishing black spores out, then the gleba powdery at maturity. Clamp connections none observed. Basidia none observed. Basidiospore 8−12 µm, round, with fine spines and netlike ridges, spore print blackish brown.

Habitat – single to many on the ground near stumps and logs of deciduous trees or on soil, associated with pine forest (*Quercus*), ectomycorrhiza.

Edibility – inedible, bitter poisonous.

Scleroderma dictyosporum Pat., Bull. Soc. mycol. Fr. 12(3): 135 (1896)

The following description is from Teerawat et al. (2007), with few adaptations to modern terminology.

Basidiomes 7-12 mm in diam, ovoid, rooted at the base by an abundance of white branching rhizomorphs, and covered in irregular brown granular warts 0.2 mm in diam.
Peridium is 0.5 mm thick, delicate, yellowish white, and rippling. Dark greyish brown gleba. Basidiospores are 7-8.5 m in diam, globose, extremely coarsely pustulate-reticulate and brown in colour.

Habitat – Solitary on soil.

Scleroderma flavidum Ellis & Everh., J. Mycol. 1(7): 88 (1885) Fig. 5e

Synonymy:
= *Actigea multifida* Raf., Précis Découv. Trav. Somiologiques (Palermo): 52 (1814)
= *Scleroderma flavidum* f. multifidum (Raf.) De Toni, in Berlese, De Toni & Fischer, Syll. fung. (Abellini) 7(1): 139 (1888)
= *Scleroderma flavidum* var. *fenestratum* Cleland, Trans. Roy. Soc. S. Australia 47: 75 (1923)

The following description is from Anong et al. (2008), with few adaptations to modern terminology.

Basidomes approximately 2−5 cm, pear-shaped to nearly round, golden yellow, cracked above and on the sides into small to large with brownish scales, apex rupturing at maturity, peridium tough, thin, open irregularly, soil, attached by yellow threads and joined into a yellow stalk-like base. Clamp connections none observed. Basidia none observed. Basidiospore 7−10 µm round, with 1−2 µm long spines, spore print purple black.

Habitat – single or group on bare soil, lawn, parks.

Edibility – edible when young.

Scleroderma lycoperdoides Schwein., Schr. naturf. Ges. Leipzig 1: 61 [35 of repr.] (1822)
Synonymy:
= *Bovistella lycoperdoides* (Schwein.) Lloyd, mycol. writ. (Cincinnati) 2(Letter 23): 280 (1906)

Fig. 5f

The following description is from Coker & John (1974), with few adaptations to modern terminology.

The appearance of the basidiome surface is about the same as in the strain, from which it differs in that the mature spore mass is clearly olive in colour, that the spores are firmly reticulated rather than just spiny and that the root is more fragile and less large. Although the colour may be slightly deeper and the markings may be less obvious than is typical for the species, these traits are too variable to be highlighted. The difference in basidiospore and the colour of greba are highly distinct, and the latter is readily visible at moderate magnification. The bright golden olivaceous matrix remains when the black olivaceous spores are shook out. Spherical, 10–13 µm long, highly reticulate, and spiky spores.

Habitat – open woodlands' moist sand.

Scleroderma polyrhizum (J.F. Gmel.) Pers., Syn. meth. fung. (Göttingen) 1: 156 (1801) Fig. 5g
Synonymy:
= *Lycoperdon polyrhizum* J.F. Gmel. [as 'polyrhizon'], Syst. Nat., Edn 13 2: 1464 (1792)

= *Sclerangium polyrhizum* (J.F. Gmel.) Lév. [as 'polyrhiza'], Annls Sci. Nat., Bot., sér. 3 9: 130 (1848)
= *Actigea sicula* Raf., Précis Découv. Trav. Somiologiques (Palermo): 52 (1814)
= *Scleroderma geaster* var. *siculum* (Raf.) Sacc., in Berlese, De Toni & Fischer, Syll. fung. (Abellini) 7(1): 139 (1888)
= *Scleroderma geaster* Fr., Syst. mycol. (Lundae) 3(1): 46 (1829)
= *Sclerangium geaster* (Fr.) Lév., Annls Sci. Nat., Bot., sér. 3 9: 131 (1848)
= *Scleroderma geaster* var. *socotranum* Henn., Bull. Herb. Boissier 1: 100 (1893)
= *Scleroderma primigenium* Bianchi, Bollettino della Società naturalisti 'Silvia Zenari' 12(no. 58): 35 (1986)

The following description is from Anong et al. (2008), with few adaptations to modern terminology.

Basidiomes 3−6 cm, round, sometimes irregularly lobed. Peridium thick 1−2 mm, brownish, surface roughened or cracked to scale with age, tough, eventually splitting into star-shaped rays. Endoperidium is thin, brownish, becomes blackened, and becomes empty in age. Clamp connections present. Basidia none observed. Basidiospores 7−12 µm, round, warted, spore print purple brown.

Habitat – On sandy soils in pine forest.

Edibility – Edible when young.

Scleroderma sinnamariense Mont., Annls Sci. Nat., Bot., sér. 2 14: 331 (1840) Fig. 5h

The following description is from Ruksawong (2001) and Siri-In et al. (2014), with few adaptations to modern terminology.

Basidiomes 8−10 cm hemispherical or subglobal. Exoperidium thick when fresh, leathery, verrucose, yellowish to lemon-yellow, and brown to dark scales. Endoperidium thin, yellowish. Sessile, rhizoid, white gleba when young become dark brown to back at maturity and pulverulent. Clamp connections present. Basidia none observed. Basidiospores 7−9 µm, globose to subglobose with short spines.

Habitat – On sandy soils in pine forest.

Edibility – No report of it being edible.

Scleroderma suthepense Kumla, Suwannar. & Lumyong, Mycotaxon 123: 2 (2013) Fig. 5i

The following description is from Kumla et al. (2013), with few adaptations to modern terminology.

Basidiomes globose or subglobose 1.1−3.5 cm in diam., 1.0−3.9 cm high, well-developed rhizomorphs, white to yellow, 0.5−1.2 cm long. Peridium 0.5−1.0 mm thick when fresh, leathery, partially smooth surface with scattered, small, and thin scales, greyish yellow to greyish brown, consisting of two layers. The exoperidium consists of cylindrical, thick-walled, yellowish to brown hypha up to 8.0 µm diam, with scattered clamp connections, turning reddish brown with KOH. The endoperidium consists of cylindrical, thick-walled, hyaline hyphae up to 6.0 µm diam, with clamp connections. Gleba when mature is dark greyish brown on the back and pulverulent. Basidia none observed. Basidiospores globose to subglobose, strongly reticulate with spines, 8.0−13.0 µm in diam. including ornamentation, spine 1.0−2.5 µm in length, dark yellowish brown in water or KOH, and not changing in Melzer's reagent.

Habitat – Terrestrial on sandy loam, under Prunus cerasoides in a dipterocarp forest.

Scleroderma verrucosum (Bull.) Pers., Syn. meth. fung. (Göttingen) 1: 154 (1801) Fig. 5j

Synonymy:
= *Lycoperdon verrucosum* Bull., Hist. Champ. Fr. (Paris) 1(1): 157 (1791)
= *Lycoperdon defossum* sensu Sowerby; fide Checklist of Basidiomycota of Great Britain and Ireland (2005)
= *Scleroderma verrucosum* var. *maculatum* Peck, Ann. Rep. Reg. N.Y. St. Mus. 53: 848 (1901)
= *Scleroderma cepa* var. *maculatum* (Peck) Lloyd, Mycol. Writ. (Cincinnati) 6(Letter 63): 950 (1920)
= *Scleroderma maculatum* (Peck) Lloyd, Mycol. Writ. (Cincinnati) 6(Letter 65): 1058 (1920)

= *Scleroderma verrucosum* var. *fascirhizum* Šebek, Sydowia 7(1-4): 179 (1953)
= *Scleroderma verrucosum* var. *violascens* Herink, Sydowia 7(1-4): 176 (1953)
= *Scleroderma verrucosum* var. *angustistipitatum* Dissing & M. Lange, Bull. Jard. bot. État Brux. 32: 394 (1962)

The following description is from Anong et al. (2008), with few adaptations to modern terminology.

Basidiome 5−10 cm, round, shortly pseudostipitate. Peridium thin, with scales, irregularly spitted apex, yellowish pale brown to brown, with stalk like base 3−8 cm, concolored with basidiome, attached to the ground by root-like threads. Basidiospores 8−10 μm, round, short spines, spore print purple brown.

Habitat – Gregarious on the ground in the woods, ectomycorrhiza.

Edibility – Edible when young.

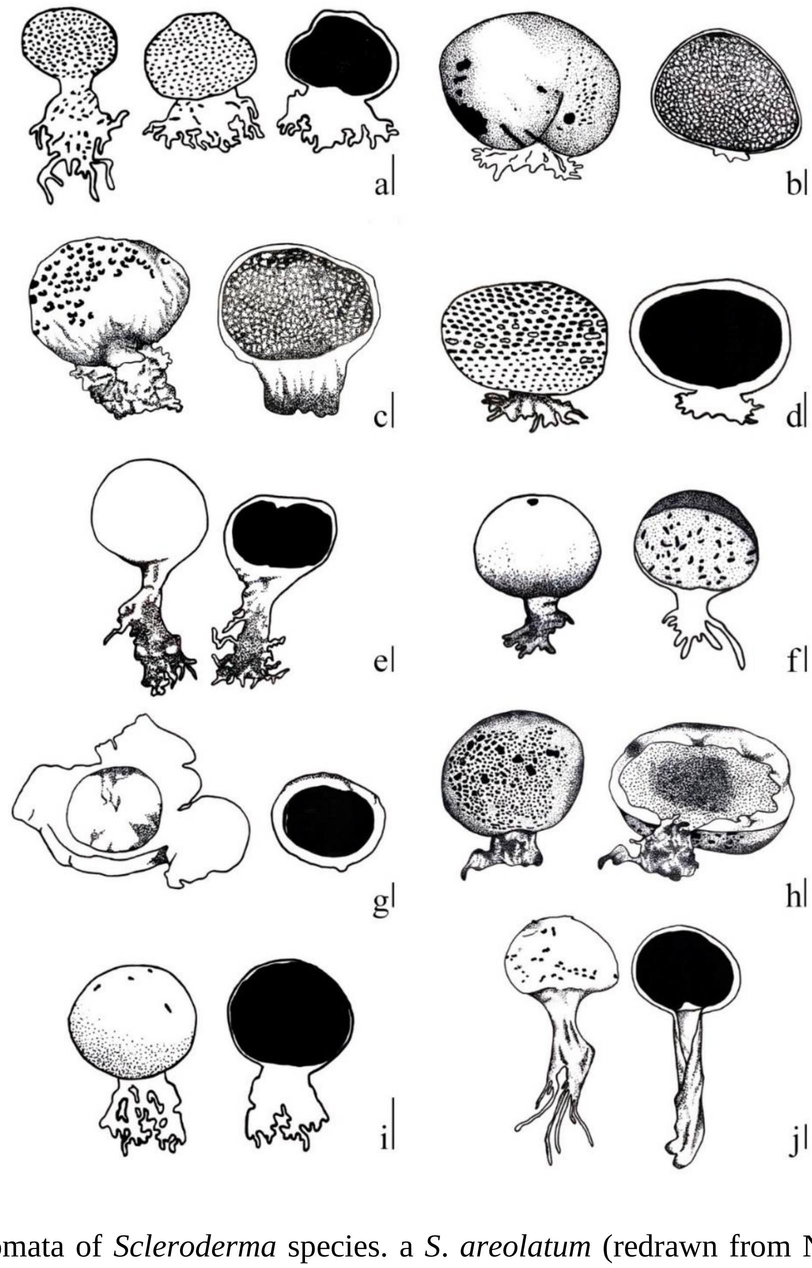


Fig. 5 – Basidiomata of *Scleroderma* species. a *S. areolatum* (redrawn from Nouhra et al. 2012). B *S. bovista* (redrawn from Nouhra et al. 2012). c *S. cepa* (redrawn from Guzmán et al. 2013). D *S. citrinum* (redrawn from Anong et al. 2008). e, *S. flavidum* (redrawn from Anong et al. 2008). f *S. lycoperdoides* (redrawn from Coker & John 1974). g, *S. polyrhizum* (redrawn from Anong et al. 2008). h, *S. sinnamariense* (redrawn from Ruksawong 2001). i, *S. suthepense* (redrawn from Kumla et al. 2013). j. *S. verrucosum* (redrawn from Anong et al. 2008). Scale bars = 1 cm.

The majority of *Scleroderma* species have historically been identified and classified according to their macroscopic characteristics (Jeffries 1999). However, due to morphological similarities within the genus, phylogenetic analysis has been used (Sims et al. 1999, Wilson et al. 2012). Wilson et al. (2012) determined the phylogenetic relationships of S*cleroderma* species and examined their evolutionary patterns. Molecular studies of *Scleroderma* have used rDNA regions, such as the internal transcribed spacer (ITS), large subunit (LSU), and small subunit (SSU) (Money 2016, Surawut et al. 2023). However, specific molecular studies on *Scleroderma* in Thailand remain limited. *Scleroderma suthepense* and *Scleroderma sinnamariense* have been found to be closely related to other species within the *Scleroderma* genus based on ITS sequences (Kumla et al. 2013, Siri-in et al. 2014).

Perspectives

To date, eleven species of *Scleroderma* have been recorded in Thailand. However, comprehensive studies on the bioactive properties of *Scleroderma* species remain limited, and research on its cultivation in Thailand is scarce, as the edibility of this mushroom has not been extensively studied. The taxonomy of *Scleroderma* species in Thailand is still underexplored, highlighting the need for more detailed molecular studies to accurately distinguish and classify species. Further research on both the taxonomy and bioactive properties of *Scleroderma* in Thailand is crucial to assess its potential as a source of bioactive compounds. Additionally, improving cultivation methods is essential to establish a sustainable supply of bioactive compounds from these species for future applications.

Acknowledgements

The authors appreciate the kind support by the Research and Researchers Industries (RRI) (Grant no. PHD62I0018/2562).

References

Amira P. 2018 – Diversity of gasteromycetes and taxonomic studies of Lycoperdaceae and Geastraceae in Peninsular Malaysia/Amira Peli (Doctoral dissertation, University of Malaya).

Anong C, Suwanarit P, Sangwanit U. 2008 – Diversity of mushrooms and macrofungi in Thailand.

Binder M, Bresinsky A. 2002 – Derivation of a polymorphic lineage of Gasteromycetes from boletoid ancestors. Mycologia 94(1).

Binder M, Hibbett DS. 2006 – Molecular systematics and biological diversification of Boletales. Mycologia 98(6).

Bradshaw B. 2000 – Salinity Tolerance of Selected Ectomycorrhizal Fungi (*Pisolithus tinctorius* Pers.) and Ectomycorrhizal Eucalypts.

Chaimongkol S, Hanbungkl S. 2025 – The investigation of mushroom poisoning outbreak in Ban Hnong Nok Ok, Nong Bua Daeng Subdistrict, Nong Bua Daeng District, Chaiyaphum Province.

Chalermpongs A. 1992 – Biodiversity of ectomycorrizal fungi in the dipterocarp forests of Thailand. Tsukuba-Workshop of Bio-Reform. May 19-21,1992, Tsukuba, Japan, 143–153.

Chandrasrikul A, Suwanarit P, Sangwanit U, Lumyong S et al. 2011 – Checklist of Mushrooms (Basidiomycetes) in Thailand. 488.

Chen Y. 2006 – Optimisation of *Scleroderma* spores inoculum for eucalyptus nurseries in China. Biological Science, Murdoch University. Perth-Western, Australia, 201.

Cho SE, Kwag YN, Han SK, Lee DH et al. 2022 – Two New Records of *Scleroderma* Species (Sclerodermataceae, Boletales) in South Korea. The Korean Journal of Mycology 50, 116.

Christensen M, Bhattarai S, Devkota S, Larsen HO. 2008 – Collection and use of wild edible fungi in Nepal. Economic Botany 62(1).

Coker WC, John NC. 1974 – The Gasteromycetes of the eastern United States and Canada. Courier Corporation.

Cortez VG, Baseia IG, da Silveira RMB. 2011 – Gasteroid mycobiota of Rio Grande do Sul State, Brazil: Boletales. Journal of Yeast and Fungal Research 2(4).
Dell B, Malajczuk N, Dunstan WA. 2002 – Persistence of some Australian *Pisolithus* species introduced into eucalypt plantations in China. Forest Ecology and Management 163(3), 271–281.
Dissing H. 1963 – Studies in the flora of Thailand, 25. Discomycetes and Gasteromycetes. Dansk Botanisk Arkiv 23, 117–130.
Ellingsen HJ. 1982 – Some Gasteromycetes from Northern Thailand. Nordic Journal of Botany 2, 283–285.
Entwistle N, Pratt AD. 1968 – 23ξ-hydroxy-lanosterol. A new triterpene fungal metabolite of the basidiomycete *Scleroderma aurantium* pers. Tetrahedron 24(10).
Entwistle N, Pratt AD. 1969 – The determination of the absolute configuration at C23 in 23-hydroxylanosterol. A triterpene fungal metabolite of the Basidiomycete *Scleroderma aurantium* pers-and its C23 epimer. Tetrahedron 25(7).
Farmer DJ, Sylvia DM. 1998 – Variation in the ribosomal DNA internal transcribed spacer of a diverse collection of ectomycorrhizal fungi. Mycological Research 102(7).
Guzmán G, Cortés-Pérez A, Guzmán-Dávalos L, Ramírez-Guillén F. 2013 – An emendation of *Scleroderma*, new records, and review of the known species in Mexico. Revista Mexicana de Biodiversidad 84, 173–191.
Guzmán G, Ovrebo CL. 2000 – New observations on Sclerodermataceous fungi. Mycologia 92(1).
Hall IR, Stephenson SL, Buchanan PK. 2003 – Edible and poisonous mushrooms of the world. Timber Press.
He MQ, Zhao RL, Hyde KD, Begerow D et al. 2019 – Notes, outline and divergence times of Basidiomycota. Fungal diversity 99, 105–367.
Hughey BD, Adams GC, Bruns TD, Hibbett DS. 2000 – Phylogeny of *Calostoma*, the gelatinous-stalked puffball, based on nuclear and mitochondrial ribosomal DNA sequences. Mycologia 92(1).
Ingleby K, Last FT, Mason PA. 1985 – Vertical distribution and temperature relations of sheathing mycorrhizas of Betula spp. growing on coal spoil. Forest Ecology and Management 12(3–4), 279–285.
Jeffries P. 1999 – *Scleroderma*. In Ectomycorrhizal fungi key genera in profile. Berlin, Heidelberg: Springer Berlin Heidelberg, 187–200.
Kaaronen RO. 2020 – Mycological rationality: Heuristics, perception and decision-making in mushroom foraging. Judgment and Decision Making 15(5), 630–647.
Kathmandu N. 2020 – *Scleroderma nastii* sp. nov., a gasteroid mushroom from Phulchoki hill, Nepal.
Kittima D, Winantha H, Janjira A. 2008 – Diversity of mycorrhizal fungi in the forest ecosystem in Chiang Dao Wildlife Conservation.
Kour H, Kour D, Kour S, Singh S et al. 2022 – Bioactive compounds from mushrooms: an emerging bioresources of food and nutraceuticals. Food Bioscience 50, 102124.
Kumla J, Suwannarach N, Bussaban B, Lumyong S. 2013 – *Scleroderma suthepense*, a new ectomycorrhizal fungus from Thailand. Mycotaxon 123(1), 1–7.
Lazarević J, Keča N. 2013 – In vitro cultivation of mycelium of ectomycorrhizal fungi: *Pisolithus arhizus* and *Scleroderma* sp. Mycologia Montenegrina 16, 95–105.
Li H, Tian Y, Menolli N, Ye L et al. 2021 – Reviewing the world's edible mushroom species: A new evidence-based classification system. In Comprehensive Reviews in Food Science and Food Safety 20(2), 1982–2014.
Liu B. 1984 – The Gasteromycetes of China. Beihefte Zur Nova Hedwigia 76.
Louzan R, Wilson AW, Binder M, Hibbett DS. 2007 – Phylogenetic placement of *Diplocystis wrightii* in the Sclerodermatineae (Boletales) based on nuclear ribosomal large subunit DNA sequences. Mycoscience 48(1), 66–9.
McIlvaine C, RK Macadam. 1902 – One Thousand American Fungi. Bowen-Merrill, Indianapolis. (Reprinted in1973 by Dover Publications, New York).

Menezes Filho ACP, Ventura MVA, Alves I, Taques AS et al. 2022 – Phytochemical prospection, total flavonoids and total phenolic and antioxidant activity of the mushroom extract *Scleroderma verrucosum* (Bull.) Pers. Brazilian Journal of Science 1(1), 1–7.

Money NP. 2016 – Fungal diversity. In The fungi. Academic Press, 1–36.

Morandini LMB, Neto AT, Pedroso M, Antoniolli ZI et al. 2016 – Lanostane-type triterpenes from the fungal endophyte *Scleroderma* UFSMSc1 (Persoon) Fries. Bioorganic and Medicinal Chemistry Letters 26(4), 1173–1176.

Morris MH, Pérez-Pérez MA, Smith ME, Bledsoe CS. 2008 – Multiple species of ectomycorrhizal fungi are frequently detected on individual oak root tips in a tropical cloud forest. Mycorrhiza 18, 375–383.

Naksuwankul K, Thongbor A, Chantharasena C, Khottawong W et al. 2022 – Identification by Morphological and Local Wisdom and Distribution of Poisonous and Edible Mushroom in Thailand. Burapha Science Journal, 66–84.

Nascimento MS, Magalhães JEM, Pinheiro TS, Silva TA et al. 2011 – Polysaccharides from the fungus *Scleroderma nitidum* with anti-infl ammatory potential modulate cytokine levels and the expression of nuclear factor KB. Revista Brasileira de Farmacognosia 22(1), 60–68.

Niwat S. 2010 – Wild Mushrooms of Thailand: Biodiversity and Utilization. Khon Kaen University, 424.

Nouhra ER, Hernández Caffot ML, Pastor N, Crespo EM. 2012 – The species of *Scleroderma* from Argentina, including a new species from the Nothofagus forest. Mycologia 104(2), 488–495.

Pradhan P, Dutta AK, Roy A, Acharya K. 2011 – Boletales of West Bengal, India. I. Sclerodermataceae: *Pisolithus* and *Scleroderma*.

Puengpholpool P, Wisitphonkul I, Jaikla T, Boonsukmark S. 2023 – Mushroom Poisoning. Nonthaburi: Department of Disease Control (TH).

Putra PM, Berredjem A, Chalot M, Dell B et al. 1999 – Growth characteristics, nitrogen uptake and enzyme activities of the nitrate-utilising ectomycorrhizal *Scleroderma verrucosum*. Mycological Research 103(8), 997–1002.

Rasalanavho M, Moodley R, Jonnalagadda SB. 2019 – Elemental distribution including toxic elements in edible and inedible wild growing mushrooms from South Africa. Environmental Science and Pollution Research 26(8), 7913–7925.

Ruksawong P. 2001 – Thai mushroom and other fungi. National Science and Technology Development Agency 252.

Sanon KB, Bâ AM, Delaruelle C, Duponnois R et al. 2009 – Morphological and molecular analyses in *Scleroderma* species associated with some *Caesalpinioid legumes*, Dipterocarpaceae and Phyllanthaceae trees in southern Burkina Faso. Mycorrhiza 19, 571–584.

Sanon KB, Bâ AM, Dexheimer J. 1997 – Mycorrhizal status of some fungi fruiting beneath indigenous trees in Burkina Faso. Forest Ecology and Management 98(1), 61–69.

Schmid R, Bresinsky A, Besl H. 1992 – A Colour Atlas of Poisonous Fungi: A Handbook for Pharmacists, Doctors, and Biologists. Taxon 41(1).

Sims K, Watling R, De La Cruz R, Jeffries P. 1997 – Ectomycorrhizal fungi of the Philippines: A preliminary survey and notes on the geographic biodiversity of the Sclerodermatales. Biodiversity and Conservation 6(1), 43–58.

Sims KP, Watling R, Jeffries P. 1995 – A revised key to the genus *Scleroderma*. Mycotaxon 56, 403–420.

Sims PK, Sen R, Watling R, Jeffries P. 1999 – Species and population structures of *Pisolithus* and *Scleroderma* identified by combined phenotypic and genomic marker analysis. Mycological Research 103(4), 449–458.

Siri-In J, Kumla J, Suwannarach N, Lumyong S. 2014 – Culture conditions and some properties of pure culture of ectomycorrhizal fungus, *Scleroderma sinnamariense*. Chiang Mai Journal of Science 41(2), 275–285.

Somrithipol S, Pinruan U, Sommai S, Khamsuntorn P et al. 2022 – Mushroom poisoning in Thailand between 2003 and 2017. Mycoscience 63(6), 267–273.

Soytong K, Sibounnavong P, Kanokmedhakul K, Kanokmedhakul S. 2014 – Biological active compounds of *Scleroderma citrinum* that inhibit plant pathogenic fungi, 79–86.
Surawut S, Kunsook C, Nak-eiam S, Khamchatra NM et al. 2023 – Biodiversity and Functional Distribution of Macrofungi from Plant Genetic Conservation Area, Chanthaburi Province, Thailand. Current Applied Science and Technology, 10–55003.
Sutthikhampa S. 2023 – Species Diversity of Mushrooms in Faculty of Science, Ubon Ratchathani University. Journal of Science and Science Education 6(1).
Teerawat B, Yosanan P, Arunee W. 2007 – Mushroom diversity in the eastern region. Biodiversity Conference on Forests and Wildlife. Department of National Parks, Wildlife and Plant.
Teerawat B. 2002 – Edible mushrooms and poisonous mushrooms in Thailand. Royal Institute Journal 27(4), 1151–1164.
Temreshev II. 2019 – Hairy Fungus beetles (Coleoptera, Mycetophagidae) of the Almaty oblast (Sout-East Kazakhstan). Acta Biologica Sibirica 5(1), 63–70.
Truyen DM, Patacsil FF. 2017 – Survey the composition and distribution of fungi species in the natural reserve Wetland Lung Ngoc Hoang, Vietnam. Journal of Advances in Technology and Engineering Research 3(1), 19–26.
Turjaman M. 2018 – Pemanfaatan Fungi Ektomikoriza di Hutan Tropis Indonesia. In Prosiding Seminar Nasional Mikoriza, 17–32.
Utis K 1999 – Ecology fundamental basics in forestry.
Van Der Sar SA, Blunt JW, Cole ALJ, Din LB et al. 2005 – Dichlorinated pulvinic acid derivative from a Malaysian *Scleroderma* sp. Journal of Natural Products 68(12), 1799–1801.
Vasun P, Preecha K, Aniwat C. 1998 – Survey, collecting mushrooms in Ton Nga Chang Wildlife Conservation and nearby areas. In the Report on Research on Biodiversity in Thailand. Biodiversity Research and Training Program- BRT.
Velíšek J, Cejpek K. 2011 – Pigments of higher fungi: A review. In Czech Journal of Food Sciences 29(2), 87–102.
Wang X, Liu P, Yu F. 2004 – Color atlas of wild commercial mushrooms in Yunnan. Yunnan Science and Technology Press, Kunming 98.
Wang Y, Yu FQ, Zhang C, Liu C et al. 2020 – Edible ectomycorrhizal fungi and their cultivation in China. In Mushrooms, Humans and Nature in a Changing World: Perspectives from Ecological, Agricultural and Social Sciences, 31–60.
Wanida P. 1999 – Diversity of mushrooms growing on the ground in the rain forest in Doi Suthep-Pui National Park, Chiang Mai Province [Master of Science Thesis]. Chiang Mai University.
Watling R. 2006 – The sclerodermatoid fungi. In Mycoscience 47(1), 18–24.
Wilson AW, Binder M, Hibbett DS. 2012 – Diversity and evolution of ectomycorrhizal host associations in the Sclerodermatineae (Boletales, Basidiomycota). New Phytologist 194(4), 1079–1095.
Winner M, Giménez A, Schmidt H, Sontag B et al. 2004 – Unusual pulvinic acid dimers from the common fungi *Scleroderma citrinum* (common earthball) and *Chalciporus piperatus* (peppery bolete). Angewandte Chemie - International Edition 43(14), 1883–1886.
Wu R, Zhou L, Qu H, Ge ZW. 2023 – Updates on *Scleroderma*: Four New Species of Section *Scleroderma* from Southwestern China. Diversity 15(6), 775.
Yuwa-Amornpitak T, Yeunyaw PN. 2020 – Diversity of wild mushrooms in the community forest of Na Si Nuan sub-district, Thailand. Journal of Biochemical Technology11(3), 28–36.
Zoirjon Sh I, Mustafaev IM, Shirqulova JP, Khabibullaev BS et al. 2023 – The first record of *Pisolithus arhizus* (Sclerodermataceae, Basidiomycota) in Central Asia. Ukrainian Botanical Journal 80(4), 337–342.