CHAPTER 2

LITERATURE REVIEW

History of the Mushroom Genus *Mycena* (Mycenaceae) from South East Asia

The genus Mycena Worldwide

The genus *Mycena* was first recognized by Persoon (as cited in Grgurinovic, 2002, p. 1) as representing a portion of the genus *Agaricus*, as section *Mycena*. At that time, most mushrooms were placed in the genus *Agaricus*, but *Mycena* was separated as a distinct section because of the small, conical, membranous pileus and fistulose stipe. Roussel (as cited in Grgurinovic, 2002, p. 1) elevated *Mycena* as circumscribed by Persoon to generic rank and included three new species (Grgurinovic, 2002, p. 1). Fries expanded the taxonomic concept of *Mycena* in *Systema Mycologicum* and divided the genus into 3 Tribes, viz., *Genuinae, Hygrocyboidea*e and *Omphalariae*, based on differences in pileus and lamellae features (Fries as cited in Grgurinovic, 2002, p. 1).

Lange was the first researcher of mycenoid fungi to use micromorphological as well as macromorphological features in the delimitation of *Mycena* species. He divided the genus into three groups based on cystidial features, as follows: (1) Ciliatae group with the cystidia conical,

cylindrical, hair-shaped or awl-shaped; (2) Granulatae group with the cystidium apices obtuse and with warts or setulae; and (3) Gummosae group with elastic almost amorphous filamentous cystidia and a slimy stipe (Lange as cited in Grgurinovic, 2002, p. 1).

In 1931 Kühner established the principle for *Mycena* classification by testing the cell wall of basidiospores with Meltzer's reagent (an iodine/chloral hydrate solution). If the basidiospore cell wall became blue or purplish blue in Melzer's reagent they were termed amyloid, and if no color change occurred they were termed inamyloid. Kühner placed positively reacting species in the following sections: *Lactipedes*, *Typicae*, *Glutinosae*, *Roridae*, *Viscipelles* and *Basipedes*. Only one section was found with a negative result, i.e., sect. *Mycenella*. Kühner's study was expanded and published under the title "Monograph of *Mycena* from Europe and North America" (Kühner as cited in Grgurinovic, 2002, p. 3).

Many *Mycena* studies published between 1938-1986 followed Kühner's system. Mètrod published "Monograph *Mycenas* de Madagascar" in 1949 in which he separated *Mycena* into 4 sections (*Basipedes*, *Granulatae*, *Nodosae* and *Ciliatae*) and 18 subsections (Mètrod, 1949, pp. 19). Singer revised the infrageneric structure of *Mycena* in 1986 in his monumental book "Agaricales in Modern Taxonomy" where he divided *Mycena* into 15 sections: viz., sections *Aciculae, Basipedes, Ciliatae, Citricolores, Cyanocephalae, Hiemales, Hygrocyboiedeae, Kermesinae, Lactipedes, Mycena, Purae, Radiatae, Roridae, Sacchariferae,* and *Viscipelles* (Singer, 1986, p. 400). More recently, Maas Geesteranus divided *Mycena* into 40

sections which he published in "Monograph of *Mycenas* of the Northern Hemisphere" in 1992 (Maas Geesteranus, 1992, p. 1) and "Mycenae Paranaenses" in 1997 (Maas Geesteranus & de Meijer, 1997, p. 11). The new system of Maas Geesteranus accepted the sections *Adonideae*, *Amictae*, *Bulbosae*, *Caespitosae*, *Carolinenses*, *Calamophilae*, *Calodontes*, *Clavulares*, *Cinerellae*, *Crocatae*, *Detrusae*, *Exornatae*, *Exiguae*, *Euspeireae*, *Filipedes*, *Fragilipedes*, *Fuliginellae*, *Galactopoda*, *Hemisphere*, *Ingratae*, *Insignes*, *Intermediae*, *Longisetae*, *Luculentae*, *Monticola*, *Oregonenses*, *Pictae*, *Phloginae*, *Polyadelphia*, *Pterigenae*, *Rarifoliatae*, *Rubromarginatae*, *Rufolimitatae*, *Sacchariferae*, *Sanguinolentae*, *Supinae,* and *Satulipede*.

In 1995 Desjardin published a worldwide monograph of *Mycena* section *Sacchariferae* (Desjardin, 1995, p. 1) wherein he subdivided the section into three new Stirps, *Amparoina*, *Alphitophora* and *Adscendens*, based on presence or absence of cherocytes and differing stipe anatomy. In the same year, Maas Geesteranus and Horak published "*Mycena* from Papua New Guinea" in which they reported 22 species (Maas Geesteranus & Horak, 1995, p. 143). The newest monographs of *Mycena* are those of Grgurinovic for Australian species (Grgurinovic, 2002, p. 1), and Robich (2003, p. 1) for European species.

The genus Mycena in South East Asia

Corner was the first taxonomist who studied *Mycena* in Southeast Asia (Malaysia). He primarily followed the infrageneric classifications of Maas Geesteranus and Singer. In 1986, Corner published "The tropical Complex of *Mycena* Section *Purae*" in which he reported 4 species, viz., *Mycena pura*, *M. decipiens*, *M. kuehneriana* and *M. pearsoniana*. A more extensive accounting of Malesian *Mycena* species was published in 1994 under the title of "Agarics in Malesia II. Mycenoid." This study divided *Mycena* into 5 groups and included 57 species (Corner, 1994, pp. 168, 183, 200, 213, 216).

Some *Mycena* species from Indonesia were published under the title "Agaricales of Indonesia 3. *Mycena* sect. *Longisetae* with comments on allied species" by Desjardin and Horak (2002, p. 69).

Mycena in Thailand was first reported from Koh Chang, Trad province in 1902 by Rostrup as part of a list of basidiomycetous fungi from Thailand. In total, in the Flora of Koh Chang, they reported 26 genera and 81 species of basidiomycetous fungi. *Mycena cuspidata* and *M. lactea* were the only two *Mycena* species reported from Thailand (Rostrup, 1902, pp. 363-364). The second report of *Mycena* in Thailand was not until 100 years later in "Thai Mushrooms and Other Fungi" (Ruksawong & Flegel, 2001, pp. 207-206) which reported *Mycena pura* and *M. tephina*. In 2002, five new species of *Mycena* were described from Thailand by Desjardin and colleagues, as *Mycena khonkhem*, *M. palmicola* (Desjardin, Boonpratuang, & Hywel-Jones, 2002, pp. 79, 82) *M. pseudoseta*, *M. mimicoseta* and *M. dermatogloea* (Desjardin, Boonpratuang, & Hywel-Jones, 2003, pp. 8, 11, 13). An

accounting of all known Thai *Mycena* was provided by Desjardin et al. in a chapter on Basidiomycetes in the book "Thai Fungi Diversity" (Desjardin, Flegel, & Boonpratuang, 2004, p. 45).

Morphology of Spinose Species in the Mushroom Genus *Mycena*

The Morphology of the Mushroom Genus Mycena

The mushroom genus *Mycena* is placed in the family *Mycenaceae* and is characterized by the following combination of these characters: small to medium-sized basidiomes typically with a conical to convex, smooth or roughened pileus, variously pigmented but rarely brightly coloured; central, fistulose, smooth or ornamented stipe; white to cream-colored, subcylindrical to globose, thin-walled, amyloid or rarely inamyloid basidiospores; clavate, 2- to 4-sterigmate basidia; with or without distinct pleurocystidia, cheilocystidia and caulocystidia; a hymeniform or cutis-type pileipellis with smooth, diverticulate or spinulose hyphae; an undifferentiated or subcellular hypodermium; typically dextrinoid tramal tissues with clamp connections (Grgurinovic, 2002, p. 54; Maas Geesteranus, 1992, p. 8; Maas Geesteranus & de Meijer, 1997, p. 11). Over 1800 species of *Mycena* have been described worldwide, primarily from the Northern Hemisphere. The *Mycena* mycota from the Southern Hemisphere is more poorly known.

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Morphology of the Spinose of Mycena

In 2002 and 2003 Desjardin et al. reported on the spinose species of *Mycena* and characterized them as forming small basidiomes with pilei having erect spines formed from pileosetae, pileocystidia or clusters of agglutinated hyphae. The pileus spines are observed easily with the naked eye and give the pileus surface a hispid or hairy appearance. Fourteen spinose species of *Mycena* were reported worldwide (Desjardin et al., 2002, p. 70; 2003, pp. 7-8). Of these, eleven species formed pileosetae that are thick-walled, aculeate to acicular, non-exudative, unicellular structures that arise as terminal cells from pileus subcuticular hyphae and project through the pileipellis (Desjardin et al., 2002, p. 71). Two species, described as new from Thailand, formed spine-like structures formed from clusters of agglutinated hyphae (*M. pseudoseta*, *M. mimicoseta*) and *M. dermatogloea*), while one species (*M. dermatogloea*) formed thin-walled, exudative pileogloeocystidia (Desjardin et al., 2003, p. 8). This study will focus only on the species from South East Asia that form pileosetae and pileocystidia and would traditionally be placed in *Mycena* sect. *Longisetae*.

The eleven species currently accepted in *Mycena* section *Longisetae* were placed in two Stirps by Desjardin et al. (2002, p. 72): Stirps *Brunneisetosa* including *M. brunneisetosa*, *M. indica*, *M. tenuisetosa*, *M. trichocephala*; and Stirps *Longiseta* including *M. aciculata*, *M. breviseta*, *M. brevisetosa*, *M. clavulifera*, *M. khonkhem*, *M. longiseta* and *M. palmicola* and *M. khonkhem* were described as new while *M. clavulifera* was redescribed based on material collected in Thailand. *Mycena aciculata* and *M.*

trichocephala are not included in the South East Asian species documented here because they are extralimital (U.S.A and Brazil, respectively).

Molecular Evolution of Spinose Species in the Mushroom Genus *Mycena* (*Mycenaceae*) from South East Asia

In 2000, Moncalvo et al. were the first systematists to seriously explore the phylogenetic relationships amongst the major evolutionary lineages of mushrooms and their relatives using molecular sequence data from the nuclear large subunit ribosomal DNA gene (nLSU). A total of 154 taxa belonging to the order Agaricales were selected for the study, including three species of *Mycena*, viz., *M. galericulata*, *M. clavicularis* and *M. rutilanthiformis*. The results indicated that the three *Mycena* species formed a monophyletic group (Clade P) with high statistical support that was sister to species traditionally accepted in the family Tricholomataceae (Moncalvo, Lutzoni, Johnson, Rehner, & Vilgalys, 2000, pp. 278, 292-293).

In 2002, Moncalvo et al. published a more robust study that included 877 homobasidiomycete taxa and again used nuclear large ribosomal subunit (nLSU) sequences and weighted parsimony-bootstrap methods to generate phylogenetic hypotheses. Of 117 monophyletic groups (clades) of euagarics recognized, many clades corresponded to traditional taxonomic groups while some did not. Nine species of *Mycena* were included in the large dataset of euagarics. Unlike their first study with only three species, the 2002 study with

nine species showed that *Mycena sensu lato* is polyphyletic. Seven of the nine species of *Mycena* clustered in the same clade, termed/mycenaceae, and included the type species of the genus, *Mycena galericulata*. All of these species share amyloid basidiospores and dextrinoid tramal tissues. The remaining two species of *Mycena* in their analyses (*M. aurantiidisca, M. adonis*) clustered in a distant clade, termed/adonis, and share inamyloid basidiospores and non-dextrinoid tramal tissues (Moncalvo et al., 2002, pp. 357, 361, 370-371, 374, 376).

Since 2002, very limited molecular phylogenetic research has included species of *Mycena*, and none have been directed specifically to the genus. Matheny et al. (2006, p. 990) published an analysis of the Agaricales based on sequences from six genes (rpb1, rpb1-intron 2, rpb2, 18S, 25S, 5.8S rRNA genes) in which they included 8 *Mycena* species. Again, the *Mycena* taxa fell into two distinct and distantly related clades, with the /adonis taxa placed in the hydropoid clade and the /mycenaceae taxa formally accepted as representing the family Mycenaceae. A more detailed study of *Mycena viscidocruenta* was presented by Petersen et al. in 2008 based on ITS and LSU sequences, which resulted in recognizing the new genus *Cruentomycena* (Petersen et al., 2008, p. 119) as sister of the genera *Resinomycena* and *Panellus*. No published molecular phylogenetic analyses have included spinose *Mycena* species. The research presented here is the first study to indicate the phylogenetic placement of spinose species of *Mycena*.

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