# PRELIMINARY STUDIES ON TAIWAN MUCORALES (I)[1]

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**Abstracts:** This study attempts to investigate the Mucorales in Taiwan especially those members of the order that are most commonly encountered and the most economically important to human welfare. Part I is devoted to isolation and identification of mucoraceous fungi obtained mainly from Taiwan soil, air or otherwise. 15 species have been recognized and 13 of them such as *Mucor abundans, M. fragilis, M. hiemalis, M. mucedo, M. racemosus, M. subtilissimus, M.* sp., *Circinella rigida, Cunninghamella echinulata, C. elegans, Helicostylum piriforme, Pilobolus kleinii, Rhizopus nigricans* were reported as new to the fungal flora of Taiwan.

## INTRODUCTION

This study attempts to investigate the Mucorales in Taiwan, especially, the members of the order that are the most commonly encountered and those most economically important to human welfare. Since the pioneer work of K. Sawada, entitled the Descriptive Catalogue of Taiwan Fungi (1919–1959, Part I to Part XI), did not treat the mucoraceous fungi as extensively as the other groups of fungi in his work, the present investigation designs to proceed into two parts, namely, Part I the isolation and identification of Taiwan Mucorales, and Part II the development and growth for the economic utilization of beneficial species as well as valuable information for scientific research.

The following account reports the results of our findings under Part I. 15 species belonging to 6 genera of Mucorales have been isolated from soil and air of seven localities. The important characters of each of these fungi have been carefully studied by repeated cultivation and finally making pure cultures upon which the present investigation is based. It was found that 6 species of *Mucor*, 1 species of *Circinella*, 2 species of *Cunninghamella*, 1 species of *Helicostylum* and 1 species of *Pilobolus* were reported new to Taiwan fungal flora.

## MATERIALS AND METHODS

1. Soil samples. Soils were collected from seven localities such as Tayuling (大禹嶺); Chitou (溪頭); Ping-tung Hsien, Ta-zu-lin shan (屏東縣大樹林山); Kan-kou (乾溝); NTU campus; Peitou (北投); Sun-moon Lake (日月潭) provided the main material for this study, besides, fungi of air borne origin were isolated from laboratory contaminates and or directly from atmosphere.
2. The methods of isolation.
   A. Dilution plate (Barron, 1971): 1. Place 25 g dry weight of soil in a sterilized measuring cylinder; 2. Add sterile water agar (0.15%) to make up the volume to 250 ml; 3. Pour the soil agar mixture into a flask, blended for 30–60 sec;

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4. Pipette out 5 ml of the blended suspension into 45 ml of sterile water-agar; 5. Repeat #4. 3 times to make 3 different concentrations of dilution: 1/100, 1/1000 and 1/10000; 6. Pipette out 1 ml of each dilution into each of 5 Petri dishes; 7. Pour 10 ml of cooled agar medium into each plate and mix well with the soil suspension.

B. Soil plate (Warcup, 1950): Measure about 0.005–0.025 g of soil and transfer it into a sterile Petri dish, add 10 ml of cooled medium and shake well to disperse the soil particles as evenly as possible.

3. The media used in this study.

A. Media for isolation: Martin's medium modified (Snyder et al., 1959).

B. Media for cultivation: The cultural media used were synthetic mucor agar (SMA) and malt extract agar (MA) for stock cultures, Potato-dextrose agar (PDA) for growing mating types and zygospores, horse dung extract agar or rabbit pellet extract agar for *Pilobolus* culture.

## OBSERVATIONS AND RESULTS

An extensive study of the selected isolates revealed 15 species belonging to 6 genera of mucoraceous fungi. Details of which are presented as follows:

1. *Mucor abundans* Povah Bull. Torrey Bot. Cl. **44**(6): 292, Pl. 17, f. 1–6, 1917; Gilman 1957; Zycha & Siepmann 1969. Pl. II, 1–2.

Turf dense, gray or tinged with brown, 1.5–2 cm tall. Sporangiophores sympodially branched, 3–6.5 $\mu$ to 10 $\mu$ in diameter. Sporangia minute, spherical, brownish, mostly 60 $\mu$ in diameter, the largest being 87.5 $\mu$ with diffluent wall. Columella globose to pyriform, mostly 30–36×30–40 $\mu$, with a flattened base; collarette at base. Spore mostly uniform, subglobose to short elliptical, 3–5×4.5–7.5 $\mu$. Chlamydospores abundant in aerial hyphae, globose, large, 25 $\mu$ in diameter. Zygospores not observed. (8–5), (8–14), (8–18), (8–21), (8–22).

2. *Mucor dispersus* Hagem Ann. Mycol. 8: 271; Gilman 1957. Pl. II, 3–6.

Turf white, dense, 2–2.5 cm high, mycelium branched with short bent, circinate branchlets, terminating in a sporangium; columellae hemispherical or dome shaped with small collarette; sporangiola of side branches usually with echinulate walls (2–4 spored); sporangiospores spherical or slightly elongate, sometimes rounded or angular, smooth; chlamydospores and gemmae absent; zygospores not observed. (11–2).

3. *Mucor fragilis* Ann. Sci. Nat., VI. **19**: 208, f. 12, 17, 1884; Gilman 1957; Zycha & Siepmann 1969. Pl. III, 2–5.

Turf gray to lead gray, up to 2 cm tall. Sporangiophores erect, tapering and septate, monopodially branched, 4–12 $\mu$ in diameter. Sporangia abundant, dark in color, obvious to naked eye, spherical, those on lateral branches smaller than those of the terminal, 13–45×12–42.5 $\mu$ and 60–80×55–72.5 $\mu$ respectively, with fragile walls. Columellae oval or pyriform, 20–37.5×22–45 $\mu$, with a more or less marked collarette. Spores uniform, oval to elliptic, 3.25–4.5×5.5–7.5 $\mu$, the smallest being 2.5×3.25 $\mu$. No chlamydospores and zygospores found. (8–12).

4. *Mucor hiemalis* Wehmer Ann. Mycol. **1**: 37, f. 1–9, 1903; Povah 1917; Gilman 1957; Zycha & Siepmann 1969. Pl. III, 6–9.

*M. erectus* Bainer, Ann. Sci. Nat. Bot., VI. **19**: 207. 1884.

*M. pallidus* Naumov, Bull. Soc. Mycol. France, **30**: 382. 1914.

*M. albus* Pispek, Act. Bot. Inst. Univ. Zagrib, **4**: 9. 1929.

*M. mustellinus* Pispek, Act. Bot. Inst. Univ. Zagrib, **4**: 12. 1929.

Turf low, about 1.5 cm high, brownish light gray, not dense. Sporangiophores usually unbranched or scarcely branched, erect at first, then prostrate by wilting, 6–17.5 $\mu$ (the broadest 25 $\mu$) in diameter. Sporangia minute, spherical, not obvious to naked eye, 52 $\mu$ in diameter (limit 30–62 $\mu$), wall diffluent. Columellae short oval, 12.5–35×13.5–38 $\mu$ (the largest 45×47.5 $\mu$), with collarette at base, spores various in shape and size, elongate, oval or reniform, usually 1: 2 as long as broad, 2.5–7.5× 5–13 $\mu$. Substrate hyphae with oil droplets, milky yellow, swollen at places. Chlamydospores numerous in the sporangiophores. Zygospore observed between (2–10) and (8–13). (2–10), (8–13).

5. *Mucor jansseni* Lendner Mucor. Suisse, p. 88, f. 30, 1908; Gilman 1957; Zycha & Siepmann 1969; Chien 1972. Pl. IV, 1–3.

Turf very low, up to 6 mm high, lead gray or dark gray tinged with brown, with white margins, loose, not dense. Sporangiophores short, much branched, sympodially or monopodially, tapering or not, 7–15 $\mu$ in diameter with a septum near apex. Sporangia black, spherical, 50–90 $\mu$ (the primary one), 25–50 $\mu$ (the side one), wall finely granular, fragile, leaving a minute collarette, columella pyriform or oblong with a flattened base, 20–33 (the broadest region) ×23–50 $\mu$, few rounded, 30–35 $\mu$ long. Spores large, mostly globose or short ovoid, 4.5–10 $\mu$ in diameter, thick walled. Culture with aromatics. (8–17).

6. *Mucor mucedo* (L.) Fresenius Beitr. Mykol. p. 7, f. 1–12, 1850; Brefeld 1872; Povah 1917; Gilman 1957; Zycha & Siepmann 1969. Pl. IV, 4–6.

*M. breviceps* Riess, Bot. Ztg., p. 136. 1853.
*M. rigidus* Leger, These Paris, p. 71. 1895.
*M. proliferus* Schostakowitsch, Ber. D. Bot. Ges., **14**: 260, Pl. 18, f. 1–14. 1896.
*M. ingricus* Naumov, Petersb. Pilze, 1915.
*M. griseosporous* Povah, Bull. Torrey Bot. Cl., **44**: 297, Pl. 18, f. 1–5. 1917.

Sporangiophores long, simple at first, scarcely branched, tapering or constricted at apex mostly 16–45 $\mu$ (the largest 60 $\mu$, the smallest 10.5 $\mu$) in diameter, the longest 4.5 cm, forming a high loose, whitish gray or gray turf. Sporangia ivory-white at first, brown when mature, spherical large mostly 145–192 $\mu$ with a flat base. Wall fragile or slowly diffluent, leaving a collarette. Columellae short ovoid, 22–68× 25–73 $\mu$ base flat; spores large, elongate, cylindrical or reniform, almost a little more than twice as long as broad, 5–7.2×10–15 $\mu$. Chlamydospores and zygospores were not observed. (8–1), (8–3), (8–4), (8–10), (8–11).

7. *Mucor racemosus* Fresenius Beitr. Mycol. p. 12, f. 24–31, 1850; Gilman 1957; Zycha & Siepmann 1969. Pl. IV, 7–9.

*M. tennis* Bainier, Ann. Sci. Nat., VI. **15**: 353. 1883.
*M. racemosus* var. *brunneus* Morini, Sacc. Syll. Fung., **14**: 433. 1896.
*M. christianensis* Hagem, Ann. Mycol., **8**: 268. 1910.
*M. muriperda* Sacc. & Sinig., Ann. Mycol., **11**: 321. 1913.
*M. lusitanicus* Bruderlein, Bull. Soc. Bot. Geneve 2. ser. **8**: 273. 1916.
*M. mediterraneus* Pispek, Act. Bot. Inst. Univ. Zagreb, **4**: 13. 1929.
*M. varians* Pispek, Act. Bot. Inst. Univ. Zagreb, **4**: 6. 1929.
*M. pispekii* Naumov 1935, Clés Mucor. 1939, p. 47.
*M. racemosus* var. *griseospora* Naumov 1935, Clés Mucor. 1939, p. 47.
*M. racemosus* var. *christianensis* (Hagem) Naumov 1935, Clés Mucor. 1939, p. 47.
*M. racemosus* var. *lusitanicus* (Bruderlein) Naumov 1935, Clés Mucor. 1939, p. 47.

Turf within 2.5 cm high, whitish gray or light gray, quickly collapsing. Sporangiophores always with numerous chlamydospores, usually scarcely branched

monopodially with 2 or more side branches, 7–18 μ in diameter. Chlamydospores numerously formed on the substrate mycelium and on the sporangiophores, those on the sporangiophores smooth, not swelling, always in square or oblong, not over 25 μ long. Sporangia spherical, the terminal ones 50–80 μ in diameter, the side sporangia always smaller. Wall more or less fragile. Columellae oblong or pyriform, 25–40×40–58 μ, 10–20×15–35 μ (the side branch), with flattened base. Spores mostly ovate or short ovate, thick-walled, 2.5–6×5–10 μ; some globose, 6–7 μ in diameter; few elliptic. Zygospores not found. Cultures smell sweetish. (10–2).

8. *Mucor subtilissimus* Oudemans Nederl. Kruidkund. Arch. **3**: 435, 1898; Zycha & Siepmann 1969.

Turf dense, whitish gray, 3.8 cm tall; sporangiophores 6–8 μ in diameter. Sporangia minute and light colored, not obvious to the naked eye, spherical, 45–75 μ in diameter, wall diffluent, collarette marked. Columellae globose to ovoid, 42×42 μ or 25×27.5–30 μ, spores minute, elongate or elliptical, almost twice as long as broad, mostly 2.5–3×5–6 μ. Chlamydospores abundant in aerial hyphae, elongate or globose, terminal or intercalary. Zygospores not found. (8–7), (8–8).

9. *Mucor* sp. Pl. III, 1.

Turf up to dish lid, about 1.5 cm high, gray or brownish gray, with golden brown margins. Sporangiophores simple at first, later sympodially or monopodially branched with few short side branches, tapering, 5–12 μ in diameter. Sporangia dark brown, spherical, 42–90 μ in diameter, with a diffluent wall, and a marked collarette. Columellae oval or spherical, 25–48×28–50 μ. Spores variable in size, 3–5×4–8 μ, reniform, or oblong-elliptical. Chlamydospores abundant, usually in chains, formed in the irregularly branched substrate mycelium. Heterothalic. Zygospores developed in the mating cultures of (3–4)×(3–5), and (3–4)×(3–6). This indicates (3–5) and (3–6) are the same strain, and (3–4) probably the opposite strain. (3–4), (3–5), (3–6).

This *Mucor* sp. is very similar to *Mucor fragilis* (8–12) in every respect, especially in the outer appearance (turf color, height) except that the sporangial wall is always diffluent, while the culture (8–12) has fragile sporangial walls. The turf color of (3–4), (3–5) and (3–6) in PDA cultures is little lighter than that of (8–12) which is mouse gray. No zygospores are produced between (3–4) and (8–12), nor (3–5) and (8–12).

10. *Circinella rigida* Smith Trans. Brit. Mycol. Soc., **34**: 19. 1951; Gilman 1957; Zycha & Siepmann 1969. Pl. II, 7–8.

Colonies matted folccose 2–5 mm high, dark gray. Sporangiophores long, mostly procumbent, at intervals forming helical coils, sympodially branched, 4–6 μ in diameter; the terminal portion of each branch 10–14 μ in diameter, coiled, with a septum little below the sporangium; sporangia globose, minutely spinulose, black in mass, dark brown by transmitted light, varying in diameter to 70 μ; wall firm, persistent. Columellae distinctive 17×30 μ, apophysate. Spores brown, globose, 4–6 μ in diameter. (11–3).

11. *Cunninghamella echinulata* Thaxter Rhodora, **5**: 98, 1903; Gilman 1957; Zycha & Siepmann 1969. Pl. I, 4–6.

*Oedociphalum echinulatum* Thaxter, Bot. Gaz., **16**: 17. 1891.
*C. africana* Matruchot, Ann. Mycol., **1**: 46. 1903.
*C. verticillata* Paine, Mycologia, **19**: 253. 1927.
*C. echinata* Pispek, Act. Bot. Inst. Univ. Zagreb, **4**: 24. 1929.

Turf white becoming yellowish with age, 1–1.5 cm high; filamentous interwoven. Conidiophores erect irregularly branched, terminal vesicles variable in size, nearly spherical to ovoid, 28×35 μ average, vesicles of lateral branches smaller. Conidia oval to elliptical, finely echinulate, 10×12 μ average. (10–6), (10–7).

12. *Cunninghamella elegans* Lendner Mucor. Suisse, p. 159, Pl. 58, 59, 1908; Gilman 1957; Zycha & Siepmann 1969. Pl. I, 2–3.
*Actinocephalum japonicum* Saito, Bot. Mag. Tokyo, **19**: 1. 1904.
*C. blakesleeana* Lendner, Bull. Soc. Bot. Geneve, **19**: 234. 1927.
*C. bertholletiae* Stadel, Diss. Kiel. 1911.

Turf white, becoming gray with age, 2.2–3.5 cm high, filaments spreading, 7–13 μ wide; conidiophores erect, multibranched, terminal vesicle 29–35 μ in diameter, spherical, smooth; lateral branches up to 3 or more whorled; terminal conidia lemon-shaped or elliptical, bearing spicules, finely echinulate. (10–6a).

13. *Helicostylum piriforme* Bainier Bull. Soc. Bot. France, **27**: 226, 1880; Gilman 1957; Zycha & Siepmann 1969. Pl. I, 7–9.
*Thamnidium piriforme* (Bainier) Migula, Kryptog. Fl. III. **1**: 207.

Sporangiophore erect, singly or unbranched, 12–30 μ thick. In each primary sporangium projecting into one sterile top bearing several spherical sporangiola, the lateral branchlets ending in a rosette of sporangioles, so that, they terminate the stipe in limited growth. The largest sporangia 90–170 μ, blackish with apophyses, columella approximately 50–108 μ, sporangioles pear-shaped, 17–20×17.5–22.5 μ, mostly with a strong, resistant wall, semispherical-shaped. Spores elliptical, 3–5×5–10 μ. Zygospores mucor-type, suspensor blackish, spherical shaped, 66–165 μ. Heterothallic. (11–4).

14. *Pilobolus kleinii* van Tieghem Ann. Sci. Nat. VI, **4**: 337, 1876; Buller 1958; Zycha & Siepmann 1969. Pl. I, 1.
*P. crystallinus* Klein, Jb. Wiss. Bot., **8**: 360. 1872.

Stipe bedecked with numerous water drops, about 1 mm long in substratum of horse dung, turnip-shaped. Sporangiophore 2.5–5 mm high, 9–150 μ thick, subsporangial vesicle oval shaped, 400–700 μ broad, 500–800 μ high, orange tinted. Sporania 300–600 μ broad, 170–260 μ high, black and undivided. Columella cylindrical and rounded below. Spores cylindrical to elliptical, 6–10×9–20 μ, orange colored with thin, smooth wall. Zygospore spherical up to 200 μ with brownish wall, surface smooth or slightly rough, with many small oil drops at maturity. Suspensor elongated up to 200 μ under the zygote. Heterothallic. (11–1).

15. *Rhizopus nigricans* Ehronberg Nova Acta Acad. Leop. 10, **1**: 198, 1820; Gilman 1957; Zycha & Siepmann 1969.
*Mucor stolonifer* Ehrenberg, Sylvae Myc. Berol. p. 25. 1818.
*Rh. niger* Ciaglinski & Hewelke, Z. Klin. Med. 12. 1893.
*Rh. artocarpe* Raciborski, Parasit. Pilze Javas, p. 11. 1900.
*Rh. niger* Gedoelst, Champ. paras. 1902.

Mycelium of two kinds, one submerged in the substratum, and the other aerial, constituting the stolons. Sporangiophores arise directly from the points where rhizoids initiate, Sporangia, white at first, bluish-black at maturity, spherical or almost spherical, flattened base. Wall not cuticularized, diffluent without collarette. Columellae broadly subjacent, hemispherical, formed after dehiscense by collapsing. Spores round or oval, angular, bluish or brown, with cuticularized wall, smooth or striate. Zygospores naked, formed in the substratum and on the stolons. Suspensers, straight, large and swollen, without appendage. (10–3), (10–4), (10–5), (11–5).

## DISCUSSION AND CONCLUSION

1. Over 60 isolates from soil, air or otherwise have been obtained from the present study and grown in pure cultures. 15 of them have been identified as mucoraceous fungi. They belong to 6 genera and 15 species. These include: *Mucor abundans, M. dispersus, M. fragilis, M. hiemalis, M. jansseni, M. mucedo, M. racemosus, M. subtilissimus, M.* sp., *Circinella rigida, Cunninghamella echinulata, C. elegans, Helicostylum piriforme, Pilobolus kleinii* and *Rhizopus nigricans.*

2. The criteria used for this identification are, in relative order of their importance: turf, columella, spores, sporangium, sporangial wall and chlamydospores.

3. The localities and other data of these fungi are given in Table I.

Table I. Collection data of species isolated

| Species | Substratum | Date of collection | Culture No. |
|---|---|---|---|
| *Mucor abundans* | Soil (8) | Mar. 31, 1972 | (8-5), (8-14), (8-18), (8-21), (8-22) |
| *M. dispersus* | Air (11) (exposed plate) | Oct. 17, 1972 | (11-2) |
| *M. fragilis* | Soil (8) | Mar. 31, 1972 | (8-12) |
| *M. fragilis* (?) | Soil (3) | Feb. 29, 1972 | (3-4), (3-5), (3-6) |
| *M. hiemalis* | Soil (2) | Feb. 29, 1972 | (2-10) |
| | Soil (8) | Mar. 31, 1972 | (8-13) |
| *M. jansseni* | Soil (8) | Mar. 31, 1972 | (8-17) |
| *M. mucedo* | Soil (8) | Mar. 31, 1972 | (8-1), (8-3), (8-4), (8-10), (8-11) |
| *M. racemosus* | Banana peel (10) | May 26, 1972 | (10-2) |
| *M. subtilissimus* | Soil (8) | Mar. 31, 1972 | (8-7), (8-8) |
| *Circinella rigida* | Laboratory contaminate (11) | May 1969 | (11-3) |
| *Cunninghamella echinulata* | Laboratory contaminate (10) | May 1969 | (10-6), (10-7) |
| *C. elegans* | Air (10) (exposed plate) | Oct. 17, 1972 | (10-6a) |
| *Helicostylum piriforme* | Horse dung (11) | May 1969 | (11-4) |
| *Pilobolus kleinii* | Horse dung (11) | May 1969 | (11-1) |
| *Rhizopus nigricans* | Tomato debris (10) | Mar. 27, 1972 | (10-3) |
| | Air (10) | Apr. 3, 1972 | (10-4), (10-5) |
| | Sweet potato (11) (soil or air) | Oct. 30, 1972 | (11-5) |

Among the other isolates 22 of them ((1-1), (1-2), (2-1), (2-2), (2-4), (2-8), (2-9), (2-22), (2-25), (2-29), (3-1), (3-2), (3-7), (3-14), (3-15), (3-17), (8-19), (8-20), (9-1), (9-2), (9-3), (10-1)) also belong to *Mucor*, but their respective species are not recognized yet.

(1)-(11) designating collection localities: (1) NTU campus; (2) NTU campus; (3) NTU campus; (4) Hsing-pei-tou, Taipei Hsien; (5) Sun-moon Lake; (6) Lou-shau; (7) Pa-shien-shan; (8) Ta-zu-lin shan, Ping-tung Hsien; (9) Tayuling; (10) Taipei vicinity; (11) Zoo, Taipei; but soil of (4)-(7) were dry and old, no mucoraceous fungi were isolated.

4. In isolation and cultivation of these molds, it was found that environmental

factors play an important role on their modes of growth, especially, the kind of media used gave most marked effect on the height and color of their turf. Therefore, all through the course of this study, the synthetic mucor agar medium was selected for use. Moreover, as the optimum temperature for these fungi is found to be around 25°C, no growth took place below or above that range, so in order to keep the cultures in good growth condition, a constant optimum temperature was maintained.

5. Most of the cultures examined reproduce by asexual means, that is, sporangiospores or conidia. However, the formation of zygospores has also been observed such as in (3–4)×(3–5), which is probably *M. fragilis*.

In order to study more precisely their mating types, strain (3–4) was crossed by a strain of close resemblance (3–6), the appearance of zygospores soon occurred, this was also observed in (3–4)×(3–5), but when (3–5), (3–6) were crossed, no zygospores were observed. This may indicate that (3–5) and (3–6) are the same strain of a mucoraceous species, but when (3–4), (3–5), (3–6)×(3–1) were mated respectively, they also gave no zygospores. So now we are sure that (3–4) and (3–5) might be different strains of *M. fragilis* and they are probably heterothallic in nature.

6. All of the pure cultures, resulting from this investigation, are deposited in the mycology laboratory of the Department of Botany of this university for further studies.

## LITERATURE CITED


BARRON, G. L., 1971. In C. Booth, Methods in Microbiology, **4**: 413–415.

BULLER, A. H., 1958. The Biology & Taxonomy of Pilobolus, in Researches on Fungi VI, Part I, pp. 1–169.

CHANG, D. Y., 1966. The cultivation of Pilobolus kleinii in vitro, unpublished thesis. Bot. Dept., National Taiwan University.

CHIEN, C. Y., 1972. A Taxonomic Study of the Mucorales in Taiwan (I). Biological Bull. Nat. Taiwan Nor. Univ., pp. 129–133.

GRAMS, W., C. Y. CHIEN & K. H. DOMSCH, 1972. Zygospore formation by the heterothallic Mortierella elongata and a related homothallic species, M. epigama sp. nov. Trans. Br. Mycol. Soc., **58**(1): 5–13.

GILMAN, J. C., 1957. A manual of Soil Fungi, pp. 13–69. The Iowa State Univ. Press. Ames, Iowa, U. S. A.

HESSELTINE, C. W., 1954. The section Genevensis of the genus Mucor. Mycologia, **46**(3): 358–366.

_____, 1955. Genera of Mucorales with notes on their synonymy. Mycologia, **47**(3): 344–363.

HIROHARU, I., 1962. Studies on Japanese Mucorales 1. on the genus Syncephalis, Science Reports on the Tokyo Kyoiku, Sec. B, No. 160.

POVAH, A. H. W., 1971. A critical study of certain species of Mucor. Bull. Torrey Bot. Club, **44**: 241–313.

SAWADA, K., 1919. Descriptive Catalogue of Taiwan Fungi Part I. Published by Agricultural Experiment Station, Formosa.

_____, 1942. Descriptive Catalogue of Taiwan Fungi Part VII. Published by Agricultural Experiment Station, Formosa.

_____, 1959. Descriptive Catalogue of Taiwan Fungi Part XI. Published by the college of Agriculture, National Taiwan University.

SNYDER, W. C., S. M. NASH & E. E. TRUJILLO, 1959. Multiple colonal types of Fusarium solani Phaseoli in field soil. Phytopathology, **49**: 310.

WARCUP, J. H., 1950. The soil-plate method for isolation of fungi from the soil. Nature, **166**: 117.

WEHMER, C., 1893. Beitrag zur kenntnis einheimischer Pilze, I. Swei nere Schimmelpilze als Erreger einer Citronen sauregahrung. Hannover and Liepzig (Hahn) p. 92.

ZYCHA, H., & R. SIEPMANN, 1969. Mucorales. Verlag Von J. Cramer.

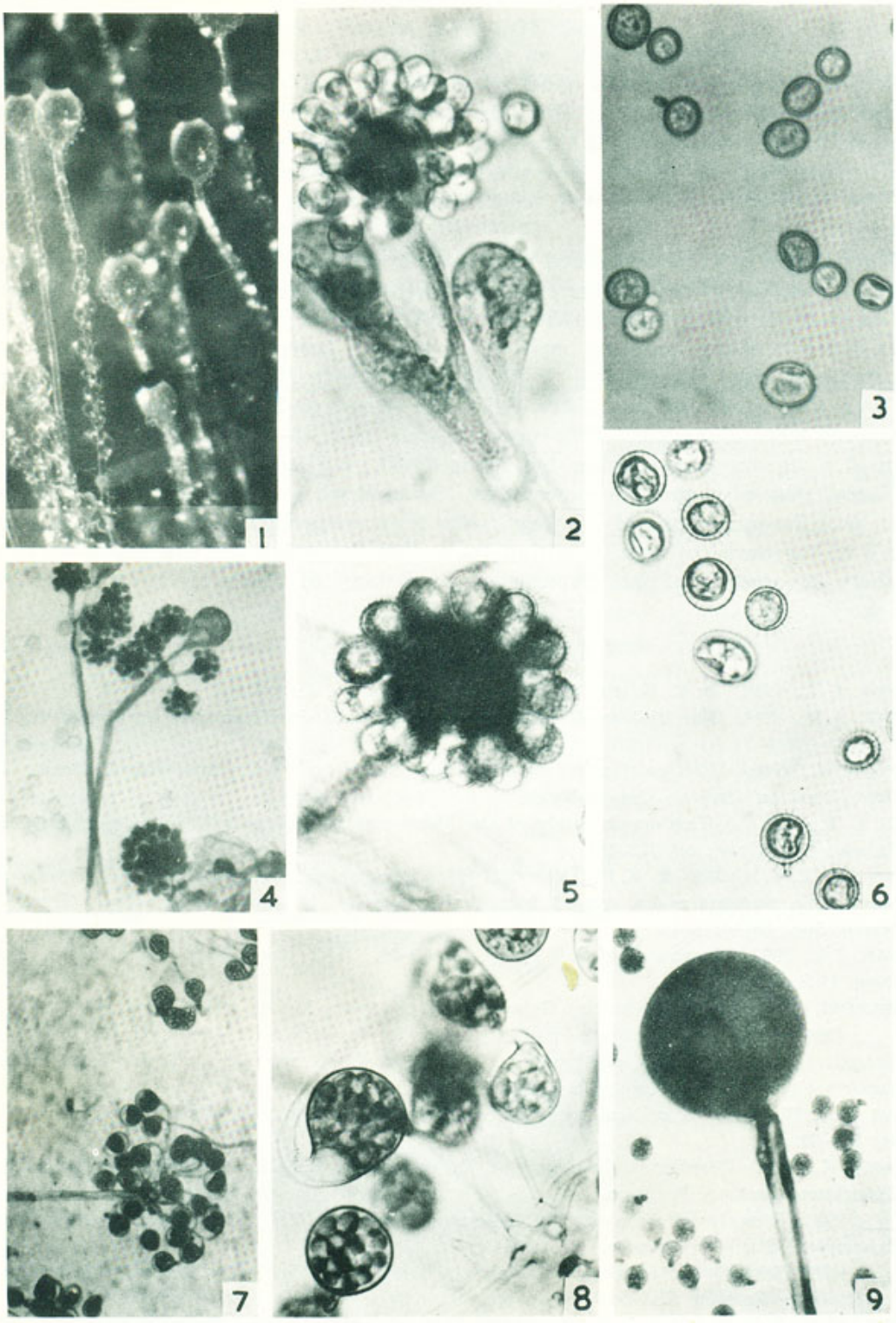


**Plate I.** 1 *Pilobolus kleinii*, sporangia and subsporangial swellings, ×16; 2-3. *Cunninghamella elegans*; 2. Terminal and lateral vesicles, ×1000; 3. Spores, ×1000; 4-6. *C. echinulata*; 4. Branched conidiophores, ×250; 5. A single head with conidia attached, ×1080; 6. Echinulate conidia, ×1080; 7-9. *Helicostylum piriforme*; 7. Habit, showing sporangioles on coiled branchlets, ×250; 8. Portion of 7. enlarged to show branchlets, stipe and spores within, ×1000; 9. A large spherical sporangium, with columella, ×1000.

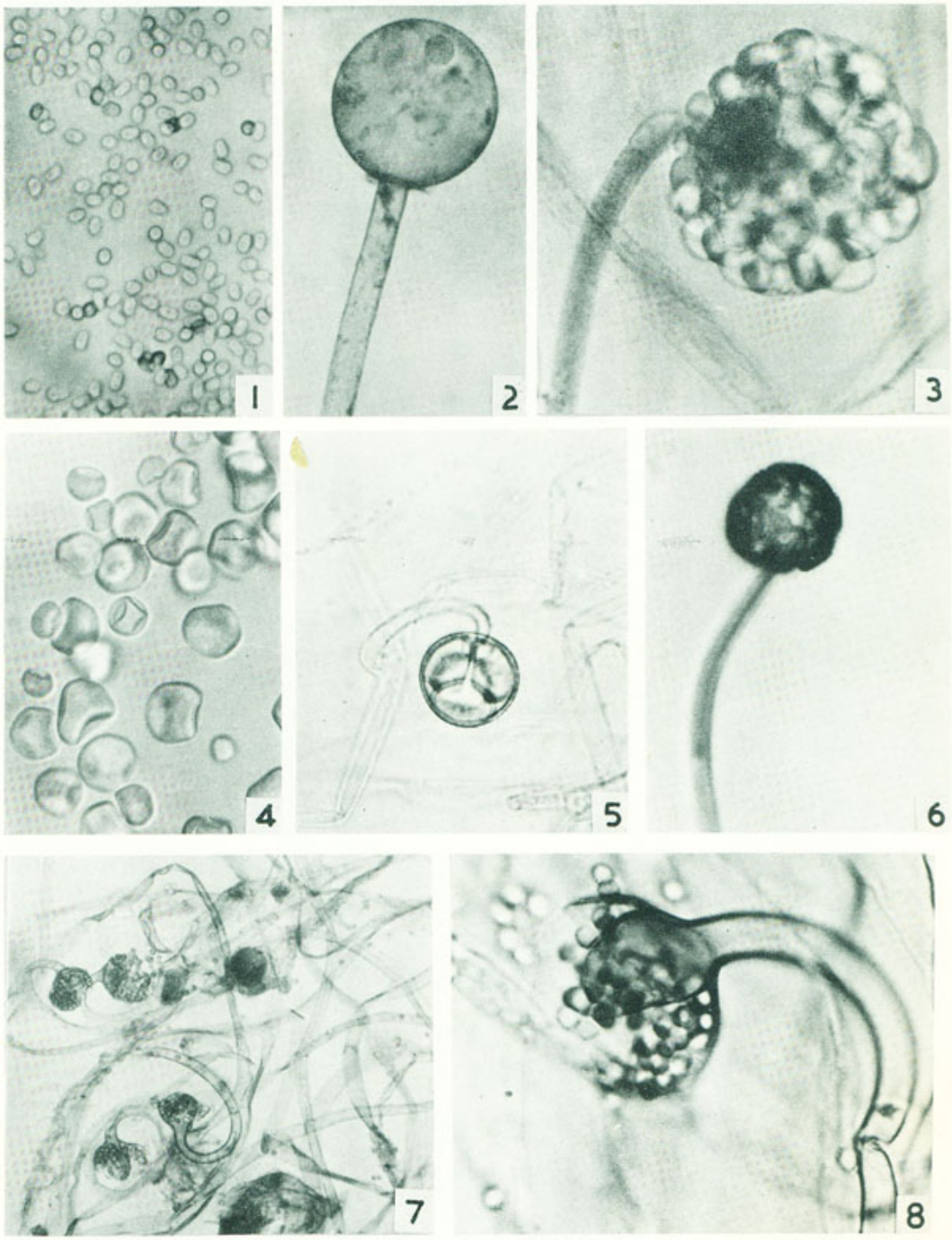


**Plate II.** 1-2. *Mucor abundans*; 1. Spores, ×1000; 2. Columella, ×1000; 3-6. *M. dispersus*; 3. Large sporangium, ×1000; 4. Spores, ×1000; 5. One 4-spored sporangiolum on circinate branchlet, ×1000; 6. Sporangium, showing echiunlate wall, ×1000; 7-8. *Circinella rigida*; 7. Showing circinate sporangiophore and sporangia ruptured, ×250; 8. A sporangium showing pear-shaped columella and septate sporangiophore, ×1000.

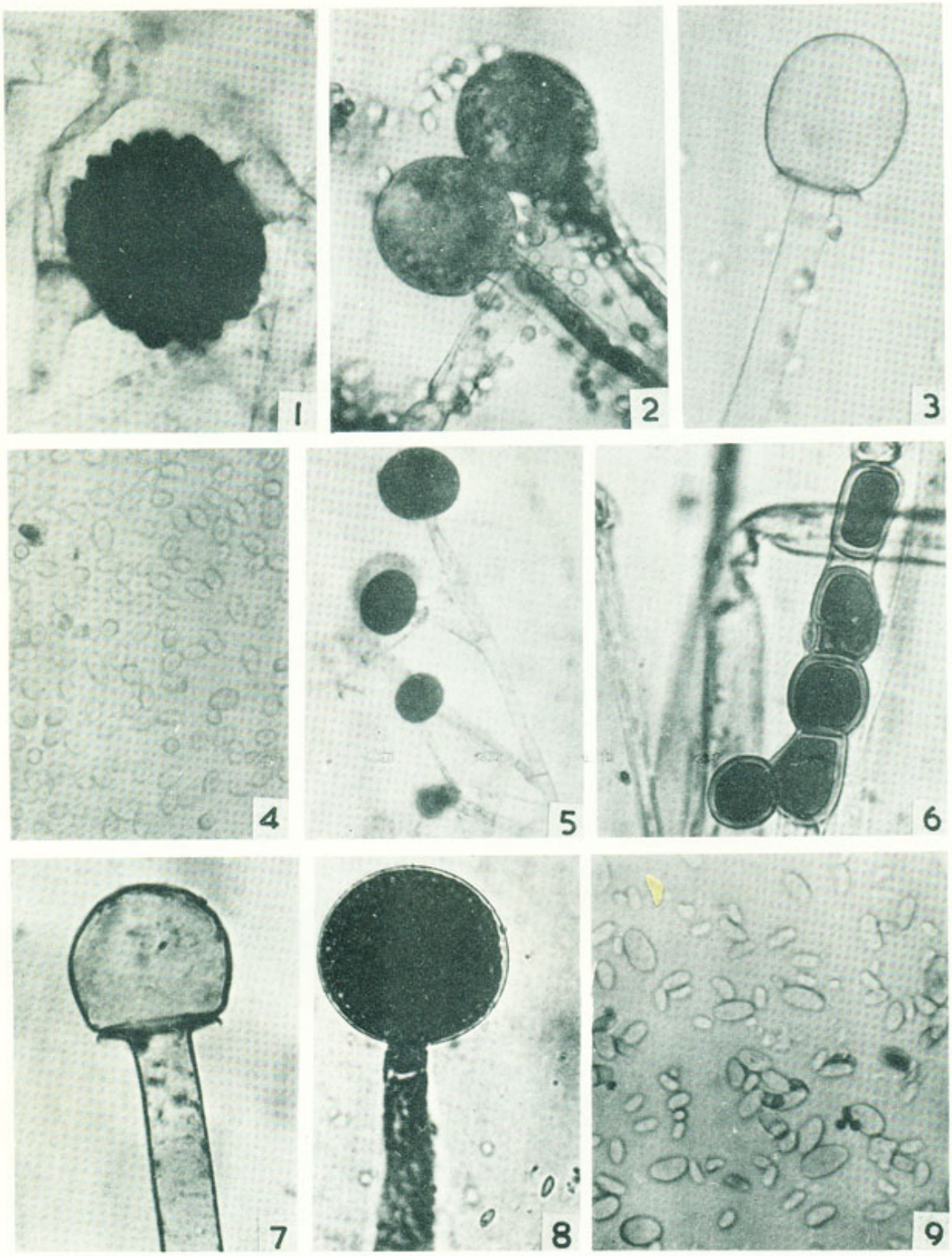


**Plate III.** 1. *Mucor sp.* zygospore produced by (3-4), (3-6), ×700; 2-5. *M. fragilis*; 2. Columella with spores, ×1000; 3. Collumella with collarette, ×1000; 4. Spores, ×1080; 5. Branched sporangiophores, ×270; 6-9. *M. hiemalis*; 6. Chlamydospores, ×1080; 7. Columella, ×1080; 8. Sporangium, ×756; 9. Spores, ×1000.

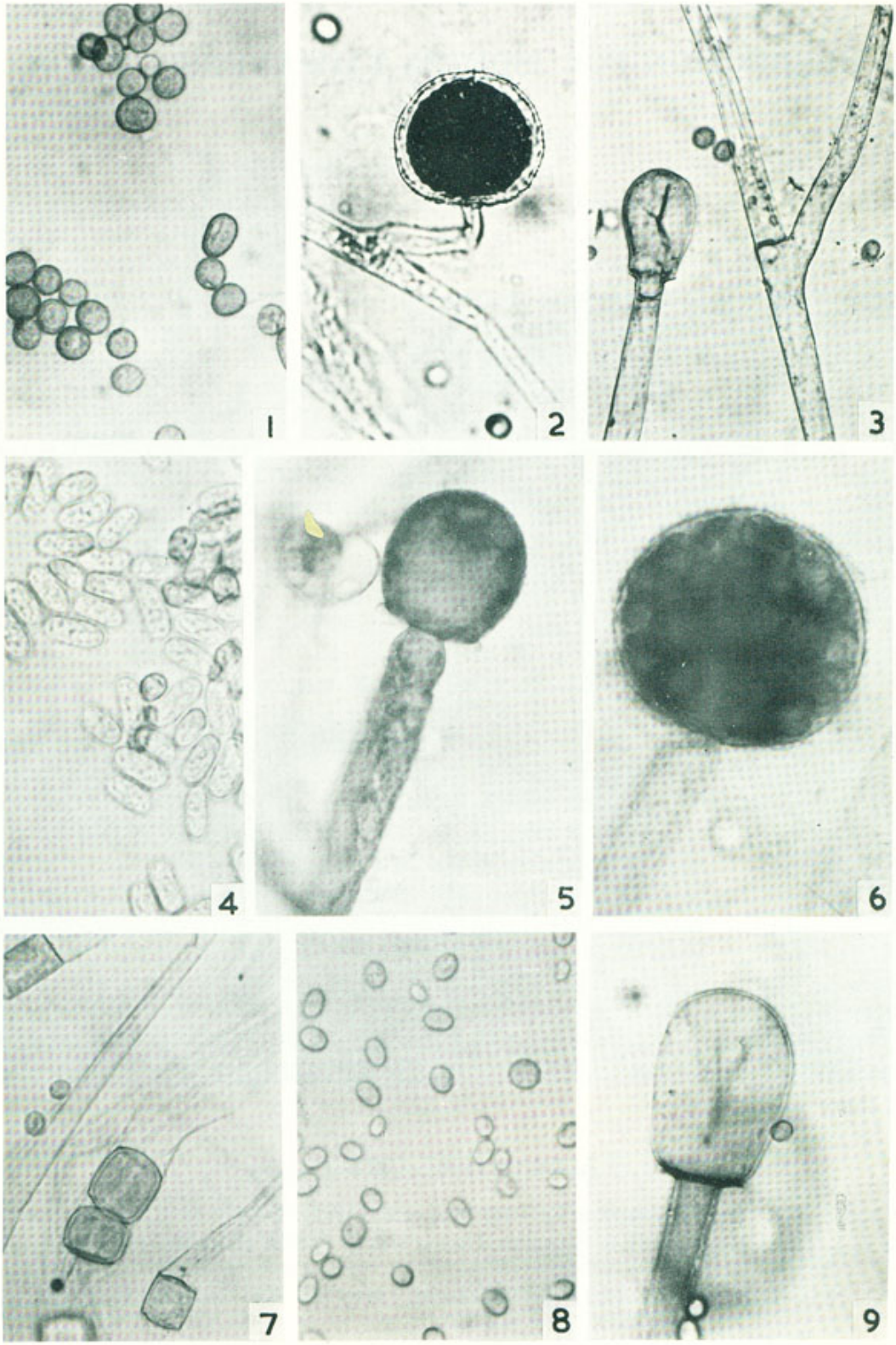


**Plate IV.** 1-3. *Mucor janssenii*; 1. Spores, ×1080; 2. Sporangium, showing surface feature, ×756; 3. Columella and branched sporangiophores, ×1080; 4-6. *M. mucedo*; 4. Spores, ×1080; 5. Columella with collarette, ×756; 6. Sporangium, ×1080; 7-9. *M. rancemosus*; 7. Chlamydospores, ×770; 8. Sporangiospores, ×1100; 9. Columella with collarette, ×770.