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Slime molds in edible mushroom cultivation sites

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ABSTRACT

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A total of 29 species and 4 varieties of slime molds have been recorded from various edible mushroom cultivation sites in Taiwan. Among them, 14 species and 2 varieties were previously not reported to be associated with cultivated mushrooms around the world. *Fuligo septica* var. *flava* Persoon is recorded for the first time in Taiwan, which is characterized by the presence of yellow inclusions in peridium, capillitium, as well as pseudocapillitium. The biological and ecological significances of slime molds-cultivated mushrooms association are briefly discussed.

Key words: mushrooms, Myxomycetes, slime molds, Taiwan

INTRODUCTION

In mushroom cultivation sites, artificial manipulation of the environment provides excessive moisture and large amounts of dead plant remains, which favors the growth of slime molds. People grow a variety of mushrooms in eastern Asia, and the reports on the occurrence of slime molds in mushroom cultivation sites are not rare. In Japan, Hamashima (4) reported twenty-two species of slime molds on logs of *Lentinula edodes* with notes on their seasonal abundance. Subsequently, Liu (20) illustrated ten common species from Taiwan. During the study of contaminants of *Lentinula edodes* grown on sawdust-filled polypropylene bags in Singapore, Lim *et al*. (14) mentioned *Fuligo septica* and an unidentified Myxomycete. In eastern (9, 15), southern (25), and northwestern (10, 11) parts of China, slime molds were also reported to be associated with edible mushroom cultivation. Zheng *et al*. (24) observed slime molds from logs for cultivating *Lentinula edodes*, *Auricularia* spp., and *Tremella* spp., indoor bed cultivation of *Agaricus* spp., bottle-cultivation of *Hericium erinaceus* as well as husk of cottonseeds cultivating *Flammulina velutipes*.

Harada probably conducted the first detailed autecological study on slime mold disease of cultivated mushrooms (5). He observed that the plasmodia of *Badhamia utricularis* could cause wilting, rotting or partial lysis of the fruiting bodies and primodia of cultivated *Pholiota nameko* and *Pleurotus ostreatus*. *Badhamia utricularis* was able to complete its life cycle on the mushroom fruiting bodies, thus fulfilled the Koch's postulate. In Taiwan, Liao studied the occurrence and life cycle of *Stemonitis splendens* on logs of *Lentinula edodes*. The logs inoculated with spores of *Stemonitis* almost completely depleted of mushroom fruiting (13). Li *et al*. observed that *Physarum pezizoides* caused lysis of wood ear (*Auricularia* spp.). They demonstrated that *P. pezizoides* secreted extracellular enzymes, which are responsible for the wood ear lysis (12).

When Liu and Liu (17, 18) and Liu *et al*. (19) studied on the diseases of edible mushrooms of China, they noted that there is no effective control method available for slime mold disease. The facts imply that slime molds might be a panic problem. We suspect that the mushrooms invaded by slime molds are probably more common than expected, since mushroom growers may fail to recognize the slime molds as a pathogen. In addition, reports on mushroom diseases caused by slime molds may be overlooked, because failure in identification. Chen (2) and Cheng (3) reported the slime mold disease of cultivated *Ganoderma* and *Auricularia* in Taiwan, respectively, and both of them failed to identify the casual organisms. Lim *et al*. also listed an unidentified Myxomycete, as mentioned above (14). We are also unaware of any attempt in any scale to estimate the degree of damage caused by the slime molds. In order to facilitate the understanding of the slime molds-edible mushrooms association, we summerize our preliminary observations on the biodiversity of slime molds associated with edible mushroom cultivation in this communication.

MATERIALS AND METHODS

The specimens of slime molds collected from mushroom cultivation sites were deposited in the Mycology Laboratory, Department of Botany, National Taiwan University and being examined in this study. In addition, one of us (Chung) has surveyed several mushroom cultivation sites in northern Taiwan during 1995-1997 to collect additional specimens and data. The identification and classification system of slime molds was adopted from Martin and Alexopoulos (21) and related references.

RESULTS

A total of twenty-nine species and four varieties of slime molds from mushroom cultivation sites in Taiwan are listed below. For each administrative area a voucher specimen is selected and cited, and taxa are arranged alphabetically within each order. According to literature records (4, 5, 9-15, 17-20, 24, 25), fourteen species and two varieties (marked with an asterisk) are not known from edible mushroom cultivation sites around the world. Species marked with double asterisks had been proved to be pathogenic to cultivated mushrooms (13).

CERATIOMYXALES

Ceratiomyxa fruticulosa (Mueller) T. Macbride

Specimen examined: Tainan City, Aug. 4, 1986, on dead wood, Liu CHLB618.

LICEALES

**Dictydiaethalium plumbeum* (Schumacher) Rostafinski

Specimen examined: Nantou County, Nov. 14, 1983, on dead wood, Liu CHLB327; Tainan City, Aug. 4, 1986, on dead wood, Liu CHLB602.

Lycogala conicum Persoon

Specimen examined: Taipei County, *s. d.*, on dead wood, Liu CHLM188; Nantou County, Oct. 26, 1981, on dead wood, Liu CHLM380.

Lycogala epidendrum (L.) Fries

Specimen examined: Tainan City, Oct. 4, 1986, on dead wood, Liu CHLB616.

**Reticularia lycoperdon* Bulliard

Specimen examined: Hsinchu County, Feb. 11, 1981, on dead wood, Liu 193.

TRICHIALES

Arcyria cinerea (Bulliard) Persoon

Specimen examined: Taipei County, Dec. 12, 1978, on dead wood, Liu CHLM1; Nantou County, Nov. 26, 1979, on dead wood, Liu CHLM32.

Arcyria denudata (L.) Wettstein

Specimen examined: Taipei County, Nov. 12, 1978, on dead wood, Liu CHLM3; Nantou County, Nov. 25, 1979, on dead wood, Liu CHLM42; Tainan City, Jun. 28, 1981, on dead wood, Liu CHLM362.

Arcyria incarnata (Persoon) Persoon

Specimen examined: Nantou County, Oct. 26, 1981, on dead wood, Liu CHLM382; Tainan City, Aug. 4, 1986, on dead wood, Liu CHLB617.

**Hemitrichia clavata* var. *calyculata* (Spegazzini) Y. Yamamoto

Specimen examined: Taipei County, Mar. 16, 1988, on dead wood, Liu CHLB794; Nantou County, Sep. 16, 1980, on dead wood, Liu CHLM150.

Hemitrichia serpula (Scopoli) Rostafinski

Specimen examined: Nantou County, Oct. 26, 1981, on dead wood, Liu CHLM388.

**Metatrichia vesparium* (Batsch) Nannenga-Bremekamp

Specimen examined: Nantou County, Nov. 26, 1979, on dead wood, Liu CHLM33.

Trichia favoginea (Batsch) Persoon *s. l.*

Specimen examined: Nantou County, Nov. 26, 1979, on dead wood, Liu CHLM34.

**Trichia scabra Rostafinski*

Specimen examined: Nantou County, Oct. 26, 1981, on dead wood, Liu CHLM392.

PHYSARALES

**Didymium clavus* (Albertini & Schweinitz) Rabenhorst

Specimen examined: Tainan City, Aug. 4, 1986, on dead wood, Liu CHLB612.

**Didymium iridis* (Ditmar) Fries

Specimen examined: Tainan City, Aug. 4, 1986, on dead wood, Liu CHLB611.

**Didymium squamulosum* (Albertini & Schweinitz) Fries

Specimen examined: Tainan City, Aug. 4, 1986, on dead wood, Liu CHLB613.

Fuligo septica (L.) Wiggers var. *septica*

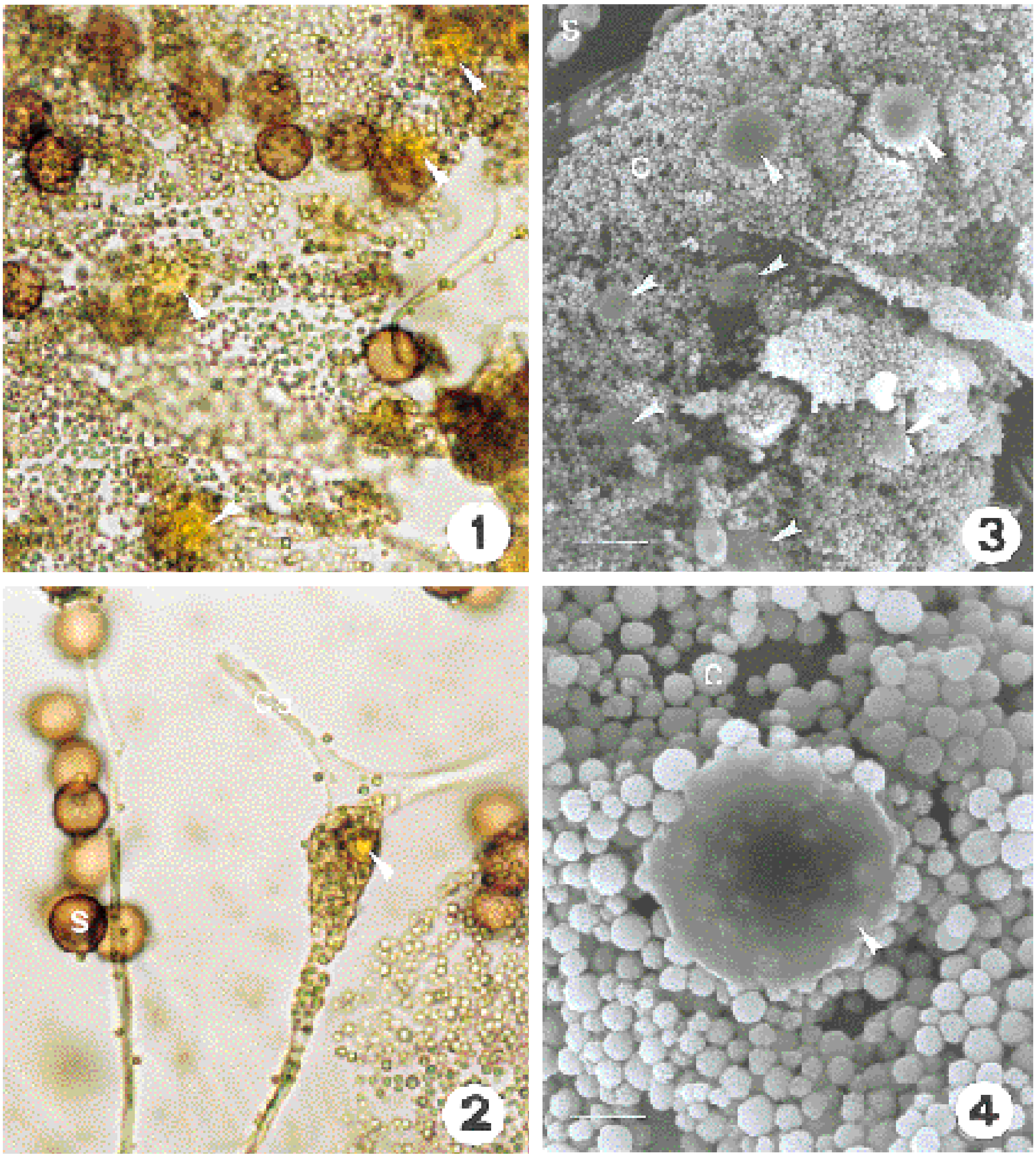
Specimen examined: Tainan City, Aug. 4, 1986, on plastics, Liu CHLB608.

**Fuligo septica* var. *flava* Persoon, Roemers Neues Mag. Bot. 1: 88. 1794. Figs 1-4.

Specimen examined: Tainan City, Aug. 4, 1986, on dead wood, Liu CHLB614.

Notes: New to Taiwan. The variety is characterized by the presence of yellow inclusions in peridium, capillitium, as well as pseudocapillitium. Some additional records of this variety in Taiwan are given below.

Additional specimens examined (not from mushroom



Figs 1-4. *Fuligo septica* var. *flava*. Fig. 1. Yellow inclusions (arrows) in pseudocapillitium under light microscope (LM), about 1,000X; Fig. 2. Yellow inclusions (arrow) in capillitium (Cp), LM, about 1,100X; Figs 3, 4. Yellow inclusions (arrows) in peridium under scanning electron microscopy, bar in Fig. 3 = 10 μ m, bar in Fig. 4. = 2 μ m. C: granular calcium deposition; S: spores.

cultivation sites): Taipei Metropolis, Main campus of the National Taiwan University, 12 V 1993, on bark of *Melaleuca leucadendra*, W. C. Leong 11; *ditto* except collected 22 VII 1996, C.-H. Chung M1294; 15 VI 1993, on dead bark of *Cryptomeria japonica*, C. P. Chang 19; Taipei County, between Shihmen and Kinshan, 28 X 1995, on dead wood along the seashore, C.-H. Chung M922.

Physarum nutans Persoon

Specimen examined: Nantou County, Apr. 8, 1981, on dead wood, Liu CHLM285.

Physarum rigidum (G. Lister) G. Lister

Specimen examined: Hsinchu County, Nov. 30, 1980, on plastic bags used for cultivating *Auricularia*, Liu CHLM52; Nantou County, Apr. 8, 1981, on dead wood, Liu CHLM310.

**Physarum viride* (Bulliard) Persoon

Specimen examined: Nantou County, Apr. 8, 1981, on dead wood, Liu CHLM289.

STEMONITALES

Collaria arcyrionema (Rostafinski) Nannenga-Bremekamp *ex* Lado

Specimen examined: Hsinchu County, Sep. 4, 1980, on dead wood, Liu CHLM107.

Stemonaria longa (Peck) Nannenga-Bremekamp, R. Sharma & Y. Yamamoto

Specimen examined: Taipei County, Feb. 26, 1980, on dead wood, Liu CHLM80; Nantou County, Sep. 15, 1980, on dead wood, Liu CHLM128; Tainan City, Aug. 4, 1986, on dead wood, Liu CHLB603.

Stemonitis axifera (Bulliard) T. Macbride var. *axifera*

Specimen examined: Nantou County, Apr. 8, 1981, on dead wood, Liu CHLM348.

**Stemonitis axifera* var. *smithii* (T. Macbride) Hagelstein

Specimen examined: Taipei Metropolis, Mar. 16, 1988, on dead wood, Liu CHLB790a; Taipei County, Oct. 18, 1984, on dead wood, Liu CHLB425; Hsinchu County, Sep. 4, 1980, on dead wood, Liu CHLM108.

Stemonitis fusca Roth var. *fusca*

Specimen examined: Nantou County, Oct. 26, 1981, on dead wood, Liu CHLM386; Tainan City, Aug. 4, 1986, on dead wood, Liu CHLB621.

**Stemonitis fusca* var. *nigrescens* (Rex) Torrend

Specimen examined: Hsinchu County, Feb. 11, 1981, on dead wood, Liu CHLM192; Nantou County, Apr. 7, 1981, on dead bark, Liu CHLM209; Tainan City, Aug. 4, 1986, dead wood, Liu CHLB619.

**Stemonitis fusca* var. *papillosa* Meylan

Specimen examined: Nantou County, Nov. 19, 1980, on dead wood, Liu CHLM167.

Stemonitis herbatica Peck

Specimen examined: Taipei County, Oct. 18, 1984, on dead wood, Liu CHLB424; Hsinchu County, Jun. 11, 1980, on plant debris, Liu CHLM75; Nantou County, Nov. 19, 1980, on dead wood, Liu CHLM77.

***Stemonitis splendens* Rostafinski

Specimen examined: Taipei Metropolis, Mar. 16, 1988, on dead bark, Liu CHLB786; Hsinchu County, Sep. 15, 1980, on dead wood, Liu CHLM124; Nantou County, Nov. 14, 1983, on dead wood, Liu CHLB339.

Notes: Liao (13) has reported this species as pathogenic to *Lentinula edodes*.

**Stemonitis virginiensis* Rex

Specimen examined: Hsinchu County, Sep. 4, 1980, on dead wood, Liu CHLM106.

**Stemonitopsis hyperopta* (Meylan) Nannenga-Bremekamp

Specimen examined: Taipei Metropolis, Mar. 16, 1988, on dead wood, Liu CHLB790b; Nantou County, Nov. 14, 1983, on dead wood, Liu CHLM337.

**Stemonitopsis typhina* (Wiggers) Nannenga-Bremekamp

Specimen examined: Taipei County, Oct. 18, 1984, on dead bark, Liu CHLB422.

DISCUSSION

True slime molds are well known to be cultured axenically for experimental biology in recent decades, but Howard (6) and Lister (16) have raised these organisms by fresh mushrooms in earlier times. Howard and Currie (8) and Howard (7) made scrutinous observations and sophisticated experiments on the mycophagy of slime molds. A total of twenty-three mycophagous taxa were proposed by them, of which eleven species are also observed from mushroom cultivation sites in this communication.

Analysis of the species diversity of slime molds found in this study at the level of order (Fig. 5) reveals that the diversity of the Stemonitales is the highest, following by the Trichiales. It is generally recognized that taxa of Physarales on litter are the major components of the tropical myxomycete biota, but taxa of Stemonitales and Trichiales are better known from dead wood (23). Rationally, these two orders are dominant in mushroom cultivation sites, where considerable amount of logs were used as substrates. On the

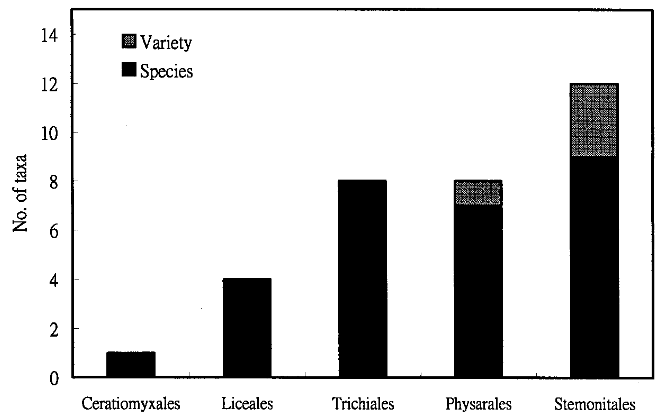


Fig 5. The relative frequency of different orders of slime molds recorded from mushroom cultivation sites in Taiwan.

other hand, taxa with minute sporocarps, *e. g. Licea* and species of Echinosteliales, tend to be overlooked in the dim light of mushroom cultivation sites. Studies using moist chamber culture techniques might make up the deficency.

Liao noted that infection rate of slime molds was lower when hardwood, *e. g. Castanopsis formosana*, was used for growing *Lentinula edodes* (13). More sporocarps of *Stemonitis* were observed on softwood, *e. g. Hibiscus tiliaceous*, blue Japanese oak, and red chink pin, in his study. However, these observations need verification, and it would be intriguing to study whether some other tree species are more resistant to slime molds colonization.

Although all of the the slime molds reported in this communication are commonly encountered in the field, about 50% (sixteen out of thirty-three taxa) of the taxa reported were not known from mushroom cultivation sites prior to this study. The paucity of our knowledge on myxomycete biota in such habitat is probably resulted from the fact that the taxonomic hierarchy was largely based on characters of sporocarps. This makes it extremely difficult to identify the mushroom-foraging plasmodial stage of Myxomycetes if no fruiting body forms. In fact, although it is easy to grow the plasmodia *in vitro* for several years, the plasmodia frequently failed to form fruiting bodies (Chung, pers. observ.). In the future, it would be interesting to characterize or even to identify the Myxomycetes without sporocarps. Specimens cited in this communication have been stored in herbarium for years for taxonomic purposes and are not suitable for culture studies.

Myxomycetes may not only affect growth of mushrooms by causing diseases but also function as weeds. Liao (13) regarded the slime molds as competitor of space and nutrition, and the logs inoculated with spores of *Stemonitis* almost completely devoid of mushroom fruiting. Several notorious pathogenic species in mushroom farms, such as *Verticillium fungicola* and *Aphanocladium album*, were found associated with fruiting bodies of Myxomycetes (22). Therefore molded fruiting bodies of Myxomycetes may serve as a temporal reservoir of mushroom-pathogenic fungi. However, due to the lack of adequate knowledge, it is premature to draw any conclusion at this stage for the nature of the association of slime molds and cultivated mushrooms and the total effect of this association on mushroom cultivation.

Currently there is no effective method available for control of slime molds in the mushroom cultivation sites. At present, remedies including reduction of water supply and removal of plasmodia and young sporocarps by physical means has been suggested (19, 24). Harada (5) applied table salt to eliminate plasmodia, and Chen (2) wiped out the slime molds growing on the surface of plastic containers with cloth wetted with gasoline. Both apporaches require not only enormous labors, also the residual gasoline may pose a possible risk of fire outbreak. In addition, the toxic additives of gasoline, *i. e.* lead, may be absorbed by the mushrooms and enter human bodies when consumed. Salting may also increase the liberation of conidia of fungal pathogens, *i. e.* (1).

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摘　要

鍾兆玄[1]、劉錦惠[2]、曾顯雄[1,3]. 1998. 養菇場之黏菌. 植病會刊 7:141-146 . ([1.] 臺北市　國立臺灣大學植物病理學系. [2.] 臺北市　國立臺灣大學植物學系. [3.] 聯絡作者：電子郵件 sst@ccms.ntu.edu.tw；傳真 +886-2-23620639)

本研究調查了臺灣各地食用菇類栽培場所的黏菌，共得二十九種及四變種；其中十四種、兩變種以往未曾於此類場所報導過。煤絨黏菌黃殼變種 (*Fuligo septica* var. *flava*) 為臺灣新記錄之黏菌，其特徵為週皮、細毛體與假細毛體上具黃色顆粒。本文並對食用菇類栽培場所出現黏菌之生物學與生態學上的重要性作了簡短的討論。

關鍵詞：食用菇、黏菌、臺灣