

## Nine Species of *Penicillium* in Korea

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### 한국 토양중 미기록 *Penicillium* spp. 에 관한 연구

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**ABSTRACT:** Soil fungi were collected from Korean soils, from July 1990 to August 1991. Thirty three species were identified, among which nine species were newly confirmed to Korea and registered here with descriptions. These fungi were *Penicillium aurantio-candidum*, *P. echinulatum*, *P. griseo-fulvum*, *P. puberulum*, *P. rubrum*, *P. rugulosum*, *P. spinulosum*, *P. variabile*, and *P. viridicatum*.

**KEYWORDS:** *Penicillium*, Korean soils.

The genus *Penicillium* have been an important fungus in man's history. Industrial production of antibiotics and other organic substances have been well developed with the submerged cultures of these fungi. Taxonomy of genus *Penicillium* in Korean soils was carried out by Min *et al.* (1980), Min and Hong (1981, 1982). The soil collections were made to identify from various places in Korea from July 1990 to August 1991. A total of 145 samples were collected from Sihung, Sungnam City, and Ansung in Kyonggi-Do, and Halla mountain in Cheju-Do. Thirty three isolates collected from the above soils were mostly identified to the species of genus *Penicillium*. Among 33 species, nine species are newly described in Korea and the others are under investigations. These fungi are *Penicillium aurantio-candidum*, *P. echinulatum*, *P. griseo-fulvum*, *P. puberulum*, *P. rubrum*, *P. rugulosum*, *P. spinulosum*, *P. variabile*, and *P. viridicatum*.

### Materials and Methods

The soil samples were collected from various

places in Korea. The medium used for isolating the fungi contains 5g peptone, 2g yeast extract, 20g sucrose, 0.5g  $MgSO_4 \cdot 7H_2O$ , 1g  $K_2HPO_4$ , 100 mg chloramphenicol, 20g agar, and 1000 ml distilled water. The isolates were inoculated on Czapek agar, Czapek yeast agar, and malt extract agar to identify. Identification was done on the basis of the morphology and growth characters on each medium for 7 days at 25°C, and microscopic observation. For the identification Abe (1956), Barron (1986), Raper and Thom (1968), and Smith (1963) were consulted for references.

### Result

#### *Penicillium aurantio-candidum* Dierckx

Dierckx, Biourge, Monograph, La Cellule 33: 116, 1923. Thom, The Penicillia, 319, 1930. *P. aurantio-candidum* Biourge.

Czapek agar, 25°C; Colonies deeply floccose and raised in the center, thinning only slightly at the margin, at first white, becoming pastel yellow

to dull green with the development of mature penicilli, some exudate produced, vivid yellow coloured in broad zones beyond the colony margin, radial furrows; reverse in yellowish orange to yellow, radial furrows. Czapek yeast agar, 25°C; Colonies very deeply radial furrows, velvety, growing restrictedly, vivid yellow exudate produced, dull green surrounded with pale yellow margin, brownish yellow to yellow coloured pigment diffusing into the surrounding agar; reverse in yellowish orange to yellow, deeply radial furrows. Malt extract agar, 25°C; Colonies plane and thin, velvety, dull green surrounded with greenish white, exudate not produced, no furrows; reverse in olive brown, no wrinkle.

Penicilli verticillate, much branches, asymmetric; conidiophores variable in length, 2.5-5.0 µm in diameter, no septate; metulae in clusters 3-5, 3.0-3.5×9.0-10.5 µm, cylindrical, smooth wall; phialides in groups 6-12, bottle shaped, tapering gradually to a conspicuous neck, 2.5-3.0×10.0-12.0 µm; conidia subglobose to broadly ellipsoidal, smooth walled, somewhat wrinkled surface, 1.9-2.2×2.0-2.3 µm, showing in SEM (Fig. 1)

Habitat: soils; Sihung Kyonggi-Do, H. K. Lee and K. H. Min, SUB 301.

Czapek 한천 배지 위에서 성장할때 콜로니 표면이 양털과 같으며, 중심이 약간 솟아있고 가장자리로 갈수록 편평해진다. 처음에는 흰색이나, 페니실리가 성숙해질수록 녹색을 띠며, 방사선상으로 주름이 잡힌다. 페니실리는 윤생하며 많은 분지가 있고, 비대칭이다. 분생자병의 길이는 다양하고, 격막은 없다. 기저경자는 무리를 이루고 있으며, 원통형이고 표면이 매끈하다. 경자도 무리를 이루고 있고, 병모양이며 목 쪽으로 갈수록 점차 가늘어진다. 분생자는 유구형이고, 표면에 주름져 있다.

#### *Penicillium echinulatum* Fassatiouva

Fassatiouva, Acta Univ. Carolina Biol. 326, 1974.

Czapek agar, 25°C; Colonies a little floccose in the center but velvety at the margin, some exudate produced, greenish grey surrounded by grey-

ish green and white line; reverse in greyish orange surrounded by dull green line. Czapek yeast agar, 25°C; Colonies deeply floccose in the center, velvety in the margin, exudate not produced, strongly radiately furrowed, greyish green to dark green, white at the margin; reverse in mustard brown, greyish yellow at the margin, radiately furrowed. Malt extract agar, 25°C; Colonies velvety, plane and thin, without any floccose, zonate exudate not produced, no furrows, dark green, appearing granular, no coloured pigment diffusing into the surrounding agar; reverse in orange shades in the center, olive green in the rest, zonate.

Penicilli verticillate arranged as an apical verticil of metulae and phialides; conidiophores mononematous but loosely synnematosus, 1-2 stage branched, with rami, metulae in small verticils of 2-3, smooth or rough walled, cylindrical, 12-15×2.3-3.5 µm; phialides in clusters, bottle shaped, tapering to a conspicuous neck, 11-15×2.3-4.5 µm; conidia globose to subglobose, conspicuously echinulate, 3.1-3.5 µm in diameter, showing in SEM (Fig. 2).

Habitat: soil; Sihung Kyonggi-Do, H. K. Lee and K. H. Min, SUB 309.

Czapek 한천 배지 위에서 성장할때 중심부 콜로니 표면은 양털과 같으나, 가장자리는 벨벳과 같고, 약간의 삼출물이 형성되며 콜로니 색은 녹색을 띠 회색이다. 페니실리는 윤생한다. 분생자병은 1-2개의 분지가 있다. 기저경자는 2-3개가 윤생하며, 매끈하거나 거친 표면을 갖고, 원통형이다. 경자는 무리를 이루고 병모양이다. 분생자는 구형 또는 유구형이고, 표면에 극모를 가지고 있다.

#### *Penicillium griseo-fulvum* Dierckx

Dierckx, Ann. Soc. Sci. Bruxelles 25: 88, 1901.

Biourge, Monograph, La Cellule 33: 164, 1923. Thom, The Penicillia, 371, 1930. Raper and Thom, A Manual of the Penicillia, 534, 1949. Samson, Stolk, and Hadlok, Mycol. 11: 24, 1976.

Czapek agar, 25°C; Colonies umbo, growing restrictedly; numerous furrows, margins abrupt, velvety and floccose, no exudate, reddish brown pig-

ment diffusing into the surrounding agar, greenish grey; reverse in reddish brown to dark brown, radiately furrows. Czapek yeast agar, 25°C; Colonies close texture, more or less growing restrictedly, velvety, margins abrupt and central area raised, radiately strong furrows, exudate not produced, zonate in marginal areas, deep reddish brown pigment diffusing into the surrounding agar, dull green; reverse in deep reddish brown, strongly radiate furrows. Malt extract agar, 25°C; Colonies mostly plane, a very thin margin, growing restrictedly, velvety, no furrows, yellow coloured pigment diffusing into the surrounding agar, dull green, no exudate, zonate in marginal areas; reverse in reddish brown in central area, light reddish brown in margin.

Penicilli divergent, with 2-3 branches, comparatively large; conidiophores mononematous, smooth walled, 2-3 branched, with rami, variable in length, 2.5-3.0 µm wide; rami 2.5-3.0×9.5-12 µm; metulae 7.0-9.3×3.0-3.5 µm in groups of 2-4; phialides commonly 4.7-6.0×2.0-2.5 µm, with a very short neck; conidia broadly ellipsoidal to ellipsoidal, sometimes subglobose, smooth surface, 2.0-2.2×2.4-3.0 µm, showing in SEM (Fig. 3).

Habitat: soil; Sungnam City Kyonggi-Do, H. K. Lee and K. H. Min, SUB 310.

Czapek 한천 배지 위에서의 생장은 콜로니 중심부가 약간 솟아있고, 표면은 벨벳과 같으며, 다소 제한적으로 성장한다. 방사상으로 심하게 주름잡히고, 배지로 붉은 갈색 색소를 분비해내며, 콜로니는 녹색이다. 페니실리는 분지상이며 상당히 크다. 분생자병은 2-3개의 분지를 갖고, 길이는 다양하며, 표면이 매끈하다. 기저경자는 무리를 이룬다. 경자는 매우 짧은 목을 갖고 있다. 분생자는 둥그스름한 타원형이거나 타원형이며 때로는 유구형이고, 표면은 매끈하다.

#### *Penicillium puberulum* Bainier

Bainier, Bul. Soc. Mycol. France 23: 16, 1907. Thom, Bur. Plant Ind. Bul. 270: 12, 1913. Thom, The Penicillia, 271, 1930.

Czapek agar, 25°C; Colonies velvety to some-

what granular, growing more or less restrictedly, radiately wrinkled in strong, a little raised in the center thinning slightly at the margin, pale green in the center, olive brown and yellow closely but delicately zonate, no exudate; reverse in yellow to tan, very deep radiate furrows. Czapek yeast agar, 25°C; Colonies velvety, compact texture, growing restrictedly, umbo, very strongly wrinkled, somewhat exudate, yellow to orange yellow pigment diffusing into the surrounding agar white margin, 1mm wide; reverse in yellowish brown, very strongly wrinkled. Malt extract agar, 25°C; Colonies velvety, loose-textured, growing restrictedly, more or less raised in the center, furrows not produced, no exudate, no pigment diffusing into the surrounding agar, dull green, white marginal zone; reverse in olive brown to dull green, white margin, 3mm wide.

Penicilli asymmetric, verticillate, irregularly branched; conidiophores 3.5-4.0 µm wide; metulae in groups of 2-4, 2.5-3.5×9.0-14 µm; phialides in clusters of 3-5, 2.5-3.5×8.5-9.5 µm, bottle shaped tapering to short neck; conidia globose to subglobose, wrinkled surface and one process on the end, 2.2-2.5×2.4-2.8 µm, showing in SEM (Fig. 4).

Habitat: soil; Halla mountain Cheju-Do, H. K. Lee and K. H. Min, SUB 318.

Czapek 한천 배지 위에서 콜로니 표면은 벨벳과 같으며, 다소 제한적으로 자라고, 방사상으로 심하게 주름지며, 중심부는 푸른 녹색이고, 가장자리는 갈색을 띤 노란색이다. 삼출물은 없다. 페니실리는 비대칭이고 운생하며, 분지는 불규칙하다. 분생자병은 직경이 넓다. 기저경자는 2-4개가 무리를 이루고있다. 경자는 병모양이고 점차 가늘어진다. 분생자는 구형이거나 유구형이고, 표면이 주름져있으며, 한쪽 끝에 돌기가 나와있다.

#### *Penicillium rubrum* Stoll

Stoll, Beit. Z. Morphol. Biol. Charakt. von *Penicillium* arten, 35, 1904. Thom, Bull. Bur. Anim. Ind. U. S. Dep. Agric. 118: 39, 1910. Thom, The Penicillia, 476, 1930. Raper and Thom, A Manual of the Penicillia, 637, 1949.

Czapek agar, 25°C; Colonies velvety, growing restrictedly, conspicuously furrowed, no exudate, olive yellow surrounded with white, more or less zonate, thinning only slightly at the margin; reverse in yellowish brown to yellow, white at the margin, furrows. Czapek yeast agar, 25°C; Colonies velvety, deeply radiately furrowed, exudate lacking, in the center dark green becoming diminished to yellow, white at the margin; reverse in yellowish brown to yellow surrounded by white margin, deep furrows. Malt extract agar, 25°C; Colonies plane and thin, velvety, tufted or funiculose, growing well, exudate lacking dark green surrounded by white margin, no furrows; reverse in oak brown tinged with reddish brown, no furrows.

Penicilli biverticillate and symmetrical; conidiphores rough walled, 2-(3) branched; metulae in groups of 2-5, 2.5-3.5×12-17 μm; phialides slender, tapering gradually to a long narrowed neck, in groups of 3-7, 2.3-3.0×13-19 μm; conidia smooth walled, wrinkled surface, ellipsoidal, 2.1-2.3×2.6-2.8 μm, showing in SEM (Fig. 5).

Habitat: soil; Ansung Kyonggi-Do, H. K. Lee and K. H. Min, SUB 321.

Czapek 한천 배지 위에서 콜로니는 제한적으로 생육하며, 표면은 벨벳과 같고 갈색을 띠며, 가장자리는 흰색이다. 콜로니가 약간 주름져있다. 페니실리는 대칭적으로 운생한다. 분생자병은 분지되어있고, 표면이 거칠다. 기저경자는 2-5개가 무리져있다. 경자는 가늘고 긴 목을 향해 점차 가늘어진다. 분생자의 표면은 주름져있고, 타원형이다.

#### *Penicillium rugulosum* Thom

Thom, Bull. Bur. Anim. Ind. U.S. Dep. Agric. 118:60, 1910. Thom, The Penicillia, 472, 1930. Raper and Thom, A Manual of the Penicillia, 648, 1949.

Czapek agar, 25°C; Colonies velvety, growing more or less restrictedly, yellowish to dark green shades surrounded by white margin, close texture, no exudate, a little raised in the center thinning only slightly at the margin, strongly wrinkled with an irregular pattern; reverse in yellowish brown,

narrow white margin, deep wrinkled in an irregular pattern. Czapek yeast agar, 25°C; Colonies velvety, growing well, deep furrows, greyish green to dark green, narrow white margin, close texture, no exudate; reverse in bronze brown, narrow white margin, deep furrows in an irregular pattern.

Malt extract agar, 25°C; Colonies plane and thin, growing well, velvety, no furrows, dark green in the center, white narrow margin, no exudate; reverse in greyish green, furrows not produced.

Penicilli biverticillate and symmetrical; conidiphores mononematous or septate, smooth walls; metulae in groups of 2-3, cylindrical 2.3-2.5×9.0-9.5 μm; phialides tapering gradually to a long narrow neck, in clusters of 5-8, 1.8-2.1×10-12 μm; conidia broadly ellipsoidal, conspicuously rough surface, 2.3×2.6-2.7 μm; conidial chains tangled, showing in SEM (Fig. 6).

Habitat: soil; Halla mountain Cheju-Do, H. K. Lee and K. H. Min, SUB 322.

Czapek 한천 배지 위에서 콜로니는 노란색을 띠며, 가장자리는 흰색이고, 콜로니 표면은 벨벳과 같으며, 삼출물은 생성하지 않는다. 콜로니는 불규칙하게 주름져있다. 페니실리는 대칭적으로 운생한다. 분생자병은 격막이있거나 없으며, 표면은 매끈하다. 기저경자는 무리를 이루고, 원통형이다. 경자는 긴 목을 향해 점차 가늘어지며, 무리져있다. 분생자는 구형에 가까운 타원형이고, 표면은 심하게 주름져있다.

#### *Penicillium spinulosum* Thom

Thom, Bull. Bur. Anim. Ind. U.S. Dep. Agric. 118:76, 1910. Thom, The Penicillia, 183, 1930. Raper and Thom, A Manual of the Penicillia, 180, 1949.

Czapek agar, 25°C; Colonies velvety, growing more or less restrictedly, loose texture, a little wrinkled, no exudate, at first white then pale cream in age; reverse in pale cream. Czapek yeast agar, 25°C; Colonies velvety to some lanate, more or less loose texture, radiately wrinkled, white, growing more rapidly; reverse in greyish orange, radiately wrinkled. Malt extract agar, 25°C; Colo-

nies plane, deeply velvety same lanate, white margin, zonate up to 1-2mm, greyish green, no exudate, no wrinkled; reverse in greenish grey, no furrows.

Penicilli monoverticillate but with an occasional branch; conidiophores variable in length, 2.5-3.0  $\mu\text{m}$  in diameter with walls almost smooth in some strains to roughened in others; phialides comparatively few in number, about 6-10 in the verticil, tapering gradually to a neck, 2.2-3.5  $\mu\text{m}$ ; conidia globose to subglobose, 2.7-3.0  $\mu\text{m}$  in diameter, conspicuously spinulose showing in SEM (Fig. 7).

Habitat: soil; Ansung Kyonggi-Do, H. K. Lee and K. H. Min, SUB 323.

Czapek 한천 배지 위에서 콜로니 표면은 벨벳과 같고, 약간 주름 잡혀 있으며, 제한적으로 자라고, 처음에는 흰색이나 생육함에 따라 흐린 크림색을 띤다. 페니실리는 대개 분지가 없으나 있는 것도 있다. 분생자병의 길이는 다양하며, 표면은 대부분 매끄럽다. 경자는 수가 적으며, 목쪽으로 점차 가늘어진다. 분생자는 구형이거나 유구형이다.

#### *Penicillium variabile* Sopp

Sopp, Monographie, 169, 1912. Thom, The Penicillia, 477, 1930. Raper and Thom, A Manual of the Penicillia, 642, 1949.

Czapek agar, 25°C; Colonies growing well, velvety, close textured basal felt, conspicuous furrows, no exudate, greyish brown tinged with deep green at the margin; reverse in brick red to greyish orange, furrowed conspicuously. Czapek yeast agar, 25°C; Colonies plane, compact texture, velvety or slightly granular, not furrowed, no exudate, some aerial hyphae, dark green surrounded by greenish white margin; reverse greyish yellow tinged with greyish orange, not furrowed. Malt extract agar, 25°C; Colonies plane and thin, looser texture, granular, no furrows, no exudate, abundant aerial hyphae, dark green; reverse in dull green, no furrows.

Penicilli biverticillate and symmetrical, usually a single verticil; conidiophores variable in length, 2.3-3.0  $\mu\text{m}$  in width; metulae in groups in 3-7,

2.3-2.5 $\times$ 9.0-9.5  $\mu\text{m}$ ; phialides tapering gradually to a narrow long neck, in clusters of 3-7, 2.5-3.0 $\times$ 14-17  $\mu\text{m}$ ; conidia strongly ellipsoidal, wrinkled surface, with smooth walls, 2.2-2.4 $\times$ 3.8-4.0  $\mu\text{m}$ , showing in SEM (Fig. 8).

Habitat: soil; Halla mountain Cheju-Do, H. K. Lee and K. H. Min, SUB 325.

Czapek 한천 배지 위에서 매우 빨리 자라며, 콜로니 표면은 벨벳과 같고, 눈에 띄게 주름져있다. 삼출물은 없고, 콜로니 색은 회색을 띤 갈색이다. 페니실리는 대칭적으로 운생한다. 분생자병의 길이는 다양하다. 기저경자는 무리를 이룬다. 경자는 가늘고 긴 목쪽으로 갈수록 가늘어지며, 3-7개가 무리져있다. 분생자는 구형이거나 유구형이다.

#### *Penicillium viridicatum*

Czapek agar, 25°C; Colonies velvety, close texture, snow white covered by a network of trailing hyphae and ropes of hyphae, exudate not produced, no furrows, more or less growing restrictedly, a little raised in the center, thinning only slightly at the margin, greenish grey; reverse in tan color, no furrows, narrow pale yellow margin. Czapek yeast agar, 25°C; Colonies compact texture, velvety, deep furrows, exudate not produced, somewhat growing restrictedly, a little raised in the center, thinning only slightly at the margin, abrupt margin, dark green to dull green, delicate zonate, very narrow white margin; reverse in tan color, deep furrows with irregular pattern. Malt extract agar, 25°C; Colonies velvety, plane and thin, more or less loose texture, no furrows, no exudate, dark green, reddish white to light orange submerged hyphae at the margin; reverse in brownish yellow, no furrows.

Penicilli not divaricate and compact, with 2 or 3 branches closely appressed, bearing cluster of metulae and phialides; conidiophores variable in length, smooth and thick walls, 4.0-4.5  $\mu\text{m}$  wide; metulae in groups of 5-7, 2.5-3.0 $\times$ 9.5-10.5  $\mu\text{m}$ , slightly inflated at apex; phialides in clusters of 7-12 in the verticil, 2.0-2.5 $\times$ 11-12  $\mu\text{m}$ , tapering gradually to a neck; conidia globose to subglobose, 2.8-3.0  $\mu\text{m}$  in diameter, thick and rough walls,

rough surface showing in SEM (Fig. 9).

Habitat: soil; Halla mountain Cheju-Do, H. K. Lee and K. H. Min, SUB 327.

Czapek 한천 배지 위에서 균사체가 콜로니 표면을 덮고있다. 콜로니에 주름은 없고, 다소 제한적으로 자라며, 중심부는 약간 솟아있고 녹색을 띤 회색이다. 페니실리는 밀집되어 있으며, 2-3개의 분지가 조밀하게 나있다. 분생자병의 길이는 다양하며, 분생자병의 벽은 매끈하고 두껍다. 기저경자는 무리져있고, 끝부분이 약간 부풀어있다. 경자는 윤생형으로 무리져있다. 분생자는 구형 또는 유구형이고, 거친 표면을 갖는다.

### 摘 要

1990년 7월부터 1991년 8월까지 한국의 여러 장소 토양으로부터 145균주를 분리하였다. 이 중 33종이 *Penicillium* 속으로 동정되었고 9종은 미기록종이었다. 한국에 처음 보고되는 종은 다음과 같다. *Penicillium aurantio-candidum*, *P. echinulatum*, *P. griseofulvum*, *P. puberulum*, *P. rubrum*, *P. rugulosum*, *P. spinulosum*, *P. variabile*, and *P. viridicatum*.

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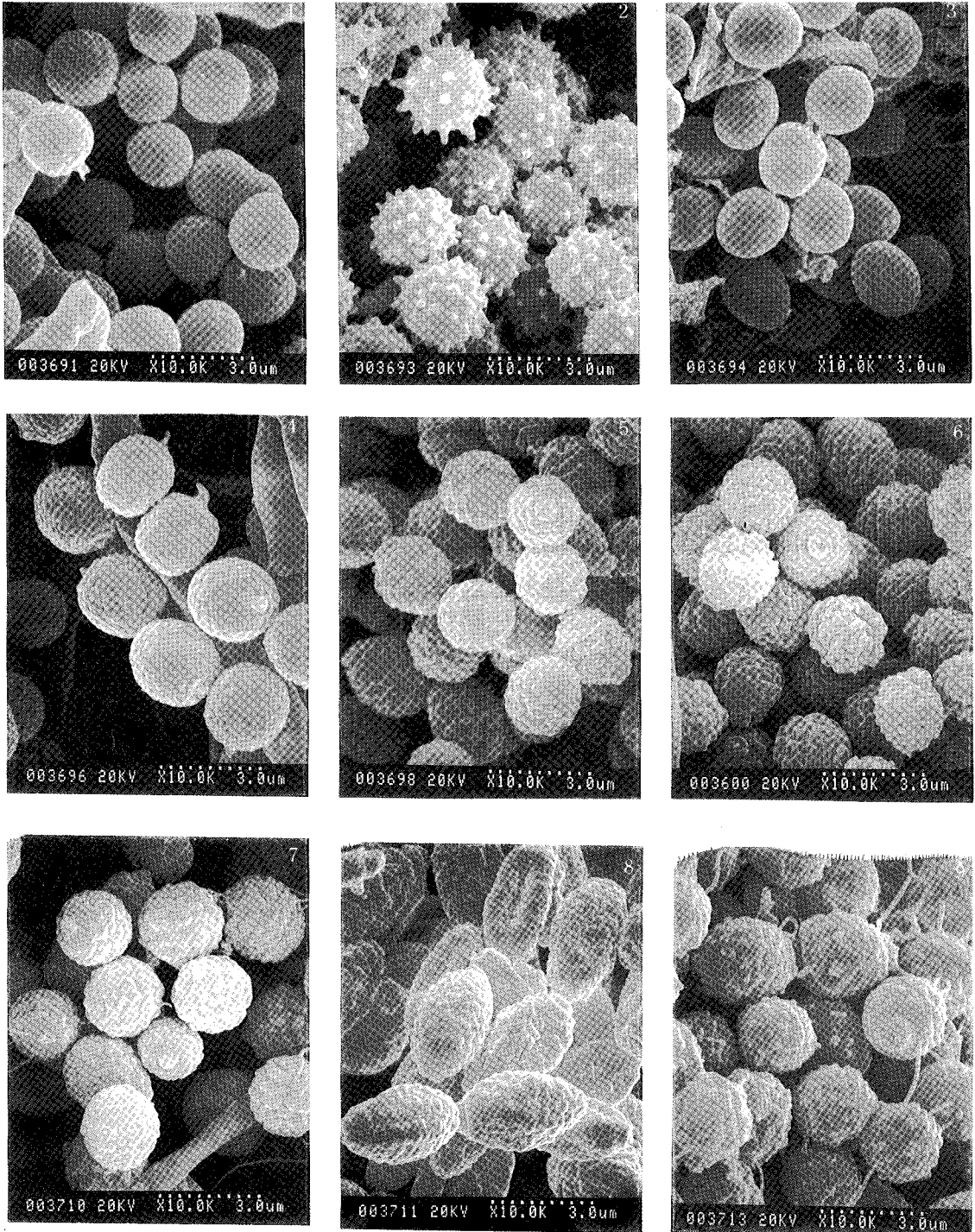
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**Figs. 1 to 9.** Scanning electron microscopic structures of conidia.

1. *Penicillium aurantio-candium*, 2. *P. echinulatum*, 3. *P. griseo-fulvum*, 4. *P. puberulum*, 5. *P. rubrum*, 6. *P. rugulosum*, 7. *P. spinulosum*, 8. *P. variabile*, 9. *P. viridicatum*.