The Section Sphaerosporus of Mucor - A Reassessment

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(With 4 Text-figs. and 3 Plates)

Sphaerosporus section of the genus *Mucor* includes species with sporangiospores usually spherical but occasionally with few short oval ones also. Zycha (1935) had placed 7 species viz., *Mucor pusillus* Lindt, *M. spinosus* van Tieghem, *M. dispersus* Hagem, *M. petrinsularis* Naumov, *M. lamprosporus* Lendner, *M. jansseni* Lendner and *M. globosus* Fischer in this Section. Linnemann (1936) added a variety of *M. dispersus* viz., *M. dispersus* var. *megalospora* and Hesseltine (1950) added 3 more species viz., *M. psychrophilis* Hesseltine, *M. brunneus* Naumov, and *M. berolinensis* Naumov. Since then five more species have been added, by various authors, to this section. They are — *M. kurssanovii* Milko and Beljakova (1967), *M. kanivcevii* Pavl. and Milko (1965), *M. miehei* Cooney and Emerson (1964), *M. suhagiensis* Mehrotra (1964 and *M. assamensis* Mehrotra and Mehrotra (1969). Recently Sarbhoy (1968) has revised this section and has added one more species, i. e., *M. brunneo-griseus* Sarbhoy (1968).

Species of *Mucor* are gaining importance because of their increasing use in making foods of different flavours. Out of the species of the section Sphaerosporus, *M. pusillus* Lindt, at present, is the most important. It is a thermophilic species and has been found to be of much use in cheese making (Rogosa and Sharpe, 1959; Arima et al., 1964). The Chedder type cheese made with coagulating enzyme obtained from this species exhibited the same characteristics as that of veal rannet extract. With the help of this coagulant several other cheese types have been successfully made on an experimental scale.

Being a thermophilic fungus *M. pusillus* also plays an important role in the decomposition of certain plant materials. Some of these organisms have been definitely associated with the process of microbial thermogenesis and the subsequent breakdown of such materials as manure, hay, guayule, mushroom compost, and other composting material. Undoubtedly, they also play a part in instances of spontaneous combustion of stored hay and grain. It is felt that their role in the fodder preparation may likely be as important as that of the current practice of adding antibiotics to animal feeds (Cooney and Emerson, 1964).

In view of the prevailing uncertainties regarding the status of the species of the section, it was considered desirable to undertake a reassesment of the available species and strains. The work was begun in August 1965 and in the meantime, the results of a survey of the species of the same section undertaken at CMI, were published by A. K. Sarbhoy (1968) who was earlier assoiated with this laboratory. This work has been of additional help in this study.

Among the earlier know species of this section some of them have been considered by nearly all monographers to be valid species. They are *M. pusillus* Lindt (1886), *M. globosus* Fischer (1892), *M. jansseni* Lendner (1907) and *M. lamprosporus* Lendner (1908). Later known species of this section are: *M. plumbeus* Bonorden (1864), *M. spinosus* van Tieghem (1876), *M. sphaerosporus* Hagem (1910), *M. plumbeus* var. *recurvus* Grove (1884), *M. petrinsularis* Naumov (1915), *M. berolinensis* Naumov (1933), *M. albatere* var. *sphaerosporus* Neumov (1939), *M. brunneus* Naumov (1939), *M. dispersus* var. *megalospora* Linnemann (1936), *M. psychrophilis* Hesseltine (1950), *M. miehei* Cooney and Emerson (1964), *M. suhagiensis* Mehrotra (1964), *M. kanivcevii* Pavl. & Milko (1965), *M. kurssanovii* Milko and Beljakova (1967), *M. falcatus* Schipper (1967), *M. strictus* Schipper (1967), *M. fuscus* Bainier (1903), *M. brunneo-griseus* Sarbhoy (1968), and *M. assamensis* Mehrotra and Mehrotra (1969).

The controversial species are being discussed here:

Mucor plumbeus Bonorden, Adh., naturfarsch Ges. Halle, 8, 109, 1864.

The isolates usually bearing spine or spines on the columellae and often having verrucose to spiny sporangiospores have been placed — from time to time — under four different species. The oldest named species, out of these four, is *M. plumbeus* Bonorden created in 1864. Later van Tieghem in 1876 named a new species *M. spinosus* and also maintained the species *M. plumbeus* Bonorden. Lendner in 1908 created another species *M. spinescens* and distinguished it from *M. plumbeus* mainly on the basis of slightly smaller sporangiospores. He, however, considered *M. spinosus* van Tieghem to be a synonym of *M. plumbeus* Bonorden. In 1929 Pispek created a species *M. adriaticus* with almost similar characters, neglecting the species already known. Still later, in 1935, Naumov created a species *M. brunneus* which he distinguished from *M. plumbeus* mainly on the basis of lesser height of the colony, smaller sporangia and echinulate sporangiospores in the former. Naumov considered *M. spinescens* Lendner and *M. recurvus* Grove as varieties of *M. plumbeus,* and also created a new variety, *M. plumbeus* var. *nana* Naumov. Hesseltine (1950) maintained *M. brunneus* as distinct from *M. plumbeus* while Sarbhoy (1968) made it a synonym of *M. plumbeus.* No definite reasons for this view have been advanced. The authors have examined an isolate from soil which resembled in all characters with Bonorden's *M. plumbeus.* The sporangia in this

strain are of the size range as described by Naumov for *M. plumbeus* and has echinulate instead of roughened sporangiospores as described by Naumov for *M. brunneus*. It is premature to express any opinion on the status of *M. brunneus*. However, from the isolates that have been studied there seems to be no point in retaining *M. brunneus*. It has therefore, been considered here a synonym of *M. plumbeus*.

M. sphaerosporus Hagem, Christiania Vidensk. — Selsk. Skrift I. Math.-naturw. Kl. No. 4, 1—152, 1908.

This species was created by Hagem in 1908 on the basis of slight differences from the earlier known species, *M. globosus* Fischer. This was not acceptable to Zycha (1935), Hesseltine (1950), and Sarbhoy (1968). However, Lendner (1908) and Naumov (1939) maintained both the species. In the opinion of the writers the earlier known species *M. globosus* Fischer (1892) should be maintained and *M. sphaerosporus* should be abandoned as there are no substantial differences between the two.

M. dispersus Hagem. Annls. mycol. 8, 271, Fig. 4, 1910.

This species was created by Hagem in 1910 and so far has been distinguished from *M. lamprosporus* on the basis of the presence of giant cells in this species. Since then all the monographers have accepted the validity of this species. Recently Schipper (1969) questioned its validity on the basis of mating reactions. She has come to the conclusion that *M. dispersus* is a synonym of *M. lamprosporus*. The authors have examined a culture, Mx. 30 described as M. Lamprosporus Baijal & Mehrotra, 1965) and which has been included by Schipper (1969) in his study of the strains of *M. lamprosporus* Lendner, and also a culture of *M. lamprosporus* received from CBS, Baarn. It has been found that *M. dispersus* differs from *M. lamprosporus* in having a colony with lesser height, smaller sporangia and larger sporangiospores, besides giant cells. Also, sporangiola in *M. lamprosporus* are generally found on curved branches, while in *M. dispersus* they have been observed on straight branches, and thus, like other monographers the authors too maintain both these species. Our strain Mx. 30 of *M. lamprosporus* is now considered by Ellis and Hesseltine (1969) as a strain of their species of the new genus *Backusella*. On a re-examination of this isolate it was found that this isolate could be a strain of *Backusella circina* Ellis and Hesseltine (1969) because of the occurence, though rare, of conidia in this isolate.

Further, a variety of *M. dispersus* named by Linnemann in 1936 as *M. dispersus* var. *megalospora* has also been examined by the authors. It is considered to be a valid variety of *M. dispersus* as it exhibits the characteristic features of the species but differs from it in the size-range of sporangiospores, which are larger in the variety.

M. fuscus Bainier, Bull. Soc. Mycol. France, 19: 153—172, 1903.

This species was erected by Bainier in 1903, but due to incomplete description and possibly due to non-availability of type culture, it remained un-noticed by later students of the genus *Mucor* particularly Lendner, Zycha, Hesseltine and Sarbhoy. In 1915 Naumov erected a species apparently on the basis of repeatedly branched sporangiophores, in which branches arise immediately below a septum formed near a sporangium. Since then this species has been maintained by all monographers. Recently, Schipper (1967) had examined a culture deposited by da Fonseca and which originated from Bainier's collection. She was of the opinion that this culture had all the characters of Bainier's *M. fuscus* and that it resembles Naumov's species *M. petrinsularis.* It has, therefore, been suggested that the species name *M. fuscus* be maintained in preference to *M. petrinsularis* on the basis of priority, a view with which the authors also agree.

M. miehei Cooney and Emerson, Thermophilic fungi. San Francisco and London W. H. Freeman & Co.

Cooney and Emerson (1964) described a new thermophilic species to distinguish from the earlier known thermophilic species *Mucor pusillus* Lindt. They distinguished the species on the basis of slight differences in colony colour, depth of colony, size of sporangia (50—80 μ in *M. pusillus* and 30—60 μ in *M. miehei,* slight difference in zygospore size (45—63 μ in *M. pusillus,* 30—60 μ in *M. miehei*), slower growth between 20—30° C in *M. pusillus* and extremely slow in *M. miehei* and no growth at 57° C of *M. pusillus* but slight growth at 57° C of *M. miehei.* The most important difference between the two however, was the heterothallic nature of *M. pusillus* as against the homothallic of *M. miehei.*

Later, Smith (1957) found a strain of *M. pusillus* which resemb-

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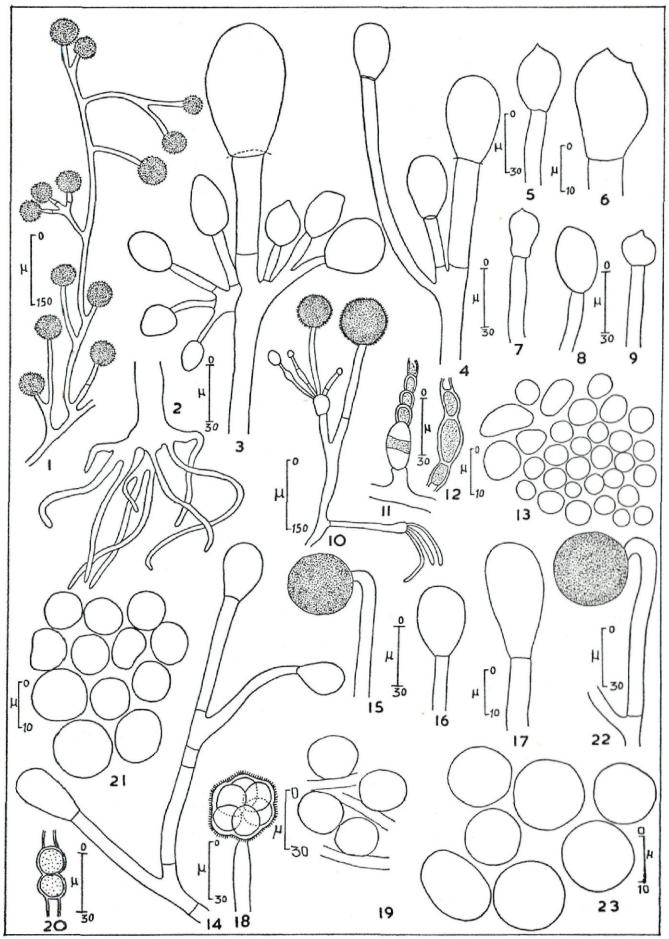
Text Figure I

Figs. 1—13. *Mucor pusillus* Lindt — 1. A portion of sporangiophore showing the pattern of branching. 2. Rhizoid like structures from the base of sporangiophore. 3. Upper portion of a sporangiophore showing the pattern of branching with terminal columella and lateral columellae. 4—9. Columellae. 10. An abnormal sporangiophore showing proliferations. 11—12. Chlamydospores. 13. Sporangiospores.

Figs. 14—21. *Mucor dispersus* Hagem — 14. Sporangiophore showing monopodial branching. — 15. An young sporangium. 16—17. Columellae. — 18. Sporangiolum at the tip of a sporangiophore. — 19. Giant cells. 20. Chlamydospores. 21. Sporangiospores.

Figs. 22—23. *Mucor dispersus* var. *megalospora* Linnemann — 22. An young sporangium. 23. Sporangiospores.

led with asexual features described for *M. pusillus* but which produced zygospores even in single spore culture. Schipper (1969) compared Smith's homothallic strain of *M. pusillus* with the homothallic species *M. miehei* and remarked that there is no difference between the asexual stage of the two species but the zygospores of the two are ob-



viously different. The zygospores of *M. miehei* are smaller and the suspensores are shorter than in the case of *M. pusillus*. We are of the opinion that the best course would be to isolate a number of strains resembling *M. pusillus* and *M. miehei* and then evaluate the characteristics on which the earlier authors have emphasized in distinguishing the two species before we can comment on the validity of the two species. For the time being it may be worthwhile to retain the species *M. pusillus* and *M. miehei*. In the present study only one strain, isolated earlier in this laboratory and resembling *M. pusillus*, was examined.

M. suhagiensis M. D. Mehrotra, Sydowia, 17, 283, 1964

In 1964 Mehrotra (M. D.) while working in this laboratory found a species of *Mucor* which he described as *M. suhagiensis*. The main characteristics of this species are: — the markedly septate sporangiophores, presence of sporangia of two size ranges, the terminal sporangia prominently larger than the lateral ones, with the later usually circinately borne. It shows resemblance to *M. plumbeus* because of the presence of echinulate spores. As M. D. Mehrotra had left no culture of this isolate here, therefore it was not available to subsequent workers. Sarbhoy (1968) doubted the validity of *M. suhagiensis* because a culture of this species was not available to him. Later Baijal (1965) again isolated this species from a soil sample of Darjeeling collected by one of us, Mehrotra, B. S. and this culture showed all the characteristics of *M. suhagiensis*. The authors have studied this species fully and its validity seams unquestionable.

M. kanivcevii Pavlenko and Milko, Nov. Sys. Plant. Vas. 101, 1965.

Pavlenko & Milko (1965) erected a new species in 1965 and named it *M. kanivcevii*. At 10° C it produces sporangiospores which are mainly cylindrical and rarely spherical, while at 20° C it produced mainly globose, rarely oval spores. Schipper (1967) concluded from a comparison of this species and that of *M. strictus* that *M. kanivcevii* is the "room temperature (18—20° C) state" of *Mucor strictus*. She thought that *M. kanivcevii* should be considered a synonym of *M. strictus*. A culture of *M. kanivcevii* was obtained through the courtesy of the Director, CBS. It has been found that at both, 10° and 20° C, it produced only cylindrical or oval sporangiospores and therefore, this species should not be included in the sphaerosporus section and it has therefore, been eliminated from the present study. Sarbhoy (1968) examined a culture of this species and came to a similar conclusion. In his opinion this species resembles with *M. geophilus* Oudemans and may be placed in the Petropolitanus section rather than the Sphaerosporus section.

M. kurssanovii Milko & Beljakova, Mikrobiologiya, 36, 118, 1967.

This species was erected by Milko and Beljakova in 1967 but it has subsequently been found by Schipper (1969) to be a synonym of *M. jansseni*. However, Sarbhoy (1968) tentatively maintained this species but he had no culture with him of this species. According to Schipper, who had studied the type culture of *M. kurssavovii*, it resembles very much *M. jansseni*. No culture of *M. kurssanovii* was available to the authors, however, they are inclined to accept Schipper's view as the evidence presented by her in favour of her view seems to be conclusive.

M. falcatus Schipper, Antonie van Leeuwenhoek, 33, 189—195, 1967.

This species was created recently by Schipper in 1967 on the basis of a strain originating from Zycha's collection, which Zycha thought to be *M. strictus*. Zycha's strain differed from Hagem's description of his species *M. strictus* in the sporangiophore being limp, drooping, sympodially branched and with a bent main stalk, sporangia yellowish brown, columellae with a flattened base and with sporangiospores mainly globose. Although, no culture of this species was available to the authors, from the description and discussion that have been given by Schipper (1967), it seems best to recognise this species.

A list of the species considered doubtful and of which neither the cultures nor sufficient data are available, is given below:

M. fimetarius Link (1809); *M. fondinus* Link (1824); *M. lateritius* Link (1824); *M. delicatulus* Berk. (1826); *M. paolettianus* Ber. et Toni (1888); *M. globosus* var. *intermedius* Sacc. (1913); *M. subchlorosporus* Naumov (1915); *M. bedrchani* Schmidt (1925); *M. adriaticus* Pispek (1929); *M. macrosporus* Pispek (1929); *M. buntingii* Lender (1930); **M. coccineus* (Mark) Fres. (1932); *M. berolinensis* Naumov (1933); *M. hagemii* Naumov (1939); *M. alboater* var. *sphaerosporus* Naumov (1939); *M. stagnalis* Novotelonova (1950); **M. chibinensis* Neophytova (1955); **M. turfosus* Neophytova (1955); and *M. psychrophilis* Hesseltine (1950).

The results of the physiological studies reported show some interesting nutritional differences between the species. However, it has not been considered desirable to include these differences in the key to the species presented here, as we must confirm these differences after testing several strains of the different species recognised here. This was not possible with the present collection of the cultures, but it will be worthwhile undertaking this type of study sometime later.

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* References to these species are not available.

A. Carbon Sources:

1. Species not assimilating arabinose: *M. assamensis.*
2. Species not assimilating xylose: *M. dispersus, M. dispersus* var. *megalospora, M. brunneo-griseus, M. globosus.*
3. Rhamnose assimilating species: *M. suhagiensis.*
4. Species not assimilating galactose: *M. assamensis.*
5. Mannose utilizing species: *M. suhagiensis, M. plumbeus, M. jansseni, M. jansseni* var. *indica.*
6. Sorbose utilizing species: *M. suhagiensis.*
7. Species not utilizing maltose: *M. pusillus* and *M. assamensis.*
8. Sucrose utilizing species: *M. plumbeus, M. suhagiensis, M. fuscus, M. lamprosporus.*
9. Lactose utilizing species: *M. pusillus, M. suhagiensis* and *M. lamprosporus.*
10. Raffinose utilizing species: *M. pusillus* and *M. suhagiensis.*
11. Species not utilizing dextrin: *M. dispersus, M. dispersus* var. *megalospora, M. assamensis* and *M. globosus.*
12. Inulin utilizing species: *M. suhagiensis.*
13. Sorbitol utilizing species: *M. pusillus, M. plumbeus, M. suhagiensis, M. jansseni, M. jansseni* var. *indica* and *M. fuscus.*
14. Mannitol utilizing species: *M. pusillus, M. plumbeus, M. suhagiensis* and *M. jansseni* var. *indica.*
15. Citric acid utilizing species: *M. plumbeus* and *M. jansseni.*

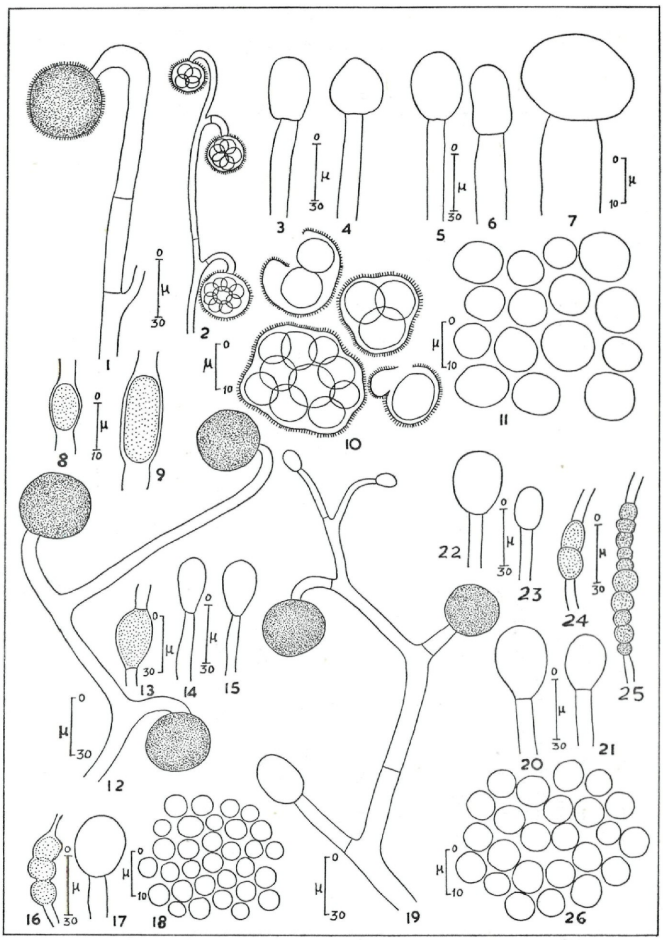
B. Nitrogen Sources:

1. Species not utilizing sodium nitrate: *M. brunneo-griseus, M. jansseni* and *M. jansseni* var. *indica.*
2. Species not utilizing sodium nitrite: *M. jansseni* and *M. jansseni* var. *indica.*
3. Species utilizing NH_4Cl: *M. pusillus, M. plumbeus* and *M. assamensis.*
4. Species not utilizing alanine: *M. dispersus, M. dispersus* var. *megalospora, M. brunneo-griseus* and *M. fuscus.*

Text Figure II

Figs. 1—11. *Mucor lamprosporus* Lendner — 1. An young sporangium. 2. A portion of sporangiophore with sporangiola at their tips. 3—7. Columellae. 8—9. Chlamydospores. 10. Magnified sporangiola showing one to ten sporangiospores. 11. Sporangiospores.
Fig. 12—18. *Mucor jansseni* Lendner — 12. Upper portion of sporangiophore showing the pattern of branching. 13 & 16. Chlamydospores. 14, 15 & 17. Columellae. 18. Sporangiospores.
Figs. 19—22. *Mucor jansseni* var. *indica* Mehrotra & Baijal — 19. A portion of sporangiophore showing the pattern of branching. 20—23. Columellae. 24—25. Chlamydospores. 26. Sporangiospores.

5. Histidine utilizing species: *M. pusillus, M. dispersus, M. plumbeus* and *M. suhagiensis.*
6. Species not utilizing glutamic acid: *M. assamensis* and *M. globosus.*



Key to Species of *Mucor* of the Sphaerosporus Section:

A. Species growing best at low temperatures, sporangiophores with a bent main stalk	*M. falcatus* Schipper (1967)
AA. Species growing best at high temperatures, colony much low with thick turf, deep neutral gray to hair brown	B
B. Usually heterothallic	C
C. Hyphae uncoloured, hyphae and sporangiophores not inflated, zygospores large, suspensors larger	*M. pusillus* Lindt (1886)
CC. Hyphae reddish or pale brown in colour, hyphae and sporangiophores inflated, zygospores not seen	**M. tauricus* Milko & Schkur. (1970)
BB. Homothallic, zygospores smaller, suspensors shorter	*M. miehei* Cooney & Emerson (1964)
AAA. Species growing best near 25° C, neither growing at low temperatures nor at very high temperatures (mesophilic)	D
D. Sporangiola present	E
E. Giant cells absent	*M. lamprosporus* Lendner (1908)
EE. Giant cells present in the substrate, sporangia few sporic, primary sporangia diffluent	F
F. Sporangiospores 10,5—17,5 μ (aver. 12—15 μ)	*M. dispersus* Hagem (1910)
FF. Sporangiospores larger, 14—23 μ (16—19 μ)	*M. dispersus* var. *megalospora* (Linnemann 1936)
DD. Sporangiola absent	G
G. Sporangiospores finely to strongly roughened	H
H. Projections on columellae more prominent and frequent, sporangiospores roughened	*M. plumbeus* Bonorden (1864)

*) This species has been published by Milko and Schkurenko (1970) while the manuscript of this paper was under publication. From the description it appears that the characters on which this species is based are new and the species is a valid one.

HH. Projections on columellae less prominent and infrequent I

I. Giant sporangiospores present, sporangiophores branching sympodially, nonseptate ..... *M. brunneo-griseus* Sarbhoy (1968)

II. Giant sporangiospores absent, sporangiophores branching irregularly, forming short circinate or erect branches, septate *M. suhagiensis* Mehrotra (1964)

GG. Sporangiospores smooth walled ..... J

J. Sporangiophores repeatedly branched, producing a side branch immediately below a septum formed near a sporangium, sporangiospores remaining adherent to columella and collar at maturity ..... *M. fuscus* Bainier (1903)

JJ. Not as above ..... K

K. Colony blackish in colour at maturity L

L. Colony floccose, aerial hyphae abundant, columellae with irregular broad projections, sporangiophores small, upto 250 μ (aver. 90—180 μ) . *M. assamensis* Mehrotra & Mehrotra (1969)

LL. Colony suppressed ..... M

M. Sporangiospores small (2,2 μ) 3,3—6 μ (aver. 3,3—4,5 μ) ..... *M. jansseni* Lendner (1908)

MM. Sporangiospores large (3,5 μ) 4,5—8,5 μ (aver. 5,2—6,7 μ) ..... *M. jansseni* var. *indica* Mehrotra & Baijal var. nov.

KK. Colony grayish in colour, sporangiospores less than 8 μ ..... *M. globosus* Fischer (1892)

7. Species not utilizing methionine: *M. plumbeus, M. suhagiensis* and *M. fuscus.*
8. Cystine utilizing species: *M. pusillus* and *M. lamprosporus.*
9. Species not utilizing peptone: *M. jansseni* and *M. assamensis.*
10. Urea utilizing species: *M. pusillus, M. dispersus, M. dispersus* var. *megalospora, M. plumbeus* and *M. suhagiensis.*

C. Sulphur Sources:

1. Species not utilizing ammonium sulphate: *M. assamensis.*
2. Species utilizing potassium sulphate: *M. pusillus, M. jansseni, M. jansseni* var. *indica* and *M. lamprosporus.*
3. Cystin utilizing species: *M. pusillus* and *M. lamprosporus.*
4. Species not utilizing methionine: *M. assamensis* and *M. globosus.*
5. Species not utilizing thiourea: *M. assamensis.*
6. Sodium sulphite utilizing species: *M. pusillus, M. fuscus* and *M. lamprosporus.*

Descriptions of the isolates

Mucor pusillus Lindt, Arch. exp. Path. Pharmak. 21, 272, 1886 (Text Fig. I: 1—13; Plate I, Figs. 1—2).

M. cornealis Sacc., 1913.
M. buntingii Lendner, 1930.

Colonies on oat-meal agar and SMA 2—3 mm high, at first whitish gray, later deep neutral gray to hair brown, turf low much thick; sporangiophores sympodially branched, often with a septum above the origin of branches, upto 17.5 μ in diameter, in some liquid cultures rhizoid-like structures present, sometimes abortive branches proliferating from sporangiophores; sporangia spherical, mostly 45—90 μ, sometimes upto 110 μ in diameter, sporangial wall incrusted, bright gray to brown, deliquescing; columellae oval or pear shaped or slightly elongate, 20—55 × 15—37 μ in size, average 22—45 × 15—28 μ, often with a collar; sporangiospores globose to subglobose, sometimes oval to slightly irregular, 2.5—4.5 μ oval ones 4.5—12.5 μ in size, averaging 3—3.3 μ (— 6 μ); chlamydospores present in only liquid cultures, terminal or intercalary, oval to irregular in shape, 7—14 × 5.2—12 μ in diameter; zygospores not seen; growth poor at 20° C but good at the temperature range of 30—50° C.

Description based on culture No. Mx. 2, isolated from soil of Gorakhpur by Baijal (1965). From India it has been reported earlier by Sarbhoy (1963), Mehrotra (1965), Baijal & Mehrotra (1965) and Nand (1967).

Mucor lamprosporus Lendner, Mucor. d. 1. Suisse 3 (1): 92 1908

(Text Fig. II: 1—11; Plate I, Fig. 6—8).

Colonies on oat meal agar, PDA and SMA white, 2—3 cm high and cottony; sporangiophores at first curved, later erect, unbranched or with a short curved branch; sporangia spherical, 30—60 (100) μ (mostly 30—60 μ); sporangial wall spiny and diffluent; columellae globose broader at base, sometimes oval, 10.5—28.1 (34.5) × 10.5—25 (30) μ in size; sporangiospores globose, sometimes oval, but mostly the former, hyaline 6—13.5 μ (mostly 7—9 μ) in diameter, oval ones 7.5—15 × 6—13.5 μ in size; at maturity the colony forming short, simple or mostly branched, permanently circinate sporangiophores bearing sporangiola at the tip and branches; sporangiola also produced on circinate branches from sporangiophores which terminate into sporangia sporangiola one to few sporic, caducous, non-dehiscent 15—35 (— 38) μ (mostly 15—25 μ) in diameter; wall spiny, persistent, chlamydospores and oidia formed only in liquid culture, variously shaped 8—28 μ in diameter; zygospores not seen.

Description based on an isolate obtained from CBS Culture Collection, Baarn.

M. dispersus Hagem, Annals. mycol. 8, 271, Fig. 4, 1910

(Text Fig. I: 14—21; Plate I, Figs. 3—4).

Colonies on oat-meal agar and SMA 1—2.5 cm high, white, cottony forming thick felt at 25° C with giant cells in the substrate mycelia; sporangiophores branched in monopodial clusters, 4.5—10 μ in diameter; sporangia spherical, (— 20) 30—60 μ, delicate, wall diffluent; columellae oval to hemispherical or dome shaped, 14—25 × 10.5—18.5 μ in size; sporangiola present mostly on erect sometimes curved sporangiophores arising primarily from substrate hyphae, globose, 15—45 μ, averaging 30—40 μ in diameter, 2—6 sporic, walls incrusted, fragile; sporangiospores globose to subglobose, angular, smooth 10.5—17.5 μ averaging 12—15 μ in size; chlamydospores present in liquid cultures only; zygospores not seen.

Description based on an isolate obtained through the courtesy of Director, CBS, Culture Collection, Baarn.

M. dispersus var. *megalospora* Linnemann, Flora, 130, 184, 1936

(Text Fig. I: 22—23; Plate I, Fig. 5).

This variety differs from *M. dispersus* only in two characters, firstly in having frequently largest sporangiospores, i. e., 16—23 μ, averaging 18—20 μ in size, and secondly in having slightly slower growth at 25° C.

Description based on an isolate No. 38935 obtained from CBS, Baarn through the courtesy of Director.

Mucor plumbeus Bonorden, Adh. naturforsch. Ges. Halle, 8, 109, 1864

(Text Fig. III: 22—30; Plate II, Figs. 1—2).

M. spinosus van Tieghem, 1876.

M. spinescens Lendner, 1908.

M. adriaticus Pispek, 1929.

M. plumbeus var. *spinescens* (Lendner) Naumov, 1935.

M. plumbeus var. *recurvus* (Grove) Naumov, 1935.

M. plumbeus var. *nana* Naumov, 1935.

M. brunneus Naumov, 1935.

Colonies on oat meal agar and SMA about 1 cm high at 25° C, mouse-gray; sporangiophores sympodially branched, with all branches terminating into a sporangium, with a septum just at the point of origin of a branch, upto 15.7 μ in diameter; sporangia spherical, mostly 45—100 μ, sometimes upto 120 μ in diameter; wall incrusted, diffluent; columellae oval or pear shaped, 15.5—65 × 10.5—45 μ in size, a few smaller ones oval to obovate 3.5—18 × 3.5—14 μ, furnished at the top with variable number of spine like projections; sporangiospores globose to slightly subglobose or oval, verrucose, light brown in mass, 3.7—9 μ, averaging 4.5—7.5 μ, oval ones 6—13.5 × 3.7—9 μ; chlamydospores numerous only in the liquid medium, intercalary, subglobose or oval or irregular in shape, 10.5—24 × 7—19.5 μ; zygospores unknown.

Description based on an isolate from soil of Calcutta. Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad, under Mx. 42.

From India it has been reported by Mehrotra, Baijal & Mehrotra (1965), Nand (1967) and Prasad (1968).

Mucor brunneo-griseus Sarbhoy, Trans. Br. mycol. Soc. 51 (1), 25—32, 1968

(Text Fig. III: 16—21; Plate II, Figs. 3—4).

Colonies on oat meal agar and SMA 1 cm high at 25° C, at first white, later deep gray or brown; sporangiophores repeatedly sympo-

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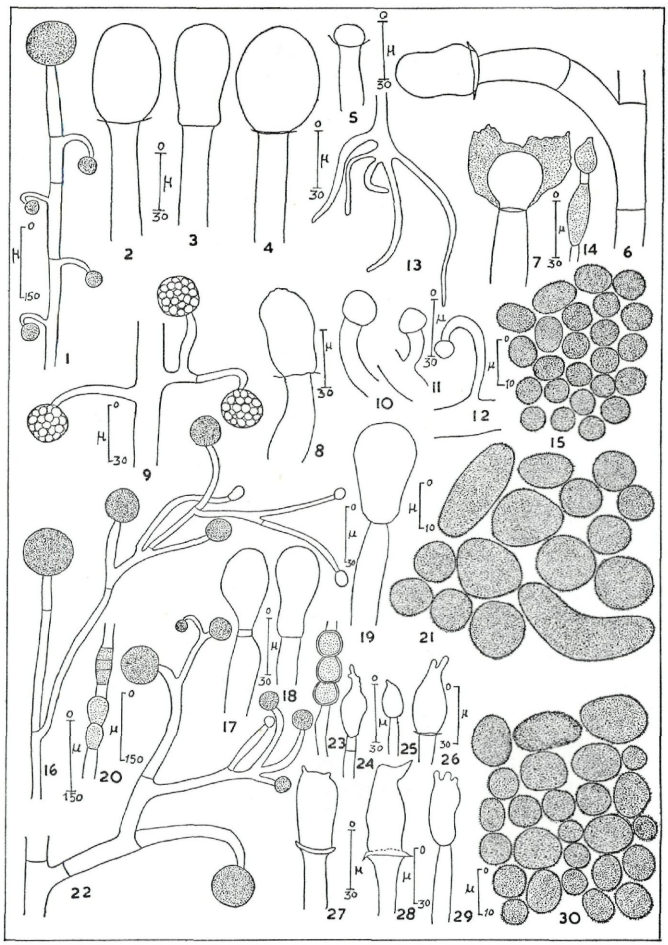
Text Figure III

Figs. 1—15. *Mucor suhagiensis* Mehrotra — 1. Upper portion of a sporangiophore with terminal and lateral sporangia. 2—8. Columellae of terminal sporangia. 9. Portion of a sporangiophore showing secondary sporangia. 10—12. Smaller columellae of lateral sporangia. 13. Rhizoid like structures at the base of a sporangiophore. 14. Chlamydospores. 15. Sporangiospores with verrucose wall.

Figs. 16—21. *Mucor brunneogriseus* Sarbhoy — 16. A portion of sporangiophore showing the pattern of branching. 17—19. Columellae. 20. Chlamydospores. 21. Sporangiospores with verrucose wall.

Figs. 22—30. *Mucor plumbeus* Bonorden — 22. Portion of a sporangiophore showing the manner of branching. 23. Chlamydospores. 24—29. Columellae with spines at their tips. 30. Verrucose sporangiospores.

dially branched, sometimes bent with sterile ends, septation above the origin of branches, 9.5—20 μ in diameter; sporangia spherical, brownish, deliquescing, 45—120 μ, (mostly 60—90 μ); columellae of various shapes, oval, clavate, obovate to sometimes pyriform, 20.5—50 × 14—35 μ, smooth or a few with one or two infrequent projections; sporangiospo-



res globose to short oval 4.5—13.5 × 4.5—10.5 μ, averaging 6.5—8.5 μ in diameter, few giant irregular sporangiospores also present, 10.5—16.5 (— 25.5 μ) × 7.5—11.5 μ in diameter, brownish in mass, finally verrucose or roughened; chlamydospores numerous only in the liquid media which are intercalary upto 22.5 μ; zygospores not seen.

Description bosed on an isolate obtained through the courtesy of Director, CBS Culture Collection, Baarn.

Mucor suhagiensis Mehrotra M. D. Sydowia, 17, 283, 1964 (Text Fig. III: 1—15; Plate II, Figs. 5—8).

Colonies on oat meal agar and SMA 1.5—2.5 cm high at 25° C, at first bluish white later on blackish; sporangiophores septate upto 24.5 μ in diameter, at first unbranched later on branched sympodially and numerous short, mostly curved, sometimes erect, unbranched sometimes branched, branches arise; primary sporangia globose, 45—105 μ in diameter; secondary sporangia 15—72 μ mostly 30—40 μ in diameter, at maturity sporangiospores remain adherent to columella; sporangial wall incrusted, deliquescent; columellae of terminal sporangia, oval, globose, pyriform or broader than long, mostly smooth rarely with projections, 21—70 (80.8) × 21—63 (7) μ; columellae of secondary sporangia 3.5—49 × 5.25—24.5 μ; on aging sometimes secondary branches fall off; sporangiospores brown, strongly roughened, globose, sub globose to oval, 3.5—10.5 × 10.5 (— 12) μ mostly 6 μ in diameter, oval ones 6—19.5 × 4.5—13 μ, chlamydospores numerous produced only in liquid medium, oval to irregular in shape, 8.7—28 × 7—17.5 μ; zygospores unknown.

Description based on culture No. Mx. — 43, isolated by Baijal from soil of Darjeeling.

Mucor fuscus Bainier, Bull. Soc. Mycol. France 19: 153—172, 1903 (Text Fig. IV: 1—6; Plate III, Figs. 1—3).

M. petrinsularis Naumov (1915).
M. plumbeus var. *intermediatus* Zach (1935).
M. petrinsularis Naumov var. *megalosporus* Smith (1957).
M. petrinsularis Naumov var. *echinosporus* Ling Young (1930).
M. bedrchani Schmidt (1925).
M. ramiger Fosteris (1942).

Colonies on oat meal and SMA 5—8 mm high at 25° C, at first white later grayish; sporangiophores 10.5—24.5 μ in breadth, branched repeatedly with a side branch arising immediately below a septum, formed near sporangium; sporangia spherical, 30—120 μ averaging 60—90 μ, grayish brown, wall deliquescing or remaining attached to columellae; columellae pyriform, oval or pear shaped, brownish, mostly smooth sometimes with infrequent projections at tip, 21—75 × 14—48 μ;

sporangiospores globose with few short oval ones, (— 4.2) 5.2—12 μ, (mostly 8.7 μ) and oval ones 8.5—19.5 μ, smooth walled, grayish brown in mass often adhering to the columella and collar; chlamydospores produced only in the liquid media, 6.5—28 μ; zygospores not seen.

Description based on culture No. Mx. 27 isolated by Baijal from the soil of Ghazipur.

From India it has been reported earlier by Baijal and Mehrotra (1965) and Nand (1967) as *M. petrinsularis*.

M. assamensis Mehrotra and Mehrotra, Sydowia 23: 183—185, 1969

(Text Fig. IV: 7—18; Plate III, Figs. 4—6).

Colonies on oat-meal agar and SMA 2 mm high at 25° C, floccose, aerial hyphae abundant, at first white later becoming blackish at maturity; sporangiophores very short mostly 90—180 μ, sometimes upto 250 μ in length, sympodially branched, often bent, septa present just below the sporangium, 7—17.5 μ in diameter; sporangia spherical blackish, deliquescing or breaking (— 17.5) 22—45 μ (mostly 30 μ); columellae globose to subglobose or oval occasionally conical 7—25 × 5.2—17.5 μ, dark gray or blackish, frequently with irregular blunt or broad projection, sometimes smooth; sporangiospores globose to subglobose 2.5—7.5 μ (average 4.5 μ) and oval ones 7—12.5 × 6—9 μ (average 9 × 6) in diameter, smooth, hyaline, blackish in mass; chlamydospores present only in liquid media, terminal or intercalary, thick walled 9.5—25 × 7.6—18 μ; zygospores not seen.

Description based on an isolate from BSM culture collection.

M. jansseni Lendner, Muc. d. 1. Suisse, P. 38; Fig. 30, 1908
(Text Fig. II: 12—18; Plate III, Fig. 7).

M. kurssanovii Milko and Beljakova, 1967.

Colonies on oat-meal agar and SMA 4—6 mm high at 25° C becoming dark gray or bluish black at maturity; sporangiophores cymosely branched, 3.5—10.5 μ in diameter; sporangia spherical, deep bluish black, 21—70 μ, averaging 35—42 μ in diameter, wall incrusted, fragile; columellae rounded to oval (— 8.7) 10.5—45 × (— 5.2) 10.5—35 μ; sporangiospores globose rarely oval 2.2—6 μ, mostly 3.3—4.5 μ, smooth walled; chlamydospores present in only liquid media, oval, turbinate or irregular 10.5—24.5 × 7—17.5 μ; zygospores unknown.

Description based on an isolate collected from the soil of Mathura, pH 6.7. Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad, under No. Mx. 4 and also at NURD, Peoria, Illinois, U.S.A.

From India it has been reported earlier by Agnihothrudu (1957), Mehrotra, Baijal & Mehrotra (1965).

Mucor janssenii var. **indica** Mehrotra & Baijal var. nov.
(Text Fig. II: 19—26; Plate III, Fig. 8).

Caespites in „oat meal agar" et „SMA" 1—2 mm alti, caeruleo-nigrescente sporangiophori symbodialiter ramosi, 4.5—7.5 μ diam.; sporangia globose, nigrescentia, 30—75 plerumque 45—50 μ diam.; pariete incrustato, fragili; columella subglobosa vel ovoidea, grisea, 15—55 × 13—45 μ, plerumque 20—43 × 18—32 μ; sporae globosae vel subglobosae (— 3.5) 4.5—8.5 μ, plerumque 6.7 μ, ovoideae 6—11 × 5.7 μ; chlamydosporae ovoideae vel irregulares, terminales vel intercalares, 9—25 × 6—16 μ; zygosporae ignotae.

Colonies on oat-meal agar and SMA, 1—2 mm high at 25° C bluish black; sporangiophores sympodially branched, 4.5—7.5 μ in diameter; sporangia spherical, blackish, 30—75 μ (aver. 45—50 μ) in diameter, wall incrusted, fragile; columellae subglobose to oval 15—55 × 13—45 μ, averaging 20—43 × 18—32 μ, few smaller ones globose to subglobose 8.7—15 × 7—12.5 μ, grayish; sporangiospores globose to subglobose (— 3.5) 4.5—8.5 μ (mostly 6.7 μ), oval ones 6—11 × 5.7 μ in size, chlamydospores observed only in the liquid media, oval to irregular, terminal or intercalary, 9—25 × 6—16 μ; zygospores unknown.

Type: M. 100, solated from soil of Ranchi, deposited in BSM Culture Collection.

M. globosus Fischer, Rabenh. Krypt. Fl. I, pp. 202, 1892
(Text Fig. IV: 19—26; Plate III, Fig. 9).

M. heterosporus-sibiricus Schostakowitsch, 1897.
M. sphaerosporus Hagem, 1908.
M. sphaerosporus var. *major*, Naumov, 1954.
M. macrosporus Pispek, 1929.
M. turfosus Neophytova, 1955.

Colonies on oat-meal agar and SMA 1 cm high at 25° C, at first white, later becoming grayish olive in age; sporangiophores richly sympodially branched, erect, 5—20 μ in diameter; sporangia spherical 30—100 μ, sometimes upto 120 μ in diameter, brownish, wall diffluent; columellae oval, oblong or pyriform, brownish (— 25) 35—60.5 × 50.8 μ; sporangiospores globose and subglobose 3.7—7.5 μ, mostly 4.5—6 μ,

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Text Figure IV

Figs. 1—6. *Mucor fuscus* Bainier — 1—2. Upper portions of sporangiophore showing the pattern of branching. 3—4. Columellae. 5. A columella with a short spine and adherent sporangiospores. 6. Sporangiospores.
Figs. 7—18. *Mucor assamensis* Mehrotra & Mehrotra — 7—8. Upper portions of sporangiospores showing the manner of branching. 9—14. Columellae with blunt projections. 15—17. Chlamydospores. 18. Sporangiospores.
Figs. 19—26. *Mucor globosus* Fischer — 19. Upper portion of a sporangiophore showing the pattern of branching. 20. Enlarged sporangium. 21—24. Columellae. 25. Chlamydospores. 26. Sporangiospores.

sometimes oval 8—10.5 × 7.5—9 μ; chlamydospores numerous only in the liquid media, oval to irregular in shape, upto 25 μ; zygospores unknown.

Description based on culture, No. CBS 115.08 obtained through the courtesy of Director CBS.

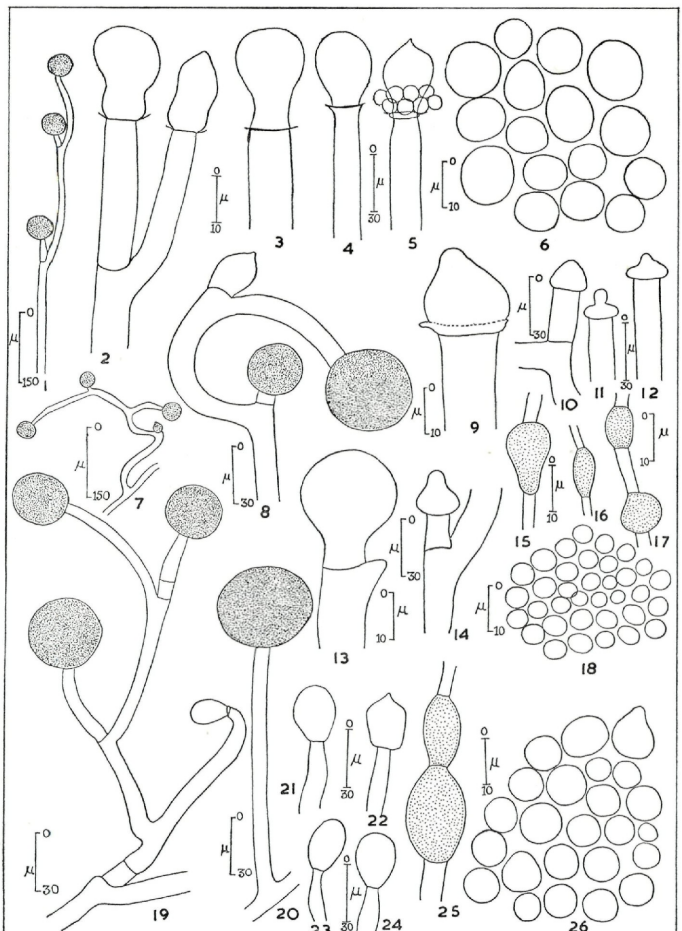

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Plate I

1—2. *M. pusillus* Lindt — 1. An unbranched sporangiophore × 500 — 2. Sporangiospores × 600.
3—4. *M. dispersus* Hagem — 3. Sporangiospores × 1300 — 4. A. portion of a sporangiophore with a sporangiolum at its tip × 600 — 5. *M. dispersus* var. *megalospora* Linnemann — 5. Sporangiospores × 1000.
6—8. *Mucor lamprosporus* Lendner — 6. A sporangiolum × 600 — 7. Columella × 600 — 8. Sporangiospores × 1000.

Plate II

1—2. *Mucor plumbeus* Bonorden — 1. Columella × 500 — 2. Sporangiospores × 2000.
3—4. *Mucor brunneo-griseus* Sarbhoy — 3. Columella × 600 4. Sporangiospores × 1000.
5—8. *Mucor suhagiensis* Mehrotra — 5. Upper portion of a sporangiophore with a sporangium at the tip × 400 — 6. Sporangiospores × 1300 — 7. Columella × 500 — 8. A sporangiophore showing the pattern of branching × 1000.

Plate III

1—3. *Mucor fuscus* Balnier — 1. A fully mature sporangium × 160 — 2. A portion of a sporangiophore showing the presence of a septum at the place of branching × 300 — 3. Sporangiospores × 2000.
4—6. *Mucor assamensis* Mehrotra & Mehrotra — 4. Upper portion of a sporangiophore showing the pattern of branching and columellae × 1000 — 5. Sporangium × 1000 — 6. Sporangiospores × 1200.
7. *Mucor jansseni* Lendner — Sporangiospores × 1500.
8. *Mucor jansseni* var. *indica* Mehrotra & Baijal — Sporangiospores × 1500.
9. *M. globosus* Fischer — Sporangiospores × 200.