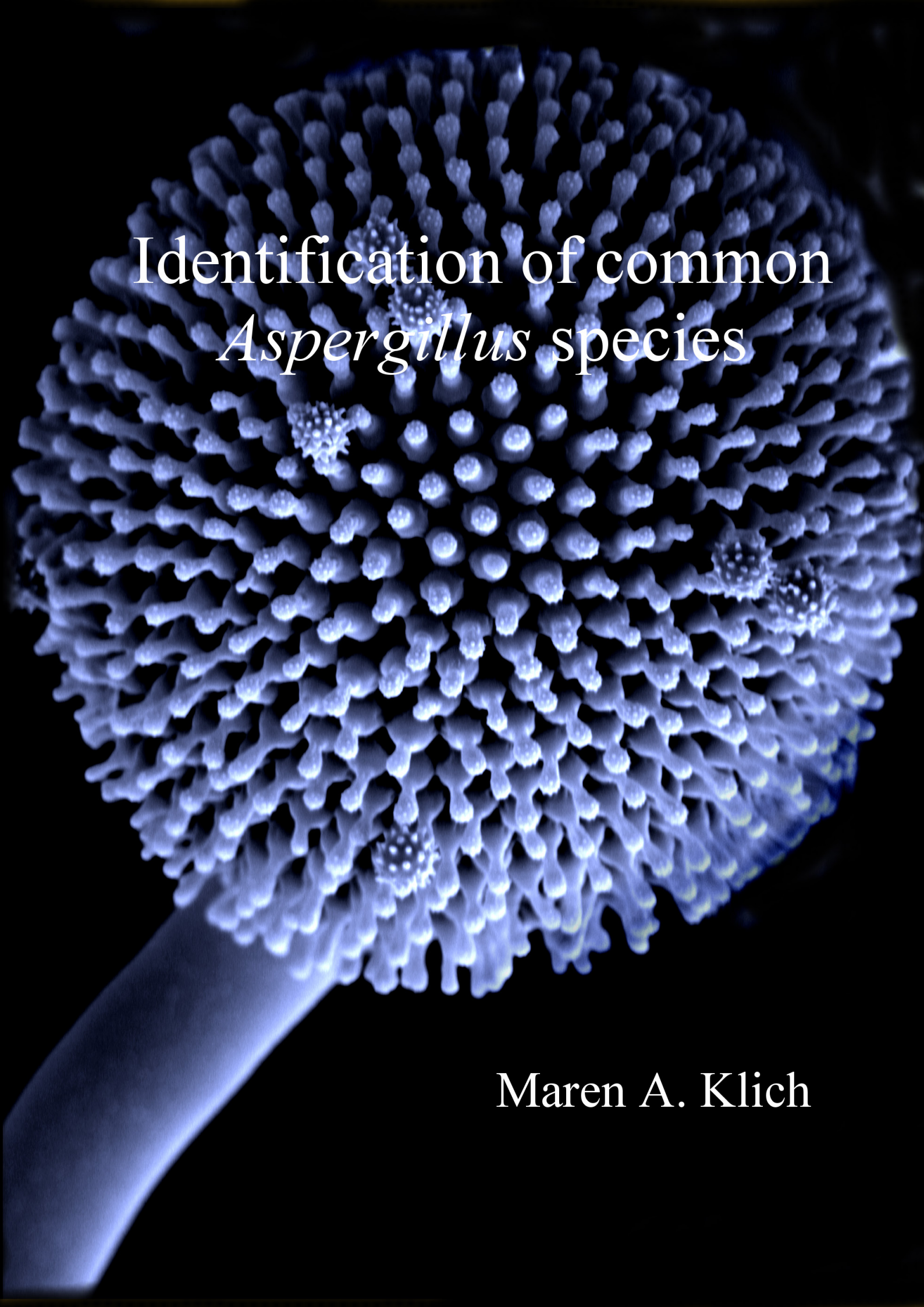

Identification of common *Aspergillus* species

Maren A. Klich

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Aspergillus Species

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Contents

Preface

The primary aim of this book is to provide a morphologically-based system for the identification of the more common *Aspergillus* species. Several uncommon species are also included in order to demonstrate the breadth of variability in the genus. The impetus for completing a working draft of the book was a workshop on *Aspergillus* identification held in New Orleans in April, 2001. The workshop was sponsored by the National Laboratory Training Network and the Texas Department of Health, Bureau of Laboratories.

To write the species descriptions herein, new information was obtained by recording morphological observations on approximately five isolates of each species. These data were then combined with previously published information to create a comprehensive species description. The key was then written based on the new species descriptions. The participants in the workshop made many helpful suggestions on how to improve the descriptions and key. These have been incorporated into the book.

I would like to thank Shannon Brennan Beltz for her excellent technical assistance in preparing cultures for observation, and for scanning the photos and preparing the photographic plates. Kanniah Rajasekaran and Weste Osbrink were extremely patient in teaching me to use digital cameras. I thank Bruce Ingber for providing the scanning electron micrographs. Steve Peterson (NRRL), John Pitt (FRR), Robert Samson (CBS), Shung-Chang Jong (ATCC) have graciously provided cultures over the years. I am very grateful to the participants in the 2001 *Aspergillus* Workshop who made many thoughtful suggestions on how to improve the book.

Robert A. Samson at CBS played a critical role in the publication of this book. He suggested CBS as a publisher, found good reviewers for the last draft of the manuscript, created the color plates, improved the quality of the black & white plates and text formatting, and was on site to assure the color quality of the color plates during printing. I am indebted to him for taking on all of these tasks.

In order to defray the some of the costs of publishing a book with so many photographic plates, four organizations have sponsored this publication. These include: Aerobiology Laboratory Associates, Inc., Reston, Virginia USA; DSM (formerly Gist Brocades), Delft, the Netherlands; Environmental Microbiology Laboratory, Inc. (EMLab), San Bruno CA & San Diego, CA, USA; and, the Fungal Research Trust, London, UK. Their contributions have significantly reduced the cost of this book. Their generous support is gratefully acknowledged.

Finally, I thank Ed and Gwen Mullaney for their patience.

Maren A. Klich March, 2002

Introduction

Economic and Medical Importance of *Aspergillus*

In 1729, when P. A. Micheli, a Florentine priest-mycologist, first described the genus *Aspergillus*, he gave it that name because the spore-bearing structure characteristic of the genus resembled an aspergillum, a device used by the Catholic church to sprinkle holy water. The resemblance was fortuitous since many of the aspergilli have indeed been a blessing to humankind. However, members of the genus have also been a curse, degrading agricultural products, producing toxic metabolites and causing disease. Several recent books have addressed various aspects the economic and medical importance of *Aspergillus* (Bossche *et al*., 1988; Bennett & Klich, 1992; Powell *et al*., 1994; Smith, 1994).

Aspergilli are among the most abundant and widely distributed organisms on earth. To adapt to the variety of niches they inhabit, they have evolved a myriad of metabolites. Some of these have been exploited by humankind. Jong & Birmingham (1992) summarized 147 US patents involving *Aspergillus* metabolites granted in the 20 years between 1971 and 1991. Many patents were filed before and since that time.

A number of *Aspergillus*-related patents have been issued for medicinal compounds. Lovastatin, produced by *A. terreus*, was one of the first commercially successful cholesterol-lowering drugs (Lam, 1983). A number of antibiotic, antitumor and antifungal agents have been derived from *Aspergillus* metabolites. For example, the experimental anti-*Candida* drug, Cilofungin, is a semi-synthetic drug, derived from a chemical modification of echinocandin B, which is produced by *Emericella nidulans/rugulosa* (Huang *et al*., 1990).

The greatest positive economic impact of the aspergilli has been in the exploitation of the enzymes and acids produced a number of species. Two of the most important industrial products produced by aspergilli are amylase and citric acid. The 'koji molds' (*A. oryzae, A. sojae* and *A. awamori*) have been used for more than a thousand years to produce a number of Asian foods and beverages including sake and soy sauce. Koji is a solid culture of a mold strain grown on steamed grain. The mold produces amylases which break down the starches and contribute to the flavor and color of the product (Hara *et al*., 1992). Alpha-amylase production from *A. oryzae* was first patented in the United States by Jokichi Takamine in 1894. This patent marked the beginning of the fungal biotechnology industry in the United States. Microbial amylases are still used today to hydrolyze the starch in grains such as corn into sugars. This market in the US has a value of more than $100 million per year (Berka *et al*., 1992). Citric acid, used to impart a pleasant acid taste to foods and beverages, was originally produced by pressing citrus fruits. Citric acid production by *A. niger* was discovered in 1916. By the mid-1920's over three quarters of the citric acid used worldwide was produced by fungal fermentation. It is still used today to produce more than 500,000 tons per year (Roehr *et al*., 1992).

Unfortunately, the positive economic impact of aspergilli and their metabolites are more than balanced by the negative aspects. Aspergilli are a major cause of degradation of agricultural products both before and after harvest. Some species are human and animal pathogens, and a number of species are allergenic. They also produce variety of mycotoxins which are secondary metabolites that are harmful to humans and animals. Aspergilli are rarely directly pathogenic to plants in the field, although *A. flavus* has been reported as a seedling pathogen of peanuts, and *A. niger* is the causal agent of a crown rot of peanut. Their main impact on agriculture is in saprophytic degradation of products both before and after harvest and in production of mycotoxins. Since members of the genus are more heat tolerant and xerophilic than most other fungal genera, they are very common food and feed spoilage organisms. Virtually all of the common aspergilli have been recovered at some time from agricultural products (Domsch *et al*., 1980; Pitt & Hocking, 1997; Samson *et al*., 2000).

Most human diseases caused by aspergilli (aspergilloses) are associated with immunosuppression. They are frequently fatal. As the number of immunosuppressed people in the population has risen, so has the importance of infection by *Aspergillus*. *Aspergillus fumigatus* is involved in about 90% of human aspergilloses, followed by *A. flavus, A. terreus, A. niger, A. nidulans* and *A. ochraceus*. Less life-threatening conditions such as non-invasive *Aspergillus* sinitus and *Aspergillus*-associated allergies are regularly reported from apparently immunocompetent people (Bossche *et al*., 1988; Young, 1990; Dixon & Walsh, 1992; Latge, 1999).

The same group of aspergilli that cause human mycoses also cause animal mycoses, with *A. fumigatus* as the dominant etiological agent. Avian aspergillosis is usually respiratory, and once accounted for 10% of all loses in broiler chicks. Improved sanitation at hatcheries has greatly reduced incidence of the disease. Mycotic abortion in cattle is a major concern in the cattle industry, sometimes affecting up to 10% of the pregnant cows in a herd (Pier & Richard, 1992).

Human illness caused by exposure to fungi in the indoor environment has become increasingly important. Surveys of indoor environments almost always include aspergilli. Lists of the fungi most commonly isolated indoors have been published (Samson *et al*., 2000; Samson *et al*., 2002). These include many of the most common 'outdoor' aspergilli (eg. *A. niger, A. ochraceus, A. terreus, A. fumigatus, A. flavus*, etc.) as well as many more xerophilic species (eg. *A. restrictus, A. penicillioides, Eurotium herbariorum, Eu. chevalieri*, etc). People sometimes present symptoms not consistent with allergies. It is assumed that the symptoms are a response to either mycotoxins or volatile organic compounds, but there is not yet a strong body of scientific evidence supporting this hypothesis (Burge, 2001).

Mycotoxins are products of secondary metabolism, indicating that their production is not necessary for the survival of the fungus. Unlike antibiotics which are toxic only to microorganisms, mycotoxins are harmful to humans and/or animals. There is a tremendous literature on mycotoxins, so only a brief overview of the major *Aspergillus* mycotoxins will be given here (some references: Richard & Thurston, 1986; Frisvad & Samson, 1991; Golinski, 1991; Smith & Henderson, 1991; Pier & Richard, 1992; Etzel, 2002). Many of these mycotoxins are produced by fungi other than *Aspergillus*, most notably *Penicillium*, however, only the *Aspergillus* species considered in this book are listed. **Aflatoxin** is the most economically important mycotoxin in the world. The most toxic form of aflatoxin is aflatoxin B_1. Aflatoxin is formed in oilseed crops (cottonseed, corn and peanuts) and tree nuts under drought conditions in the field. It can form in virtually any stored grain that can support fungal growth (Diener *et al*., 1987). It is one of the few fungal toxins regulated by the US Food and Drug Administration, and more is known about its biology and biosynthesis than any other mycotoxin. The primary organ affected is the liver. Acute aflatoxicosis results in liver necrosis, hemorrhage and often death. Lower levels lead to decreased growth rates and impaired immune systems. Chronic exposure leads to liver cancer in animals, and aflatoxin is a probable human carcinogen. (Species considered: *A. flavus*, *A. parasiticus*.) **Sterigmatocystin** is not commonly reported in foods and feeds, however, it is a precursor in the aflatoxin biosynthetic pathway. Like aflatoxin, it is hepatotoxic and carcinogenic. (Species considered: *Emericella nidulans, Em. quadrilineata, Em. rugulosa, A. versicolor.*) **Cyclopiazonic acid** is frequently co-produced with aflatoxin in the field. Major effects include liver necrosis, necrosis and other changes in kidney tubules, fatty acid changes and death at high doses. (Species considered: *A. flavus, A. oryzae*, *A. tamarii.*) **Ochratoxin A** occurs predominantly in corn barley oats and wheat, in high latitude countries such as Canada and Denmark, and in those areas, the fungi producing most of the toxin are penicillia. In the tropics, occurrence is usually associated with *A. ochraceus*. It is teratogenic and carcinogenic with the kidney as the primary target organ. In poultry, it also affects the central nervous system. Low dose symptoms in poultry include reduced growth rate and egg production. It also reduces antibody-producing ability. In humans, ochratoxin A has been implicated as the cause of Balkan endemic nephropathy. (Species considered: *A. alliaceus, A. melleus, A. ochraceus, A. ostianus, A. sclerotiorum, A. niger, A. carbonarius*.) **Patulin** is produced by a number of fungi. In foods it is generally associated with apples and apple juice where it is usually formed

by penicillia. Major effects in humans include gastritis and nausea. It causes pulmonary and cerebral edema in laboratory animals. (Species considered: *A. clavatus, A. terreus.*) **Citrinin** is nephrotoxic and teratogenic. Its natural occurrence is not well documented. (Species considered: *A. carneus, A. terreus.*) **Penicillic acid** is associated with stored grains and foods. Effects of this toxin include liver, kidney and thyroid necrosis. It is also carcinogenic. (Species considered: *A. ochraceus, A. melleus, A. ostianus, A. sclerotiorum*.) **Cytochalasin E** prevents cell division, is teratogenic, inhibits thyroid function and amylase secretion. No natural outbreaks have been reported. (Species considered: *A. clavatus.*) **Verruculogen** and **Fumitremorgin A and B** are tremorgenic, but only the fumitremorgans have been associated with natural outbreaks (Species considered: *Neosartorya fischeri, A. fumigatus.*) **3-nitropropionic acid** has been implicated in fatal food poisoning of humans and is toxic to mice. (Species considered: *A. flavus, A. oryzae*.) **Gliotoxin** interferes with macrophage function and blood formation. There is some evidence that gliotoxin may be a virulence factor for *A. fumigatus* mycoses. (Species considered: *A. fumigatus*, *A. terreus.*) **Xanthomegnin**, **viomellein** and **vioxanthin** are nephrotoxins that have been isolated from wheat barley and rapeseed oil. (Species considered: *A. ochraceus, A. melleus*.) **Citreoviridin** occurs in corn and other feeds. It is a neurotoxin causing ascending paralysis, residual lameness and muscular atrophy. This toxin is the cause of acute cardiac beriberi in humans, a disease causing death within a few days. (Species considered: *A. terreus.*) **Austamide, austidiol, austins** and **austocystins** are a group of mutagenic and/or toxigenic mycotoxins produced by only one species, *A. ustus*.

Systematics

Aspergillus is a genus of anamorphic fungi reproducing by production of phialospores (conidia borne on phialides). It is a large genus with over 180 recognized species (Pitt *et al*., 2000). Many of these species are quite rare. Others are among the most common fungi on earth. *Aspergillus* is characterized by its distinctive conidiophore (Fig. 1). The base of the conidiophore usually forms a 'T' or 'L' shape where it connects with the vegetative hyphae. This is commonly called the 'foot cell' even though it is not a separate cell. The stipe extends from the foot cell and may be quite short (50 μm or less) to several millimeters in length. The apex of the stipe expands into a vesicle. Vesicles may have various characteristic shapes (Fig. 2). In some species, the conidia-bearing phialides arise directly from the vesicle. This form is called uniseriate. In other species, there is a second layer of cells between the vesicle and the phialides. These cells are called metulae and aspergilli with metulae are referred to as biseriate species. An important character that distinguishes *Aspergillus* from several closely related genera is that the phialides/metulae arise simultaneously on the vesicle.

Some species that produce *Aspergillus* anamorphs also produce a sexual state. By definition, *Aspergillus* is an asexual (anamorphic) genus. The sexual states belong to eight or more teleomorphic genera. Some would argue that once a teleomorphic state is found, the anamorphic name should no longer be used. This is not practical with a large genus like *Aspergillus* with so many economically important species. So, currently, those species with teleomorphic states have two legal names, and the *Aspergillus* name should only be used when referring to the asexual, anamorphic state. In this book, I have used the teleomorph name if that state is usually present with the anamorph. If the teleomorph state is known, but rarely seen, I have used the anamorph name.

In naming fungi, mycologists have followed the International Code of Botanical Nomenclature (Greuter *et al*., 1994). If all of the rules of nomenclature are not followed, a proposed new species name is not acceptable. One of the rules has been that a typical sample of the new species must be dried and deposited in an herbarium. The dried sample is called a type specimen. This works well for vascular plants. For a variety of very good reasons, early *Aspergillus* taxonomists did not always designate type material. In order to keep the old names, other taxonomists have designated type material (neotypes) for virtually all of

the species of *Aspergillus* (see Samson & Gams, 1985). Another rule is that of priority. If two people unknowingly describe the same species, the name published first has priority and is the correct name. This has been a problem for several common species of *Aspergillus* including common species names like *A. niger* and *A. ochraceus.* To preserve these names, special approval must be acquired. A final type of nomenclatorial problem in *Aspergillus* is the rule that one cannot describe a teleomorph in an anamorphic genus. Many of the older species descriptions of aspergilli contained information on the teleomorph (e.g., Thom & Church, 1926; Thom & Raper, 1945; Raper & Fennell, 1965). That made the names illegal, so the anamorph name had to be changed. Examples of this in this may be seen in the descriptions of most teleomorphic species in this book.

To deal with the numerous species in the genus, early researchers divided them into groups or series based on conidial color, vesicle size and shape, presence of a teleomorphic state, etc. The groups were formally changed to subgenera and sections by Gams *et al*. (1985) in order to fit the Botanical Code. The following is a brief summary of the current scheme. Placement of some species and the existence of some of these groups have been questioned (Kozakiewicz, 1989; Samson & Frisvad, 1991; Peterson, 2000). Appendix 1 lists the species considered in this book according to their subgeneric classification.

Subgenus *Aspergillus* - uniseriate, xerophilic, growth on CY20S>CYA25, grey green conidia
- Section *Aspergillus* - teleomorph *Eurotium* - yellow cleistothecia with wall made up of a single layer of polygonal pseudoparenchymatous cells, hyaline ascospores
- Section *Restricti* - strictly anamorphic, slow growth on all media

Subgenus *Fumigati* - uniseriate, vesicles predominantly pyriform, conidia grey green, blue green to orange
- Section *Fumigati* - conidia grey green to blue green
- Section *Cervini*- conidia light orange to orange-grey

Subgenus *Ornati*- uniseriate, conidia grey-green, yellow-green or olive brown.

Subgenus *Clavati* - uniseriate, vesicles predominantly clavate, conidia grey-green
- Section *Clavati* - as for subgenus

Subgenus *Nidulantes* - biseriate, conidial colors variable
- Section *Nidulantes* - stipes short often brown, conidia green, Hülle cells often present, most species with *Emericella* teleomorph. Cleistothecia soft-walled, surrounded by Hülle cells, ascospores red to purple.
- Section *Versicolores* - stipes hyaline to brown, conidia green, grey green or blue green
- Section *Usti* - stipes brown, conidia dull red, brown or olive
- Section *Terrei* - stipes hyaline, conidia buff to orange-brown.
- Section *Flavipedes* - stipes hyaline to pale brown, conidia white to buff

Subgenus *Circumdati* - uniseriate or biseriate, vesicles spherical to pyriform.
- Section *Wentii* - conidia buff, yellow brown or olive brown
- Section *Flavi* - conidia yellow green to olive brown
- Section *Nigri* - stipes smooth-walled, conidia black or near black
- Section *Circumdati* - predominantly biseriate, conidia yellow, buff or ochraceus
- Section *Candidi* - conidia white or nearly white
- Section *Cremei* - conidia brown, yellow or blue-green
- Section *Sparsi* - conidia pale grey to olive buff

Subgenus *Stilbothamnium* - species forming synnemata (none considered in this book)

Morphological Features of Importance for Identification

Macromorphology - features observed with the naked eye or stereo microscope.

Conidial color - The color of the conidial heads. Aspergilli come in almost every color. This is a major feature for subgeneric classification.

Colony diameter - The diameter of the colony after a certain growth period. In this book, I use a 7-day growth period, with Petri plates inoculated at three points. The maximum diameter of each of the three colonies is measured by holding the plate up to the light so that all of the new (sometimes very thin) growth may be measured. Colony diameter in many species is strongly influenced by media content and temperature.

Mycelial color - Mycelia are the strands of vegetative cells that give rise to the conidiophores. It is usually white, but some species produce distinctively colored mycelia.

Exudate - Droplets of liquid that form on the surface of the mycelium.

Reverse color - The color observed under the colonies by looking at the agar side of the plate. Color is often media dependent.

Soluble pigment - The pigment that diffuses into the agar beyond the margin of the colony.

Sclerotia - Firm masses of hyphae, usually spherical, subspherical or ellipsoidal which contain no spores.

Cleistothecia - These are ascomata (fruit-bodies) with no natural openings, containing asci and ascospores.

Micromorphology - features seen through a compound light microscope. (Fig. 1)

Seriation - This term refers to the series of cell layers between the vesicle wall and the conidia, uniseriate species have only phialides, biseriate species have phialides and metulae.

Vesicle - The swollen apex of the conidiophore stipe. The shape (Fig. 2) and size of the vesicle is an important feature of some taxa.

Conidia - The shape, size and surface texture are determinative features.

Stipe - Length, color and surface texture of the stipe are important.

Hülle Cells - Thick-walled, highly refractive cells associated with some species (Figs. 37, 38, 40), associated with the cleistothecia of some species.

Cleistothecial wall - the shape and texture of the cells making up the cleistothecial wall are major features determining teleomorph genera.

Ascospores - color, size, ornamentation of the ascospores, including flanges or grooves encircling the ascospore and surface texture of the convex wall.

Learning to Recognize Morphological Features

The easiest way to learn to recognize the important features of any genus is to attend a workshop or class and learn directly from someone already familiar with the genus. Since this is not always possible, the International Commission on *Penicillium* and *Aspergillus* (ICPA - a commission of the International Union of Microbiological Societies) has created a set of cultures which demonstrate the major characteristics of *Aspergillus*. The booklet "*Aspergillus* Reference Cultures" is available online on the ICPA website www.cbs.knaw.nl/ICPA/ICPA.HTM The isolates needed in order to use the booklet are listed therein and are available from major culture collections.

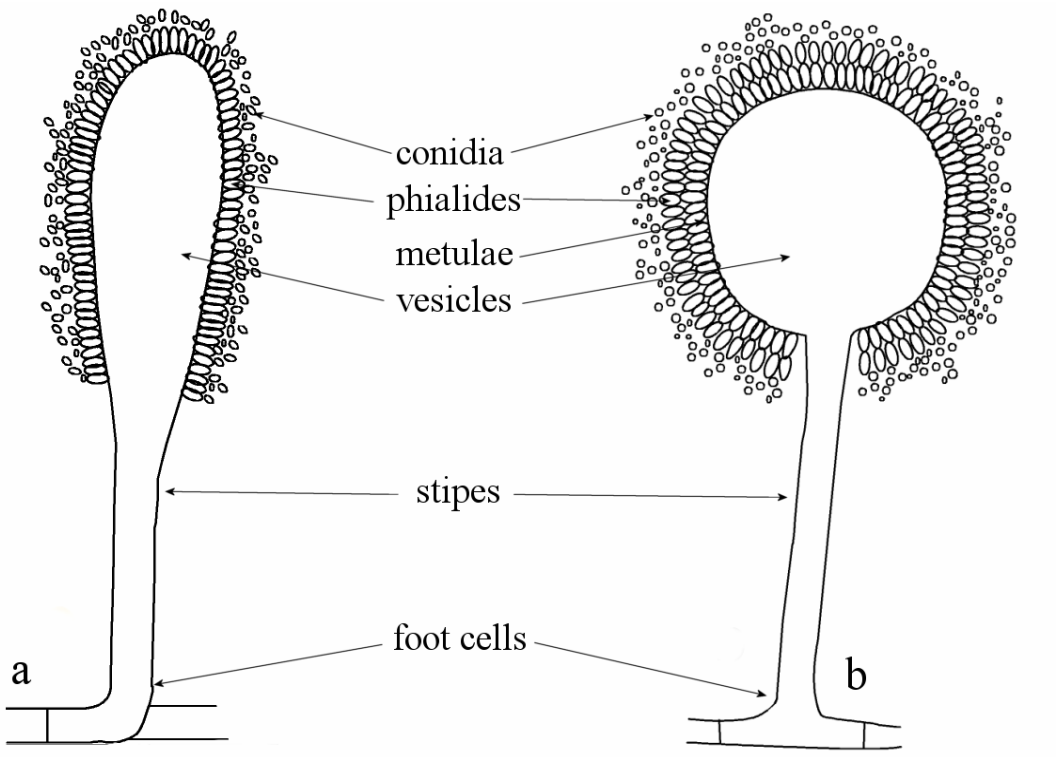

Fig 1. Conidiophores of a. *A. clavatus* (uniseriate) and b. *A. flavus* (biseriate).

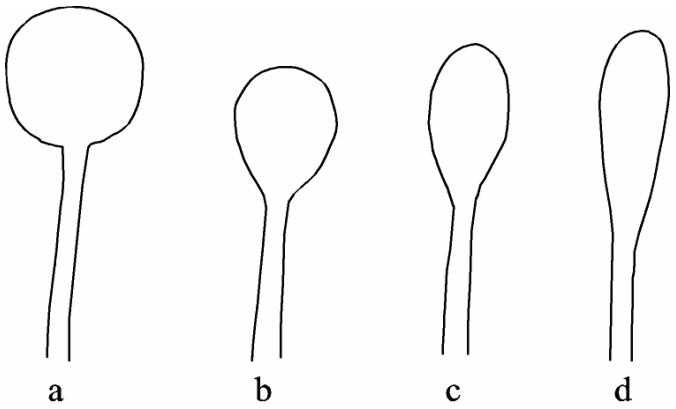

Fig 2. Some common vesicle shapes a) globose or spherical; b) pyriform; c) spathulate; d) clavate.

Media and Incubation

This book contains morphological data on colonies grown on four media, with one medium incubated at two temperatures. Only the first three are used in the keys. The last, CZ, is an 'old standard' still used by many labs, and is included to provide morphological data for that medium at seven days incubation. The media are as follows:

CYA25 - Czapek Yeast Extract Agar incubated for seven days at 25 C (Pitt, 1973);

CYA37 - Czapek Yeast Extract Agar incubated for seven days at 37 C (Pitt, 1973);

CY20S - Czapek Yeast Extract Agar with 20% sucrose incubated for seven days at 25 C (Pitt & Hocking, 1985);

MEA - Malt Extract Agar incubated for seven days at 25 C (Blakeslee, 1915);

CZ - Czapek Dox solution agar incubated for seven days at 25 C (Dox, 1910).

Note, trace metals Zn and Cu (Smith, 1949) have been added to all of the Czapek-based media.

Media formulae:

Czapek Concentrate
(with trace metals)

$NaNO_3$	30.0 g
KCl	5.0 g
$MgSO_4.7H_2O$	5.0 g
$FeSO_4.7H_2O$	0.1 g
$ZnSO_4.7H_2O$	0.1 g
$CuSO_4.5H_2O$	0.05 g
Distilled Water	100 ml

Czapek Yeast Agar with 20% Sucrose (CY20S)

K_2HPO_4	1.0 g
Czapek Concentrate	10.0 ml
Powdered Yeast Extract	5.0 g
Sucrose	200.0 g
Agar	15.0 g
Distilled Water	1.0 l

Czapek Dox Agar (CZ)

Czapek Concentrate	10.0 ml
K_2HPO_4	1.0 g
Sucrose	30.0 g
Agar	17.5 g
Distilled Water	1.0 l

Czapek Yeast Agar (CYA25, CYA37)

K_2HPO_4	1.0 g
Czapek Concentrate	10.0 ml
Powdered Yeast Extract	5.0 g
Sucrose	30.0 g
Agar	15.0 g
Distilled Water	1.0 l

Malt Extract Agar (MEA)

Powdered Malt Extract	20.0 g
Peptone	1.0 g
Glucose	20.0 g
Agar	20.0 g
Distilled Water	1.0 l

These media should be sterilized by autoclaving at 121^{o} C for 15 min. Distilled water is recommended, but not essential, because none of the media is fully defined. Chemicals should be of analytical grade where possible; however, table grade sucrose (free from sulphur dioxide), commercial malt extract, bacteriological peptone, and U.S.P. grade agar are acceptable. Agar strengths vary and may need to be adjusted. **Twenty-five ml** of media should be poured into standard (100 mm) Petri dishes. The volume is important since media depth or head space differences can lead to morphological changes (Okuda *et al*., 2000).

For each culture, four plates are used, two of CYA, and one of each of CY20S and MEA. Each plate is inoculated at three points, equidistant from the center and incubated **in the dark** for seven days. One CYA plate is incubated at 37 C. The rest are incubated at 25 C. Ordinary laboratory thermometers can be extremely variable at the 37 C range. It is suggested that the incubator temperature be checked with a medical thermometer, as these tend to be very accurate in this temperature range.

In order to prevent stray colonies on the plates, it is suggested that the inoculations be made from a spore suspension. I use a medium consisting of 0.2% agar and 0.05 % Tween 80 (Pitt & Hocking, 1997). One ml aliquots are pipetted into small glass vials and sterilized. Conidia from a 7-14 day old agar slant are mixed into the medium. Then 2 µl aliquots are placed on each of three equidistant points on the agar plate using a micropipetor.

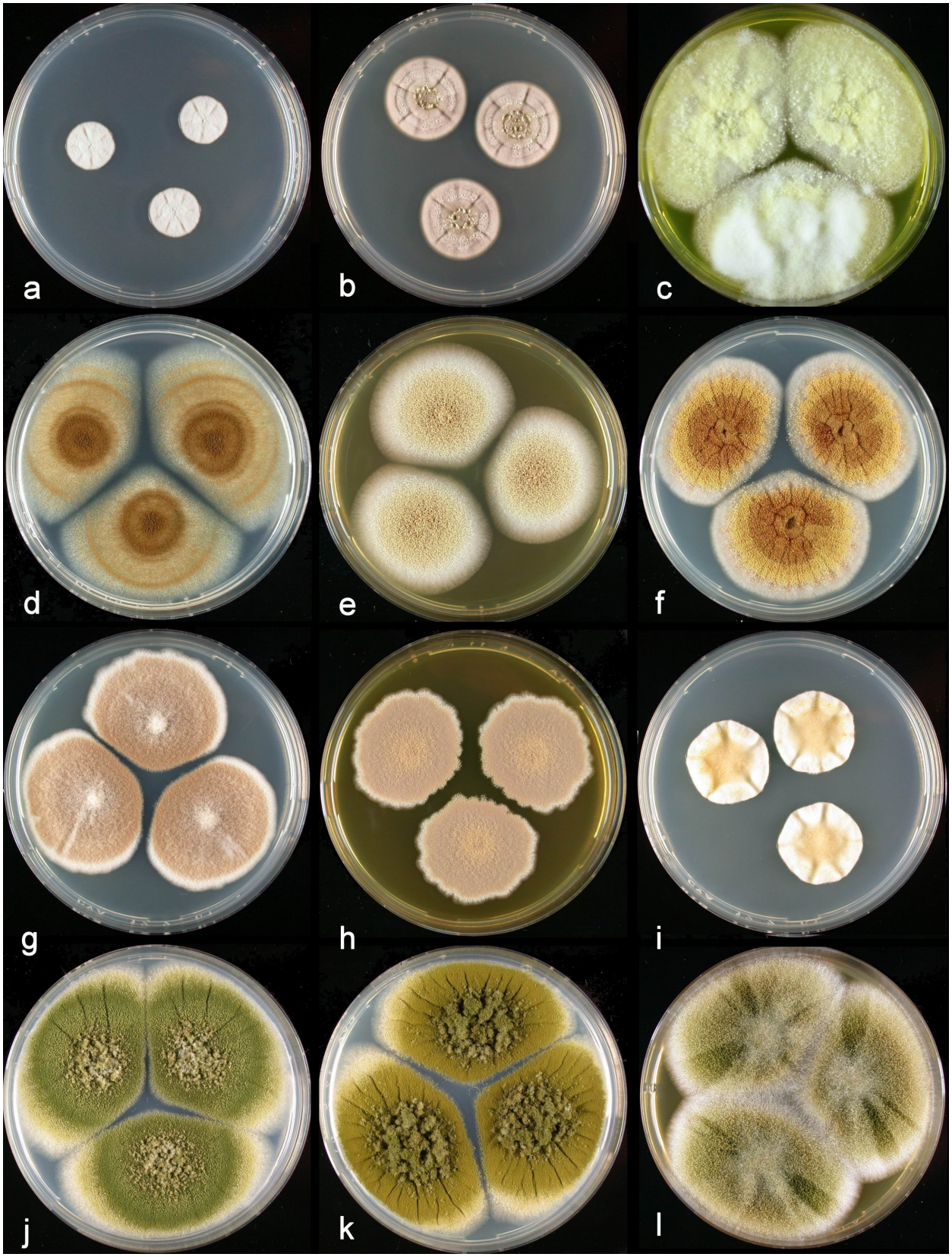

Fig. 3. Seven day old colonies on media indicated: a. *A. candidus* (CZ); b. *A. ustus* (CZ); c. *A. paradoxus* (CBS-MEA 2%); d. *Sclerocleista ornata* (CZ); e. *A. melleus* (CBS-MEA 2%); f. *A. ostianus* (CZ); g. *A. terreus* (CZ); h. *A. cervinus* (CBS-MEA 2%); i. *A. wentii* (CZ); j. *A. flavus* (CZ); k. *A. parasiticus* (CZ); l. *A. oryzae* (CBS-MEA2%). CBS-MEA 2% = 200 ml of malt extract diluted with water to 10% sugar content+ 800 ml water + 15 g agar (Samson *et al*., 2000). Photos courtesy of Robert Samson, CBS.

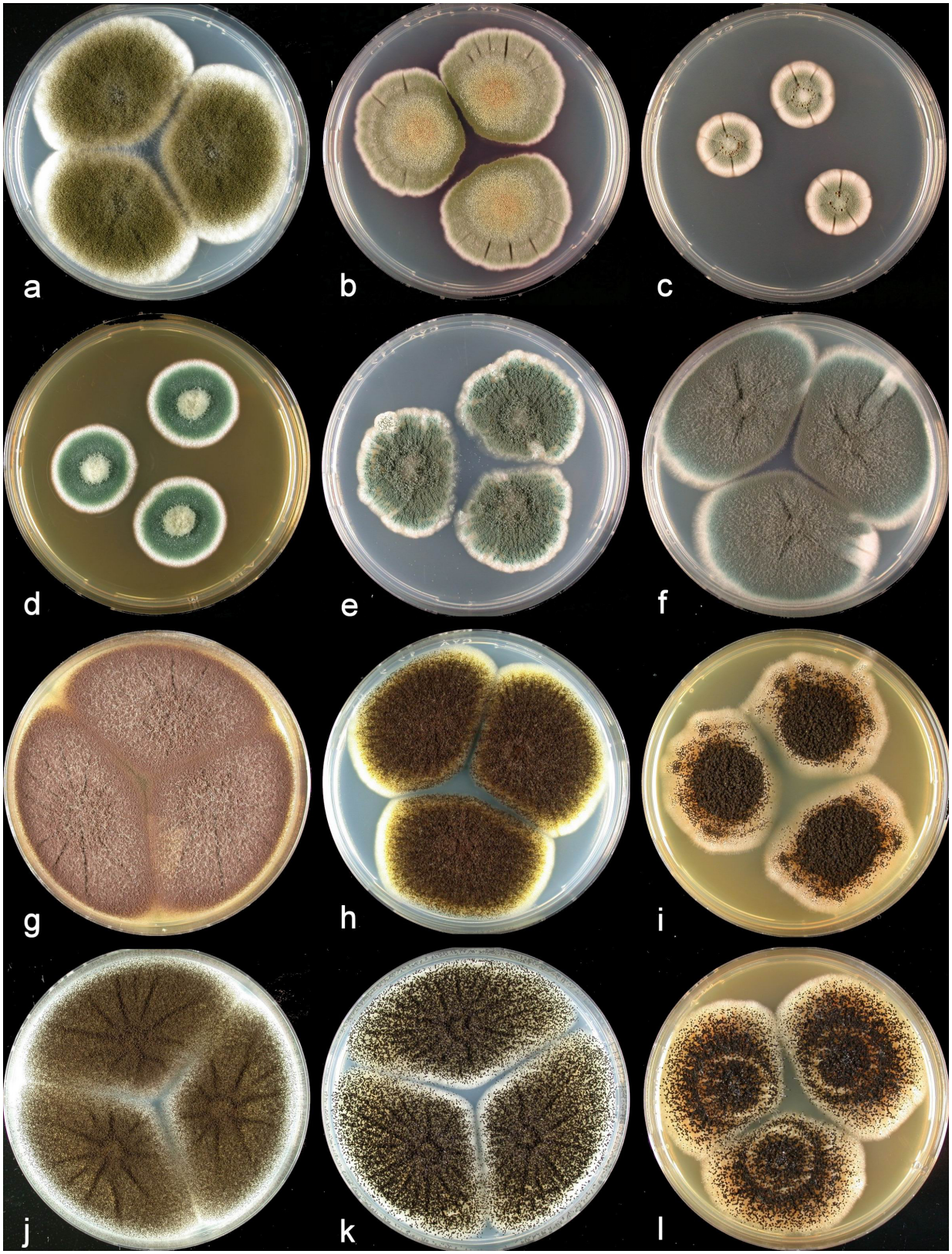

Fig 4. Seven day old colonies on media indicated: a. *A. sojae* (CBS-MEA2 %); b. *Emericella nidulans* (CZ); c. *A. versicolor* (CZ); d. *A. unguis* (CBS-MEA 2%); e. *A. clavatus* (CZ); f. *A. fumigatus* (CZ); g. *A. japonicus* (CBS-MEA 2%); h. *A. foetidus* (CZ); i. *A. niger* (CBS-MEA 2%); j. *A. awamori* (CZ); k. *A. carbonarius* (CZ); l. *A. carbonarius* (CBS-MEA 2%). CBS-MEA 2% = 200 ml of malt extract diluted with water to 10% sugar content+ 800 ml water + 15 g agar (Samson *et al*., 2000). Photos courtesy of Robert Samson, CBS.

Using this Book

The species descriptions are alphabetical by **species** name. The teleomorphic genus name is used if the teleomorph is the form usually observed. So, for instance, I use *Emericella nidulans* rather than *Aspergillus nidulans* because the teleomorphic state is usually present in culture. However, I use *Aspergillus flavipes* rather than the teleomorphic name *Fennellia flavipes,* because the *Fennellia* state is not normally observed in culture.

All measurements are taken after seven days incubation. Colony diameters of 70 mm indicate that the colonies fill the Petri dish. Measurements are reported in an (a) b-c (d) format where 'a' is the minimum observed measurement, 'b-c' represents the range observed for most isolates, and 'd' the maximum observed measurement. Colony colors were determined using the *Methuen Handbook of Colour* (Kornerup & Wanscher, 1978). Plates 3-5 demonstrate the colors of many of the aspergilli included in this book. For microscopic observations, MEA was used unless otherwise noted.

On the page opposite each species description are photos of the colonies, conidial heads, conidia and other distinctive features. The scanning electron micrographs (SEMs) are included in order to give a more three dimensional view of the conidia than can be photographed through a light microscope. It should be noted that conidia often shrink in the SEM preparation, so sizes and exact conidial wall textures may not be as seen in these photos.

Hints for Making Observations and Using the Key

Before using the key, take a few minutes to look carefully at a number of conidia, conidial heads and other structures. Make mounts from at least two media as there is some variability on the different media. Mounting media with stains may affect characters such as stipe color. Using a clear mounting medium (e.g., Pohl, 1954) avoids this problem. Some mounting media affect conidial diameters. Avoid using these. Also, when making mounts take some material from the center of the colony (for mature conidia, etc.) as well as from the margin area where color is just starting to show (for young conidiophores). Look at both before starting to use the key. Appendix 2 provides a data sheet for tabulating morphological characteristics of an isolate.

If it is difficult to determine if an isolate is uniseriate or biseriate, gently crush the conidiophores by pressing on the cover glass with a blunt object. In the biseriate species, the metulae and phialides will often stay together, and can easily be seen (Figs. 12, 28, 33). Some species are variable in seriation. Choose the form that appears to be dominant. The key is written so that most of the variable species will key out either way.

The terms rough, finely rough and smooth are admittedly qualitative. For the aspergilli, generally, rough walled spores will appear rough even at 40X magnification. Finely roughened spores will be spiny or irregular under oil immersion. Smooth spores will appear smooth under oil immersion.

ALWAYS read the species description to be sure that your identification is correct. If your isolate doesn't match the species description reasonably well, it may be one of the less common species, or even a new species. Check the references in the species description.

If an isolate doesn't sporulate or sporulates poorly, there are several methods available that help induce sporulation. Try placing the plates in indirect light for a few days. Several *Aspergillus* species are light sensitive and sporulate poorly in the dark. Another method that works for some isolates is to grow them on agar slants for several weeks. Medical isolates often sporulate more readily after they have been transferred several times

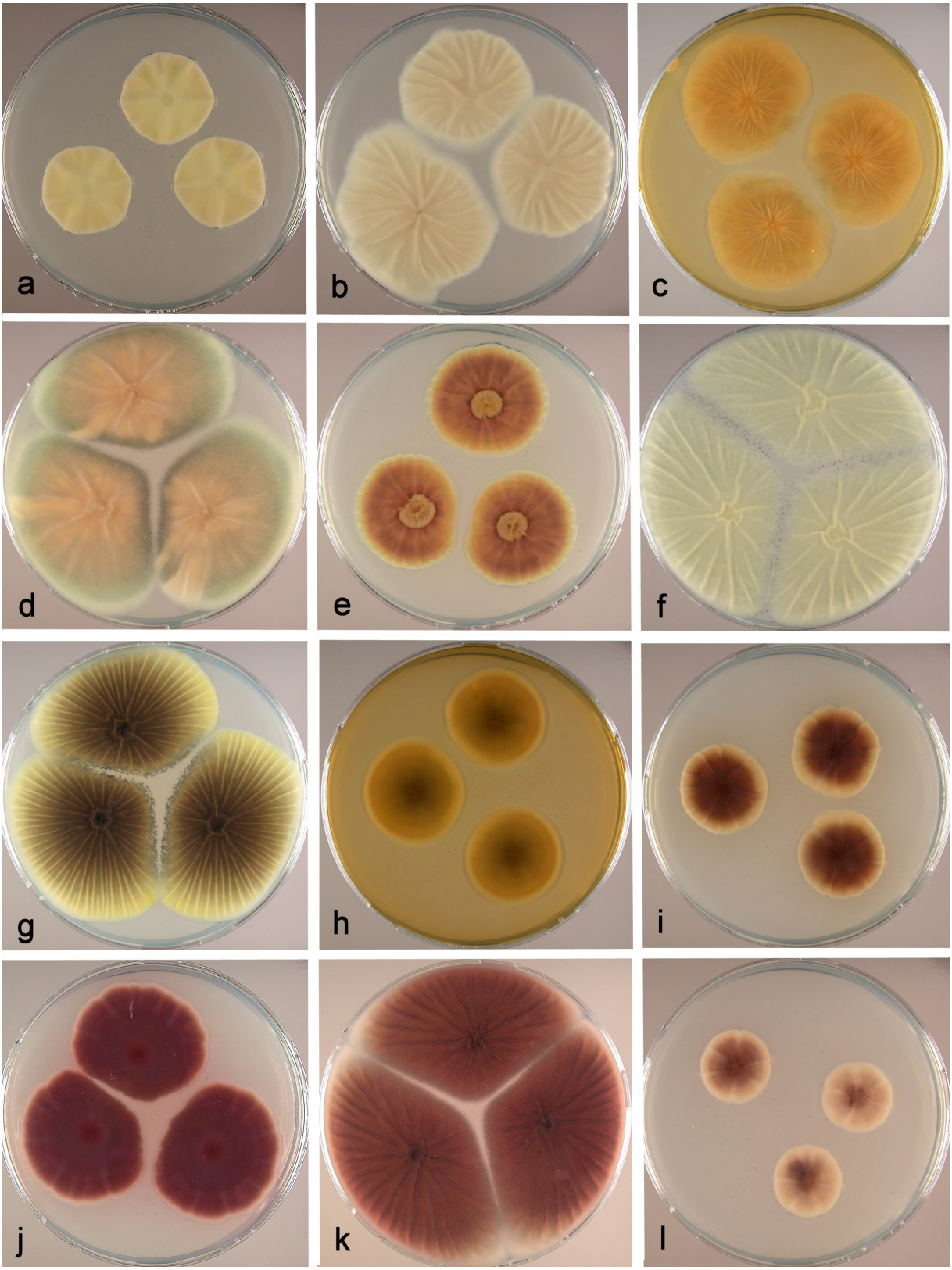

Fig. 5. Reverse of seven day old colonies on media indicated: a. *A. wentii* (CZ); b. *Neosartorya fischeri* (CZ); c. *A. clavatus* (CBS-MEA 2%); d. *A. fumigatus* (CZ); e. *A. ochraceus* (CZ); f. *A. carbonarius* (CZ); g. *A. foetidus* (CZ); h. *A. ustus* (CBS-MEA 2%); i. *A. sydowii* (CZ); j. *Emericella nidulans* (CZ); k. *A. japonicus* (CZ); l. *A. versicolor* (CZ). CBS-MEA 2% = 200 ml of malt extract diluted with water to 10% sugar content+ 800 ml water + 15 g agar (Samson *et al*., 2000). Photos courtesy of Robert Samson, CBS.

Identification Key

IMPORTANT:
Colony diameters are from 7 day old cultures
*indicates that there are related species that should be considered. These are discussed at the bottom of the species description

1. Predominantly biseriate 2
1. Predominantly uniseriate 43

2 (1) Colony diameter greater than 45 mm on CYA25 and/or MEA 3
2 (1) Colony diameter less than 45 mm on CYA25 and MEA 22

3 (2) Conidia in shades of green to blue-green on CYA25..... 4
3 (2) Conidia not green on CYA25..... 11

4 (3) Largest vesicles less than 20 µm wide, stipes becoming brown in age .. 5
4 (3) Largest vesicles greater than 25 µm wide, stipes remaining uncolored.. 7

5 (4) Colony diameter less than 35 mm on CYA37, cleistothecia absent ..... *A. caespitosus*
5 (4) Colony diameter greater than 50 mm on CYA37, cleistothecia present. 6

6 (5, 28) Ascospores with 2 thin longitudinal flanges ..... *Emericella nidulans*
6 (5, 28) Ascospores with 4 longitudinal flanges, 2 quite small..... *Emericella quadrilineata*

7 (4, 50) Conidial walls smooth to finely roughened..... 8
7 (4, 50) Conidial walls coarsely roughened 9

8 (7) Conidia usually greyish yellow to olive brown in age on CYA25, conidial diameter 4-8.5 µm..... *A. oryzae*
8 (7) Conidia remaining olive green to parrot green in age on CYA25, conidial diameter 3-6 µm..... *A. flavus**

9 (7) Conidia usually 3-6 µm in diameter, colonies remaining in deep olive or green shades on CYA25 in age ..... *A. parasiticus*
9 (7) Conidia usually 5-8 µm in diameter, colonies usually bronze to brown in age on CYA25 10

10 (9) Conidial heads predominantly uniseriate, conidia not ornamented with dark-colored tubercles ..... *A. sojae*
10 (9) Conidial heads variable, uniseriate and biseriate both usually present, conidia ornamented with dark-colored tubercles. ..... *A. tamarii**

11 (3) Conidia in black, dark brown or bronze colors 12
11 (3) Conidia in cinnamon, buff or yellow colors..... 16

12 (11) Maximum conidial diameter less than or equal to 6 µm 13
12 (11) Maximum conidial diameter 7 µm or greater..... 15

13 (12) Conidia rough walled ..... *A. niger* *
13 (12) Conidia with smooth to finely roughened walls..... 14

14 (13) Colony diameter on CYA37 65-70 mm, mycelia on CY20S uncolored to pale yellow ..... *A. awamori*
14 (13) Colony diameter on CYA37 predominantly less than 65 mm, mycelia on CY20S often distinctly yellow ..... *A. foetidus*

15 (12) Colonies less than 30 mm on CYA37, conidial areas black ..... *A. carbonarius*
15 (12) Colonies greater than 40 mm on CYA 37, conidial areas olive to bronze ..... *A. tamarii**

16 (11, 34) Conidia 4-6 µm long..... *A. ostianus*
16 (11, 34) Conidia predominantly 3.5 µm or less in length 17

17 (16) Conidial heads compactly columnar, conidia in camel to cinnamon colors, colony diameters on CYA37 predominantly 55-70 mm..... *A. terreus*
17 (16) Conidial heads radiate when young, conidia in yellow to ochraceus colors, colony diameter on CYA37 usually less than 55 mm. 18

18 (17) Stipe walls smooth ..... *A. alliaceus*
18 (17) Stipe walls rough to warted..... 19

19 (18) Mature conidia yellow..... 20
19 (18) Mature conidia ochraceus, cream or buff..... 21

20 (19) Colonies on CYA25 dominated by yellow to orange sclerotia..... *A. auricomus*
20 (19) Sclerotia, when present, white to buff in color ..... *A. sclerotiorum*

21 (19) Sclerotia, when present, dull pink to purple, longest stipes generally greater than 1000 µm on MEA ..... *A. ochraceus*
21 (19) Sclerotia abundant, small, yellow becoming brown in age, longest stipes generally less than 800 µm on MEA ..... *A. melleus*

22 (2) Conidia predominantly greater than 4 µm in length..... 23
22 (2) Conidia predominantly 4 µm or less in length 26

23 (22) Vesicles predominantly less than 20 µm in diameter and conidial areas grey green to dark green..... *A. caespitosus*
23 (22) Vesicles predominantly greater than 20 µm in diameter, conidia variable 24

24 (23) Conidia dark brown to black, colonies greater than 45 mm on CYA37 ..... *A. foetidus*
24 (23) Conidia yellow, buff or green, colonies less than 35 mm on CYA37 25

25 (24) Conidia yellow to buff, colony diameter 38-50 mm on CYA25 ..... *A. ostianus*
25 (24) Conidia sparse, blue-green in color, colony diameter 10-25 mm on CYA25 ..... *Chaetosartorya cremea*
25 (24) Conidia bronze or olive brown, colony diameter 25-35 mm on CYA25 ..... *A. wentii*

26 (22) Conidia in green to blue-green colors on CYA25 27
26 (22) Conidia in other colors on CYA25 34

27 (26) Growth on CYA37 greater than 50 mm, cleistothecia present, surrounded by Hülle cells 28
27 (26) Growth on CYA37 less than 50 mm, cleistothecia, if present, not surrounded by Hülle cells 29

28 (27) Colonies on CYA25 less than 35 mm ..... *Emericella rugulosa*
28 (27) Colonies on CYA25 greater than 35 mm ..... go back to 6

29 (27) Vesicles predominantly greater than 20 µm in diameter 30
29 (27) Vesicles predominantly less than 20 µm in diameter 31

30 (29) Colonies on CY20S greater than 50 mm in diameter, conidia on MEA olive to orange-yellow ..... *A. wentii*
30 (29) Colonies on CY20S less than 40 mm, conidia on MEA cream to buff ..... *A. sparsus*

31 (29) Sterile thick-walled hyphae rising above the conidial heads ..... *A. unguis*
31 (29) Sterile thick-walled hyphae absent 32

32 (31) Colony diameter on CY20S and CYA25 greater than 35 mm ..... *A. caespitosus*
32 (31) Colony diameter on CY20S and CYA25 less than 35 mm 33

33 (32) Colonies grey-blue to blue-grey, conidia rough-walled ..... *A. sydowii*
33 (32) Colonies dull green to grey green, conidia smooth to finely roughened ..... *A. versicolor**

34 (26) Conidia yellow to ochraceus in color AND colonies greater than 40 mm on CY20S and less than 40 mm on CYA37 ..... go back to 16
34 (26) Conidial color and colony diameters not as above 35

35 (34) Vesicles predominantly greater than 20 µm in diameter 36
35 (34) Vesicles predominantly less than 20 µm in diameter 37

36 (35) Conidia white to pale yellow ..... *A. candidus*
36 (35) Conidia buff, tan or olive ..... go back to 30

37 (35) Colony diameters 55-70 mm on CYA37 and CY20S, conidial heads compactly columnar ..... *A. terreus*
37 (35) Colony diameters less than 55 mm on CYA37 and CY20S, conidial heads not compactly columnar 38

38 (37) Conidia on CYA25 white to pale yellow 39
38 (37) Conidia on CYA25, pink buff or tan 40

39 (38, 45) Vesicles predominantly greater than 15 µm, metulae covering the entire surface of the vesicle ..... *A. candidus*
39 (38, 45) Vesicles predominantly less than 15 µm, metulae covering the upper one to two thirds of the vesicle ..... *A. niveus*

40 (38) Conidia smooth-walled, conidia pink to tan on MEA or CY20S 41
40 (38) Conidia finely to coarsely roughened, conidia green, brown or olive on MEA or CY20S 42

41 (40) Conidia dull pink on CYA25 or MEA ..... *A. carneus*
41 (40) Conidia dull brownish-orange on CYA25 or MEA ..... *A. flavipes*

42 (40) Overall color on CYA25 pale orange/pink to tan, conidia usually finely roughened ..... *A. puniceus*
42 (40) Overall color on CYA25 pale brown to grey brown, conidia rough-walled, spiny ..... *A. ustus*

43 (1) Conidia on CYA25 black, white, tan, yellow or pink 44
43 (1) Conidia on CYA25 in shades of green, olive or turquoise 47

44 (43) Conidia on CYA25 very dark brown to black, rough-walled ..... *A. japonicus**
44 (43) Conidia not black/brown on CYA25, smooth-walled 45

45 (44) Conidia white to off-white on CYA25, colonies on MEA less than 40 mm in diameter ..... go back to 39
45 (44) Conidia cream to yellow on CYA25, colonies 65-70 mm on MEA ... *A. alliaceus*
45 (44) Conidia pale orange to pink on CYA25, colonies 40-65 mm on MEA 46

46 (45) Growth on CY20S predominantly 5-10 mm, longest stipes greater than 450 µm ..... *A. kanagawaensis*
46 (45) Growth on CY20S predominantly 10-19 mm, longest stipes less than 450 µm ..... *A. cervinus*

47 (43) Colony diameter on MEA greater than 30 mm 48
47 (43) Colony diameter on MEA less than 30 mm 53

48 (47) No growth on CYA37 49
48 (47) Growth on CYA37 50

49 (48) Reverse and soluble pigment generally bright yellow on CYA25, conidial walls smooth to finely roughened..... *A. paradoxus*
49 (48) Reverse uncolored to dull yellow, soluble pigment absent on CYA25 conidial walls very rough ..... *Sclerocleista ornata*

50 (48) Conidia yellow green, olive to bronze ..... go back to 7
50 (48) Conidia grey green to blue green 51

51 (50) Conidial heads predominantly clavate, colonies on CYA37 less than 30 mm in diameter..... *A. clavatus**
51 (50) Conidial heads predominantly pyriform to spathulate, colonies on CYA37 greater than 55 mm in diameter 52

52 (51) Cleistothecia present ..... *Neosartorya fischeri**
52 (51) Cleistothecia absent..... *A. fumigatus*

53 (47) Cleistothecia absent..... 54
53 (47) Cleistothecia present 55

54 (53) Colony diameter 8 mm or less on CYA25 and less than 12 mm on CY20S, phialides covering more than half the vesicle, conidia borne as ellipses..... *A. penicillioides*
54 (53) Colony diameter predominantly greater than 8 mm on CYA25, and greater than 15 mm on CY20S, phialides restricted to the upper third of the vesicle, conidia borne as cylinders ..... *A. restrictus*

55 (53) Ascospores rough-walled ..... *Eurotium amstelodami*
55 (53) Ascospores smooth-walled..... 56

56 (55) Ascospores with two distinct flanges..... *Eurotium chevalieri*
56 (55) Ascospores without flanges..... *Eurotium herbariorum**

SPECIES DESCRIPTIONS

Aspergillus alliaceus Thom & Church — Fig. 6.

The Aspergilli: 163. 1926. Neotype TRTC 46232.
Teleomorph: *Petromyces alliaceus* Malloch & Cain Canad. J. Bot. 50: 2623. 1972. Holotype TRTC 46323.

Subgenus: *Circumdati* Section: *Flavi*

Colony Diameters at 7 days incubation, in mm: CYA25 (55) 68-70; MEA 65-70; CY20S 65-70; CYA37 (36) 40-55; CZ (42) 65-70.

Colony Colors and Textures. On CYA colonies frequently lightly sporulating; conidia cream (4A3) to yellow (4A6) or yellow ocher (4-5 B3-8); mycelium white floccose; sclerotia/stromata initially white becoming dark grey to black; reverse in drab tan to pale yellow or yellowish brown colors; colonies floccose, deep, sporulating irregularly. Colonies on MEA sparsely sporulating in light yellow-gold colors (4A-B3-4); mycelium white, dense or sparse; sclerotia/stromata white, becoming dark grey; reverse pale yellow to bright yellow; colony texture generally floccose, with mycelium variable in density Colonies on CY20S similar to those on CYA25 in appearance except the conidial colors tend to be in deeper gold shades (4B4-8). On CYA37, sporulating more heavily than on other media, conidia buff to ochraceus (4-5 B-D3-5); colonies lanose to floccose, plane to radially sulcate, other characters similar to those on CYA25. Conidia on CZ frequently sparse, in dull yellow, buff or ochraceus (3A5, 4A-B5-6, 5C5), texture velutinous to floccose, plane or sulcate; other characters similar to those on CYA25.

Microscopic Characteristics. Large conidial heads radiate, smaller ones often columnar. Stipes variable in length 40-2000 x 5-9 µm, smooth-walled, uncolored. Vesicles spherical to pyriform, variable in width (8) 20-50 (100) µm. Conidial heads biseriate on large vesicles, on small vesicles often uniseriate, metulae or phialides covering at least the upper half of the vesicle; metulae 6-12 (18) x 2.5-5 (6) µm; phialides (5) 6-9 (13) x (1.5) 2-2.5 (4) µm. Conidia (2.5) 3-3.5 (4) µm in diameter, smooth-walled, subglobose to ovoid. Mature ascospores not observed: *fide* Malloch & Cain (1972); over a period of months the sclerotial bodies act as stromata containing ascocarps with 8-spored asci which are dehiscent. Ascospores ellipsoidal 5.5-9 x 5-7 µm, smooth-walled, uncolored, and may have a fine longitudinal furrow when young.

Distinguishing Features. *A. alliaceus* is distinguished by colonies spreading to fill the petri dishes on MEA, yellow gold conidia, and grey black sclerotial bodies which may mature slowly into stromata.

Taxonomic References. Raper & Fennell, 1965; Malloch & Cain, 1972; Christensen, 1982; Klich & Pitt, 1988; Kozakiewicz, 1989.

Note. The black sclerotia, some molecular data (Peterson, 1995), and electron microscopic data (Kozakiewicz, 1989) indicate that this species belongs in Section *Flavi* rather then Section *Circumdati.*

Habitats. This species has been isolated from desert, grassland and cultivated soils, cacti, and onion and garlic bulbs. It has been reported at greater than expected frequencies in studies at latitudes between 36-45 degrees (Christensen, 1982; Klich, 2002).

Major Mycotoxins. Ochratoxin A.

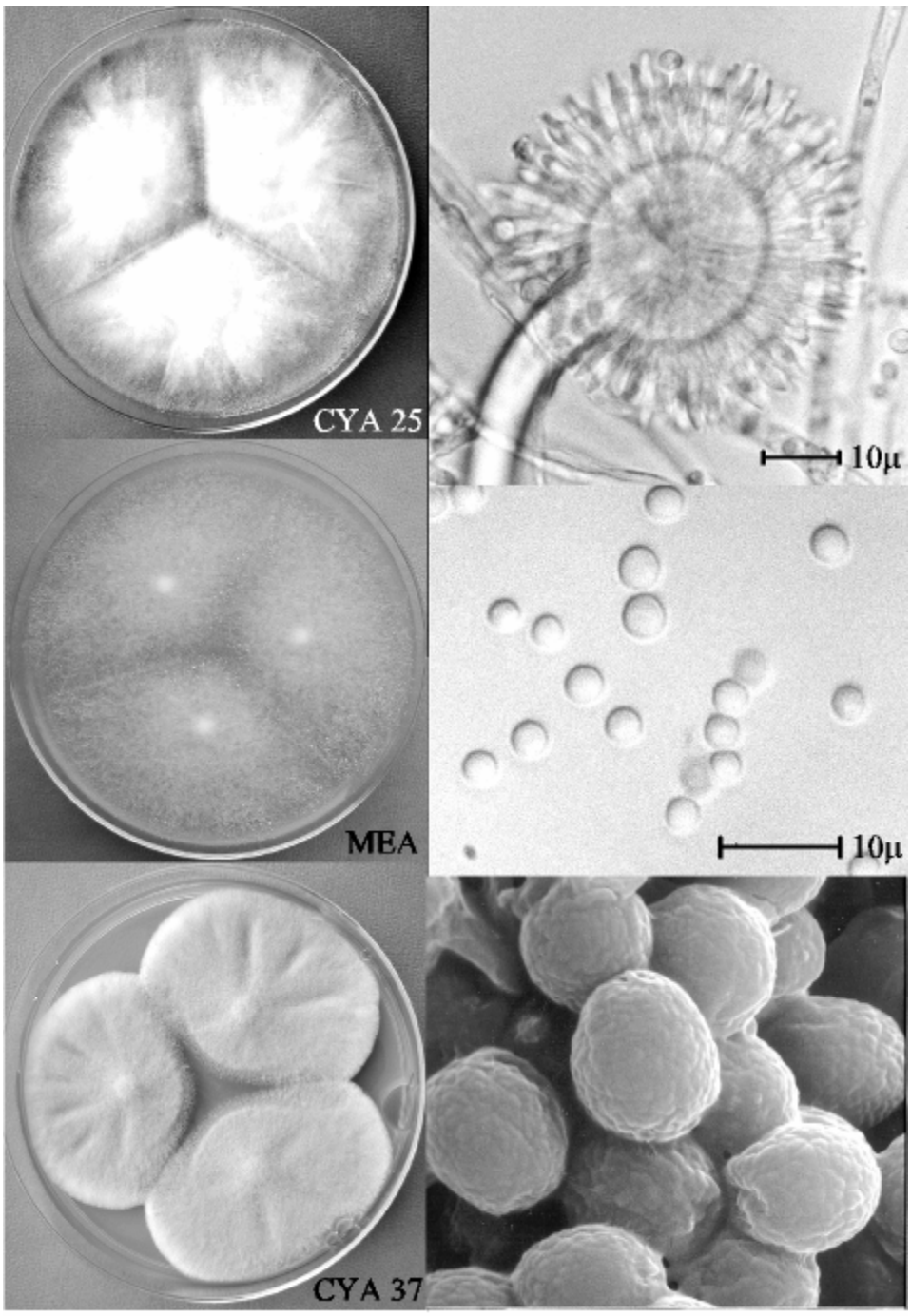

Fig. 6. *Aspergillus alliaceus:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, conidia, and SEM of conidia (x 8000).

Eurotium amstelodami Mangin — Fig. 7.

Ann. Sci. Nat., Bot., ser. 9, 10: 360. 1909. Neotype CBS 518.65.
Anamorph: *A. vitis* Novobr. Novosti Sist. Nizs. Rast. 9:175. 1972. Neotype IMI 174724.

Subgenus: ***Aspergillus*** **Section:** ***Aspergillus***

Colony Diameters at 7 days, in mm: **CYA25** (10) 14-20 (21); **MEA** (13) 18-22 (16); **CY20S** (31) 34-59; **CYA37** 2-13; **CZ** 7-19.

Colony Colors and Textures. Conidia on **CYA25** green, grey green, greyish turquoise or dark green (24-29D-F4-8); mycelium white, yellow or yellow grey; cleistothecia yellow; reverse uncolored, yellow, green or brown; exudate, when present, uncolored to brown; soluble pigment, when present, brown; colony low, plane to sulcate. On **MEA** conidia dark green (28-29F8); inconspicuous white to yellow mycelium; cleistothecia, when present, yellow; reverse uncolored or yellowish centrally; colonies not dense, low, granular. Conidia on **CY20S** dull green (27-28E3-4) or dark green (29-30F8); mycelium and cleistothecia colored as on CYA25, reverse generally yellow (beneath cleistothecia) or green (beneath conidia). Colonies on **CYA37** consisting of white dense mounds with uncolored to grey brown reverse colors. Conidia sparse on **CZ**, overall appearance dominated by bright yellow cleistothecia; reverse uncolored to yellow or green; colonies velutinous.

Microscopic Characteristics. **Conidial heads** radiate to loosely columnar; **stipes** smooth-walled, uncolored to slightly brown, (90) 110-350 (500) x (5) 7-12 µm; **vesicles** globose to spathulate (10-) 17-30 (-40) µm; **uniseriate**, phialides 5-8 x 3-4.5 µm covering at least the upper two-thirds of the vesicle. **Conidia** globose to subglobose or broadly ellipsoidal, finely roughened to densely spinulose, (3) 4-5 (7) µm in length. **Cleistothecia** yellow, globose to subglobose, (50) 75-150 (170) µm in diameter; wall consisting of a single layer of angular pseudoparenchymatous cells. Asci globose 9-15 µm, dehiscent, 8-spored, ascospores maturing within two to three weeks. **Ascospores** lenticular 4.5-6 x 3.5-4 µm, uncolored, rough-walled, with a longitudinal furrow and conspicuous ridge of irregular height on either side.

Distinguishing Features. *E. amstelodami* is distinguished by colony diameter on CY20S twice that on CYA25, yellow cleistothecia with hyaline, rough-walled ascospores each with a furrow and two longitudinal ridges.

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980; Pitt, 1985; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Common Synonyms. *A. amstelodami* (Mangin) Thom & Raper. This name is invalid because the original description included the teleomorph.

Habitats. *E. amstelodami* is more commonly encountered in tropical and subtropical regions than elsewhere and reported at higher than expected frequencies in studies conducted in desert soils and at latitudes between 25 and 36 degrees (Klich, 2002). It is frequently reported from soils and dried or concentrated food products, indoor environments, and has been reported from a variety of other sources (Domsch *et al*., 1980; Pitt & Hocking, 1997; Samson *et al*., 2001).

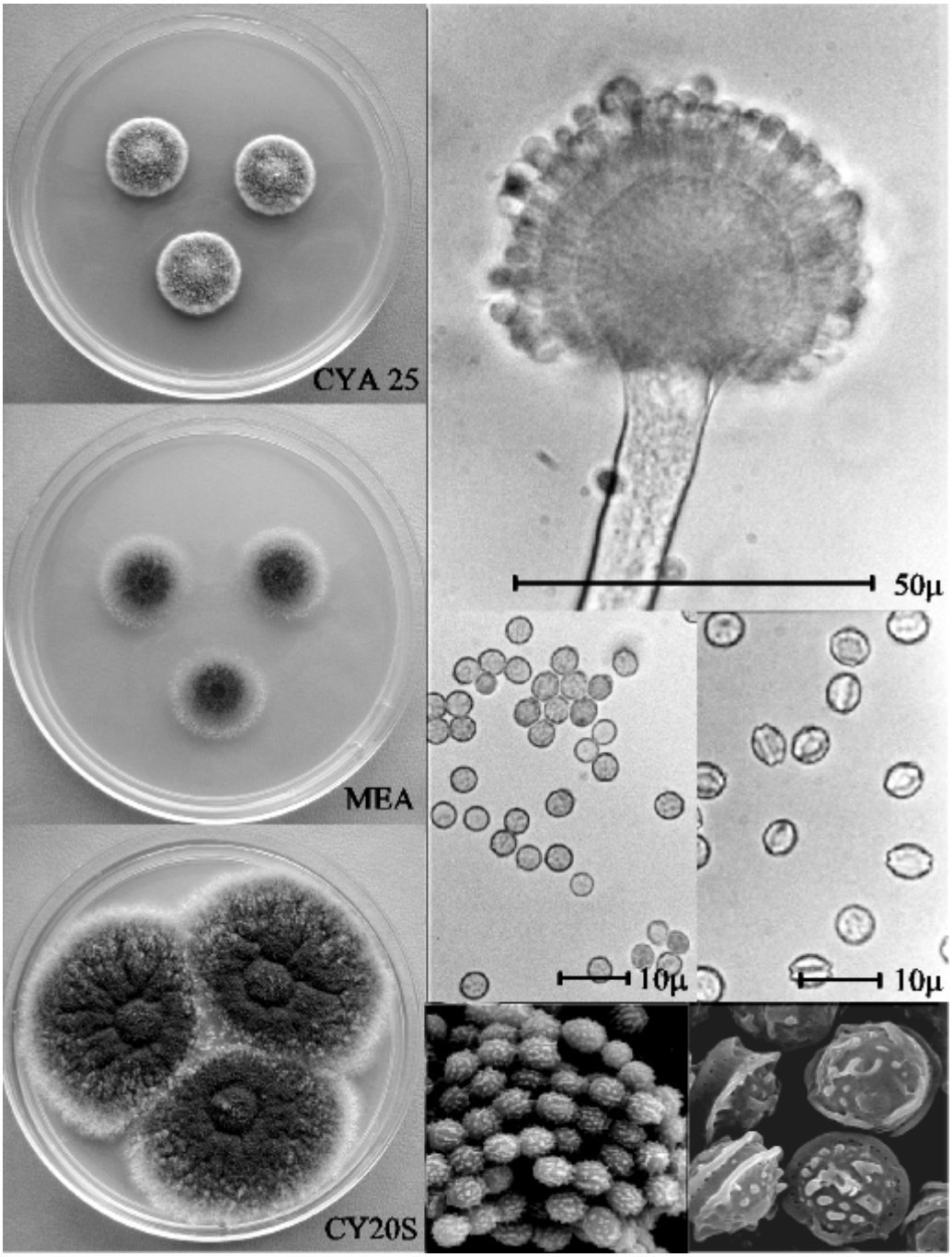

Fig. 7. *Eurotium amstelodami*: left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom, left to right), conidial head, conidia, ascospores, SEM of conidia (x 3000), and SEM of ascospores (x 8000).

Aspergillus auricomus (Guegen) Saito — Fig. 8.

J. Ferment. Technol. 17: 3. 1939. Neotype CBS 467.65.

Subgenus: *Circumdati* Section: *Circumdati*

Colony Diameters after 7 days incubation, in mm: **CYA25** 30-50; **MEA** (33) 40-60; **CY20S** (36) 45-60 (70); **CYA37** 0-25; **CZ** 18-27 (35).

Colony Colors and Textures. Conidial production on **CYA25** very limited in light yellow shades (4A3); mycelium white, generally inconspicuous; colony dominated by abundant sclerotia in golden yellow to orangish yellow (4-6A-B3-7) shades; exudate, when present, uncolored to yellow; reverse greyish yellow (5B3-4) to greyish red (7B4); soluble pigment yellow when present. On **MEA** conidia not abundant, light yellow to greyish yellow (4A-B4-5); mycelium white, inconspicuous; sclerotia either in a continuous layer or in small clusters, gold (4-5A-C5-8); reverse pale yellow to gold. Colonies on **CY20S** similar to those on CYA25 except that conidia are sometimes more abundant. When present, colonies on **CYA37** similar in colors to those on CYA25, with reverse colors pale yellow to dull red-brown shades. On **CZ**, conidia frequently absent, pale yellow (4A3-4) when present; white mycelium, sometimes inconspicuous; exudates uncolored to yellow when present; reverse dull yellow; sclerotia golden yellow to orange yellow (4A5-6, 5A-B5-6).

Microscopic Characteristics. **Conidial heads** radiate, splitting into columns; **stipes** 300-1000 (3500) x 7-18 µm, walls usually rough, uncolored to yellowish; **vesicles** globose to spathulate, widths in two size ranges, 12-17 µm or 25-35 (60) µm; **biseriate**; metulae covering at least the upper half of the vesicle, usually covering the entire vesicle, in two size ranges, 5-8 x 2.5-3 µm and 10-20 x 5-6 µm; phialides 5-9 x 2.5-3.5 µm. **Conidia** 2.5-3 (4) µm in diameter, smooth to finely roughened, globose, subglobose, or broadly ellipsoidal. **Sclerotia** abundant, globose (150) 500-700 (1000) µm in diameter.

Distinguishing Features. The solid mat of golden to orange sclerotia on CYA25, light yellow conidial heads, and small conidia make this a very distinctive species.

Taxonomic References. Raper & Fennell, 1965; Christensen, 1982; Klich & Pitt, 1988; Kozakiewicz, 1989.

Habitats. *A. auricomus* was originally isolated from an aqueous solution of potassium iodide (Christensen, 1982). It has also been isolated occasionally from soils (Klich, 1998).

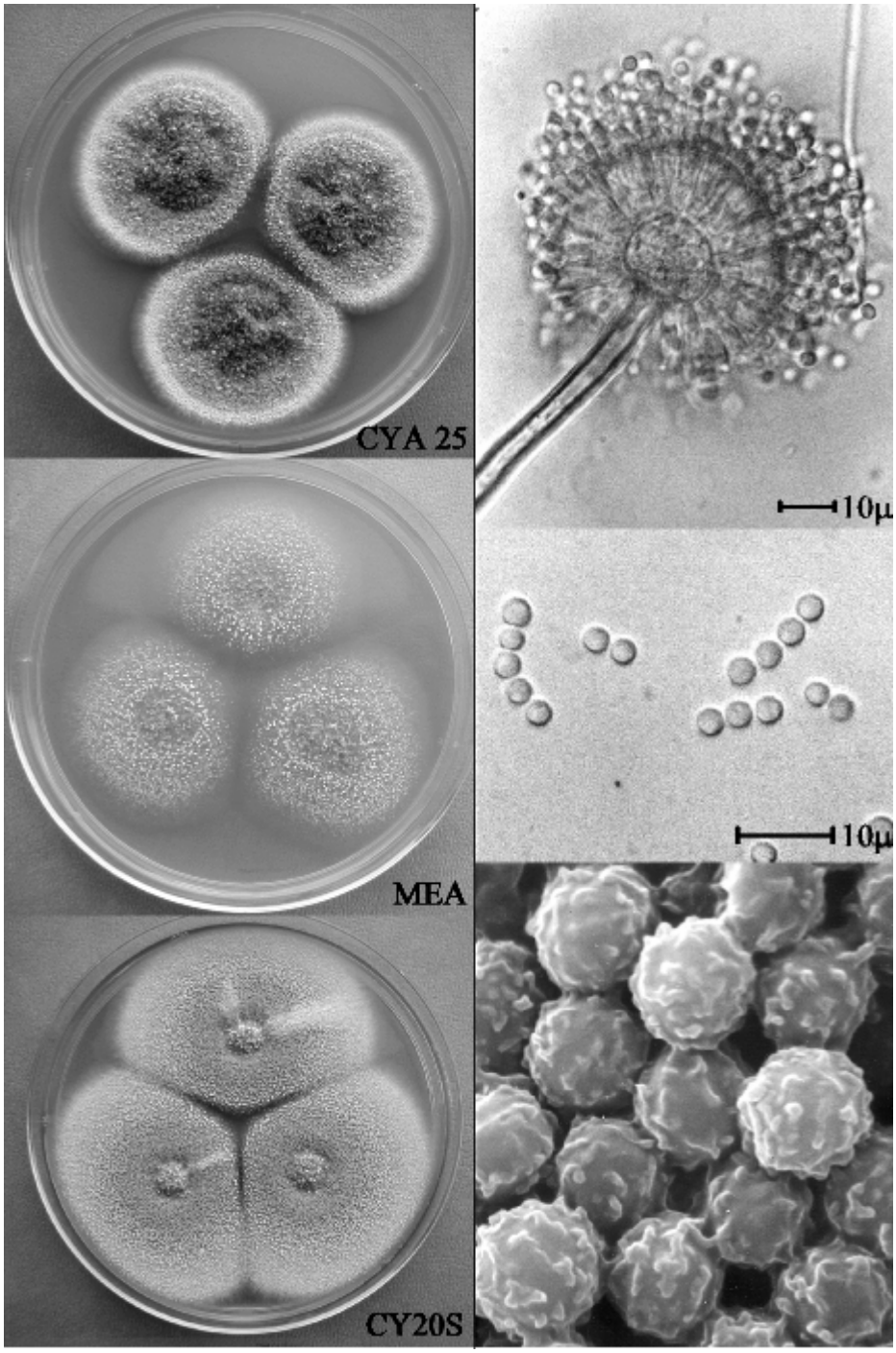

Fig. 8. *Aspergillus auricomus:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus awamori Nakaz. — Figs. 9 and 4j.

Rep. Gov. Res. Inst. Formosa 1907: 1. 1907. Neotype CBS 557.65.

Subgenus: *Circumdati* Section: *Nigri*

Colony Diameters at 7 days, in mm: **CYA25** (58) 60-70; **MEA** (55) 60-70; **CY20S** 60-70; **CYA37** (62) 65-70; **CZ** 30-60.

Colony Colors and Textures. Conidia on **CYA25** dark brown (5-6F2-5) to almost black; mycelium white to yellow, usually inconspicuous, sometimes in a floccose overlay; small droplets of hyaline to dark red brown exudate sometimes visible; reverse dull brown, dull yellow, intense yellow or grey brown; soluble pigment dull yellow when present; colony low, velutinous to granular, sometimes radially sulcate, occasionally with a floccose overlay. On **MEA**, conidia dark brown (5-6F3-5) to black; mycelium inconspicuous; colony plane, individual conidial heads uncrowded. Colonies on **CY20S**, **CYA37** and **CZ** similar in morphology to those on CYA25, however, the reverse on CYA37 was consistently dark brown to black.

Microscopic Characteristics. **Conidial heads** radiate, splitting into columns at maturity; **stipes** 300-1500 x 7-17 µm, smooth-walled, uncolored to slightly pigmented near the apices; **vesicles** globose (14) 20-40 (55) µm; predominantly **biseriate**; metulae (6) 10-20 (25) x 4-8 µm, over at least the upper half of the vesicle; phialides (5) 6-9 (10) x 2.5-4 µm. **Conidia** (3.5) 4-5 (6) µm in diameter, spherical, smooth to delicately roughened.

Distinguishing Features. Dark brown to almost black colonies, with biseriate conidial heads and smooth to delicately roughened conidia separate this taxon from others.

Taxonomic References. Raper & Fennell, 1965; Al-Musallam, 1980; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990.

Common Synonyms/Related species. *A. niger* v. *awamori* (Nakazawa) Al-Musallam.Al-Musallam (1980) reduced this species to varietal status, Kozakiewicz (1989) considered it to be a synonym of *A. niger*. The final status remains to be determined.

Habitats. This species appears to be associated with Asian food fermentations, but the literature on this point is confusing. It has been reported from soils, predominantly in latitudes between 16 and 35 degrees (Klich, 2002). *A. awamori* has also been reported infrequently from other habitats (Raper & Fennell, 1965).

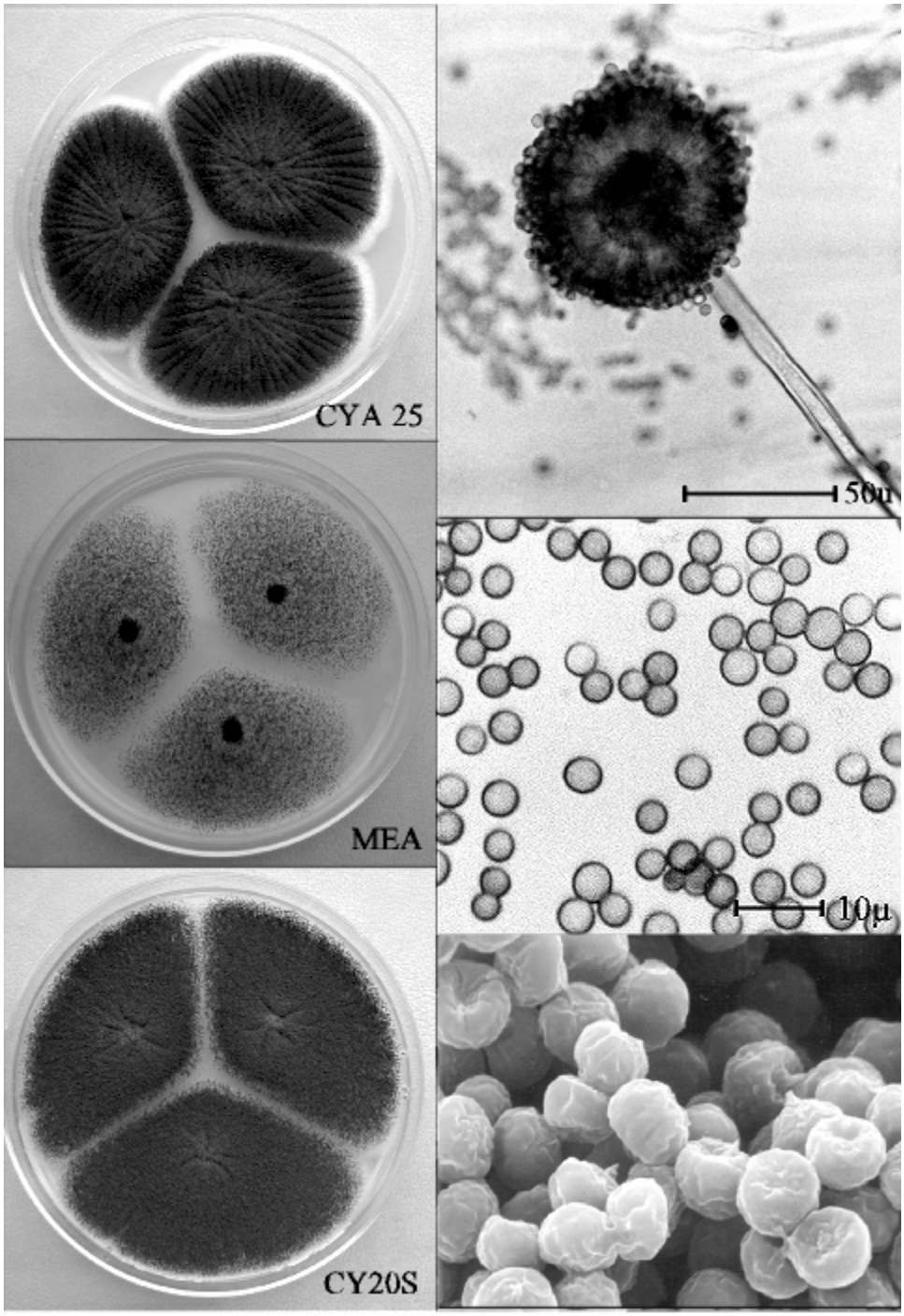

Fig. 9. *Aspergillus awamori*: left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial head, conidia, and SEM of conidia (x 3000).

Aspergillus caespitosus Raper & Thom — Fig. 10.

Mycologia 36: 563. 1944. Neotype IMI 16034ii.

Subgenus: ***Nidulantes*** **Section:** ***Versicolores***

Colony Diameters after 7 days incubation, in mm: **CYA25** 35-50 (52); **MEA** 47-60; **CY20S** 40-58; **CYA37** (5) 10-35; **CZ** 30-40.

Colony Colors and Textures. On **CYA25**, conidia greyish green (28-30D-E4-6) to greyish yellow green (1-3C-D4-5); mycelium white to yellow, usually inconspicuous; Hülle cells, when present, at first hyaline, becoming reddish in age; exudate uncolored when present; reverse bright yellow, red brown to purplish red (2B6, 8F8, 10D-C4), occasionally green (29E5); soluble pigment usually absent, occasionally purplish red; colony usually low velutinous, and sulcate. On **MEA,** conidial areas dark green (27-28E-F8); mycelium usually inconspicuous, white reddish yellow (4B7); reverse yellow to red-brown; colony very low, conidia not abundant, margins often fimbriate. On **CY20S**, colonies similar to CYA in appearance. On **CYA37**, conidia dull grey green to drab green/olive (3D3, 5C-D3-4), mycelium white, or inconspicuous, reverse in dark green, brown or gold colors, colonies dense frequently radially sulcate. Conidia on **CZ** greyish yellow to olive (1-2B-D3-4, white to yellow mycelium, reverse yellow or centrally dark brown to black, exudate minute droplets when present, uncolored; colony velutinous, dense, sulcate.

Microscopic Characteristics. **Conidial heads** radiate on CYA25 and generally columnar to loosely columnar on MEA; **stipes** (60) 100-300 (450) x 3-6 µm, with thick, usually smooth walls, brown in age, expanding into pyriform to spathulate to **vesicles** 9-15 (20) µm wide; **biseriate**; metulae 4-9 (10) x (2.5) 3-4 µm, covering half to two thirds of the vesicle; phialides (5) 6-8 (9) x (2.5) 3-4 µm. **Conidia** spherical, (3) 3.5-4.5 (5) µm in diameter, usually rough-walled, occasionally finely roughened. **Hülle cells** present in some isolates, globose to ellipsoidal.

Distinguishing Features. Sparse dark green colonies with a yellow to red-brown reverse on MEA, brown stipes bearing biseriate conidial heads and rough-walled 3.5-4.5 µm spherical conidia distinguish this species from others.

Taxonomic References. Raper & Fennell, 1965; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Klich, 1993.

Note. Kozakiewicz (1989) and Peterson (2000) both placed this species in Section *Nidulantes*.

Habitats. *A. caespitosus* has been reported predominantly from soil (Raper & Fennell, 1965), occurring with greater than expected frequencies in reports from desert soils and latitudes of 36-45 degrees (Klich, 2002). It has also been reported from sugarcane bagasse (Sandhu *et al*., 1980).

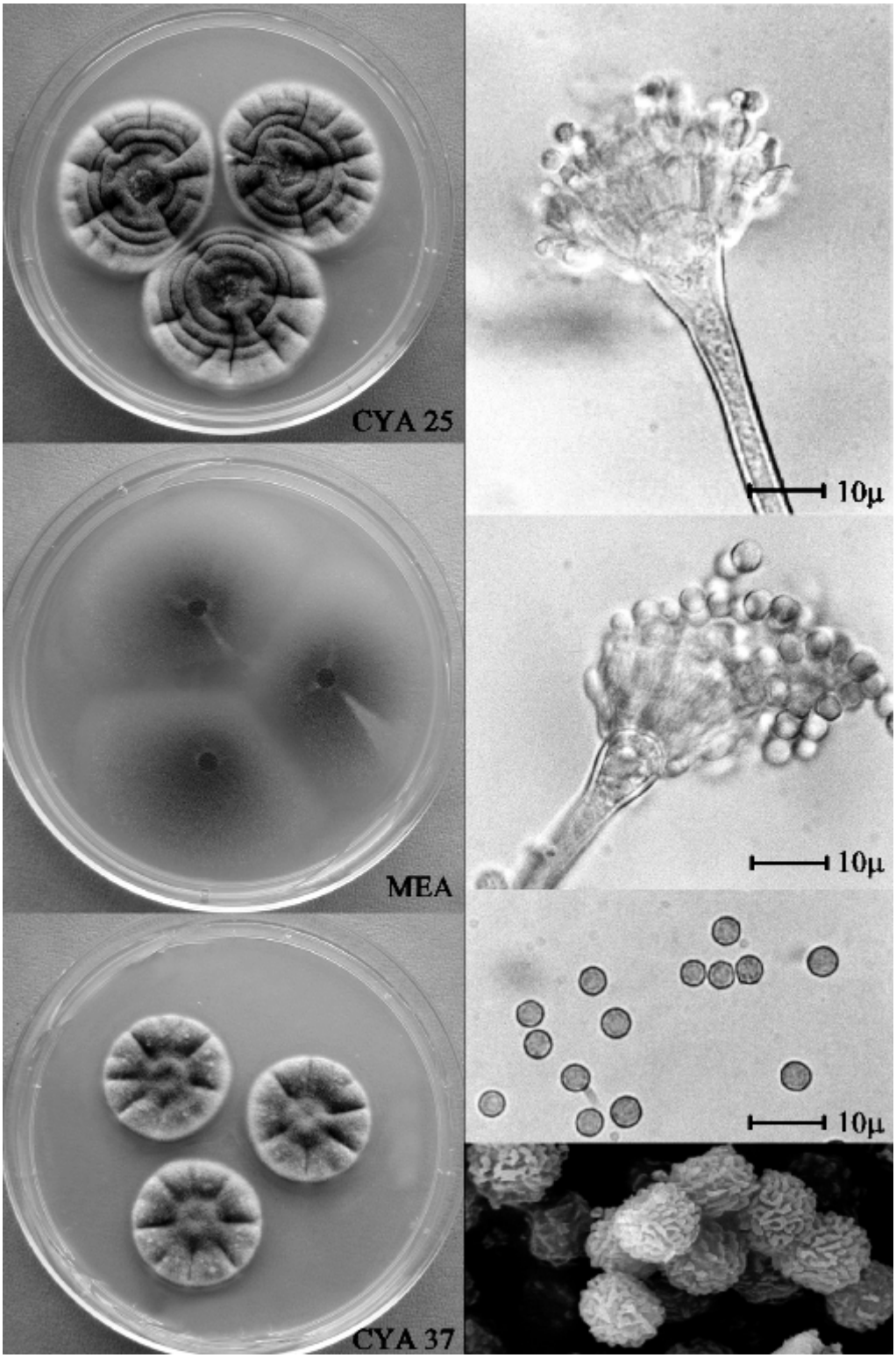

Fig. 10. *Aspergillus caespitosus:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus candidus Link — Figs. 11 and 3a.

Ges. naturf. Freunde Mag. Nevesten Entdeck. Gesammten Naturk. 3: 16. 1809. Neotype CBS 567.65.

Subgenus: *Circumdati* Section: *Candidi*

Colony Diameters after 7 days incubation, in mm: **CYA25** (13) 15-28; **MEA** 14-23 (26); **CY20S** (14) 19-33; **CYA37** 0-25; **CZ** (12) 14-27.

Colony Colors and Textures. Conidia on **CYA25** pure white to pale yellow (2A3); mycelium white, dense; sclerotia sometimes formed, dull pinkish purple initially, becoming black in age; exudate, when present, uncolored to yellow; reverse uncolored, light yellow (3-4A4-5) or yellowish orange (4A7); colony dense, velutinous to lanose, plane or radially sulcate. Conidia on **MEA** white to pale yellow (2A3); mycelium inconspicuous, white; reverse usually yellowish white to pale yellow (3A2-3) occasionally dull brown; colony low, granular. Conidial colors on **CY20S** similar to those on CYA25, colony texture frequently more granular than on CYA25. Colony colors on **CYA37** similar to those on CYA25; colonies velutinous, sulcate. Colony color and texture on **CZ** similar to that on CYA25.

Microscopic Characteristics. **Conidial heads** radiate; **stipes** (100) 200-500 (750) x 4-10 (12) µm, walls smooth to finely roughened, uncolored; **vesicle**s (12) 17-35 (40) µm wide, globose to somewhat elongate; predominantly **biseriate**, but smaller ones often **uniseriate**; metulae (5) 7-20 x (3) 5-8 µm, covering the entire surface of the vesicle; phialides 6-9 (11) x 2-3 µm, often only 2-3 phialides per metula. **Conidia** globose to slightly ovoid, (2.5) 3-4 (5) µm, smooth-walled.

Distinguishing Features. This species is distinguished by white to cream-colored conidia with colony diameters usually less than 35 mm on all media, and biseriate conidial heads with few phialides per metula. It is distinguished from the other predominantly white spored *Aspergillus* species, *A. niveus*, by its larger vesicles, metulae which cover most of the vesicle, and often having only 2-3 phialides per metula.

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Habitats. *A. candidus* is a common species predominantly occurring in tropical and subtropical regions. It has been reported from soils, grains, other seeds, flour, nuts, fruits, various other foodstuffs, indoor environments, and dung (Domsch *et al*., 1980; Pitt & Hocking, 1997; Samson *et al*., 2001; Klich, 2002).

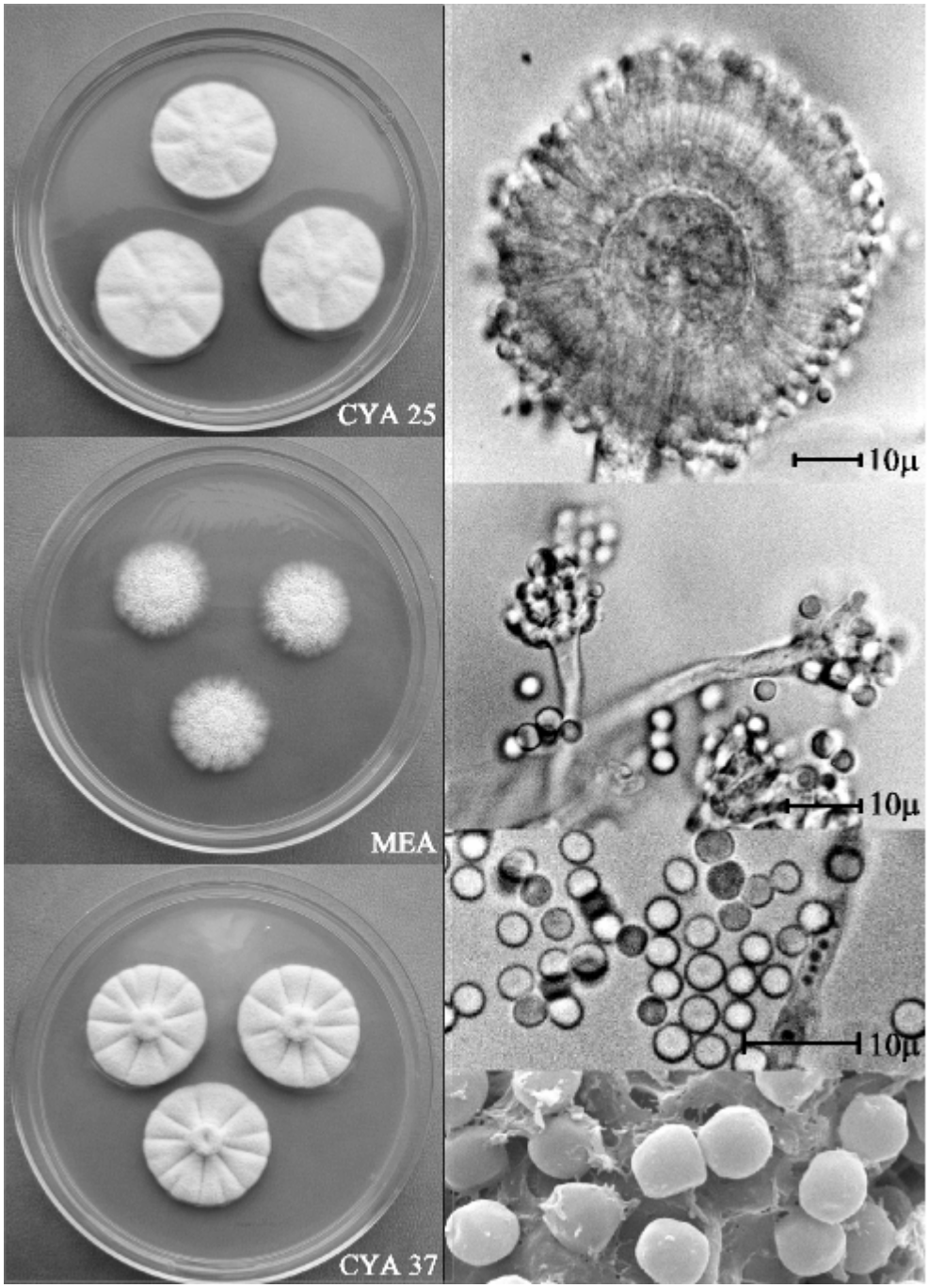

Fig. 11. *Aspergillus candidus:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, diminutive conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus carbonarius (Bainier) Thom — Figs. 12, 4k, 4*l* and 5f.

J. Agric. Res. 7: 12. 1916. Neotype CBS 556.65.

Subgenus: *Circumdati* Section: *Nigri*

Colony Diameters at 7 days, in mm: **CYA25** (60) 65-70; **MEA** (50) 55-70; **CY20S** 68-70; **CYA37** 10-30; **CZ** (30) 35-45.

Colony Colors and Textures. Conidia on **CYA25** olive black to black; mycelium white, usually inconspicuous; hyaline to brownish-black exudate sometimes formed; sclerotia, when present, yellowish buff or pinkish; reverse uncolored or in dull yellow to dark grey shades; colony a dense mat of long-stiped conidiophores. On **MEA**, conidia black and uncrowded; mycelium inconspicuous or as a white basal felt; sclerotia, if present, yellow to buff; reverse uncolored to slightly yellow; mycelium low, long stipes of individual conidiophores conspicuous. Colony characters on **CY20S** similar to those on CYA25, except stipes often 3-4 mm long and conidiophores not as dense. Colonies on **CYA37** similar in colors to those on CYA25, except reverse colors consistently black to grey, and brown soluble pigment sometimes visible; conidiophores shorter than on CYA25. Colonies on **CZ** similar to those on CYA25, but conidiophores not as densely packed.

Microscopic Characteristics. **Conidial heads** radiate, splitting into columns in age. **Stipes** (400) 1000-3500 (6000) x (9) 15-20 (30) µm, thick-walled, smooth to finely roughened, uncolored or brownish near apices; **vesicles** (48) 65-90 (100) µm, nearly spherical; **biseriate**; metulae over the entire vesicle surface, measuring (15) 25-40 (60) x (5) 6-11 (14) µm; phialides 8-12 x 5-7 (8) µm. **Conidia** very large, (6) 7-10 (11) µm in diameter, globose, walls extremely rough with spikes or tubercles when mature.

Distinguishing Features. *A. carbonarius* is characterized by its nearly black conidia, stipes up to several millimeters long, and large (7-11 µm) very rough-walled conidia.

Taxonomic References. Raper & Fennell, 1965; Al-Musallam, 1980; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990.

Habitats. This distinctive fungus has not been reported frequently. It has been reported from mud and wood in a mangrove swamp, soil, and polluted water (Kamal & Kumar, 1979; El-Dohlob & Ali, 1981; Jaitly & Rai, 1982). It is apparently tropical in distribution in soil with the greatest proportion of reports from 0-15 degrees latitude (Klich, 2002).

Major Mycotoxins. Ochratoxin A.

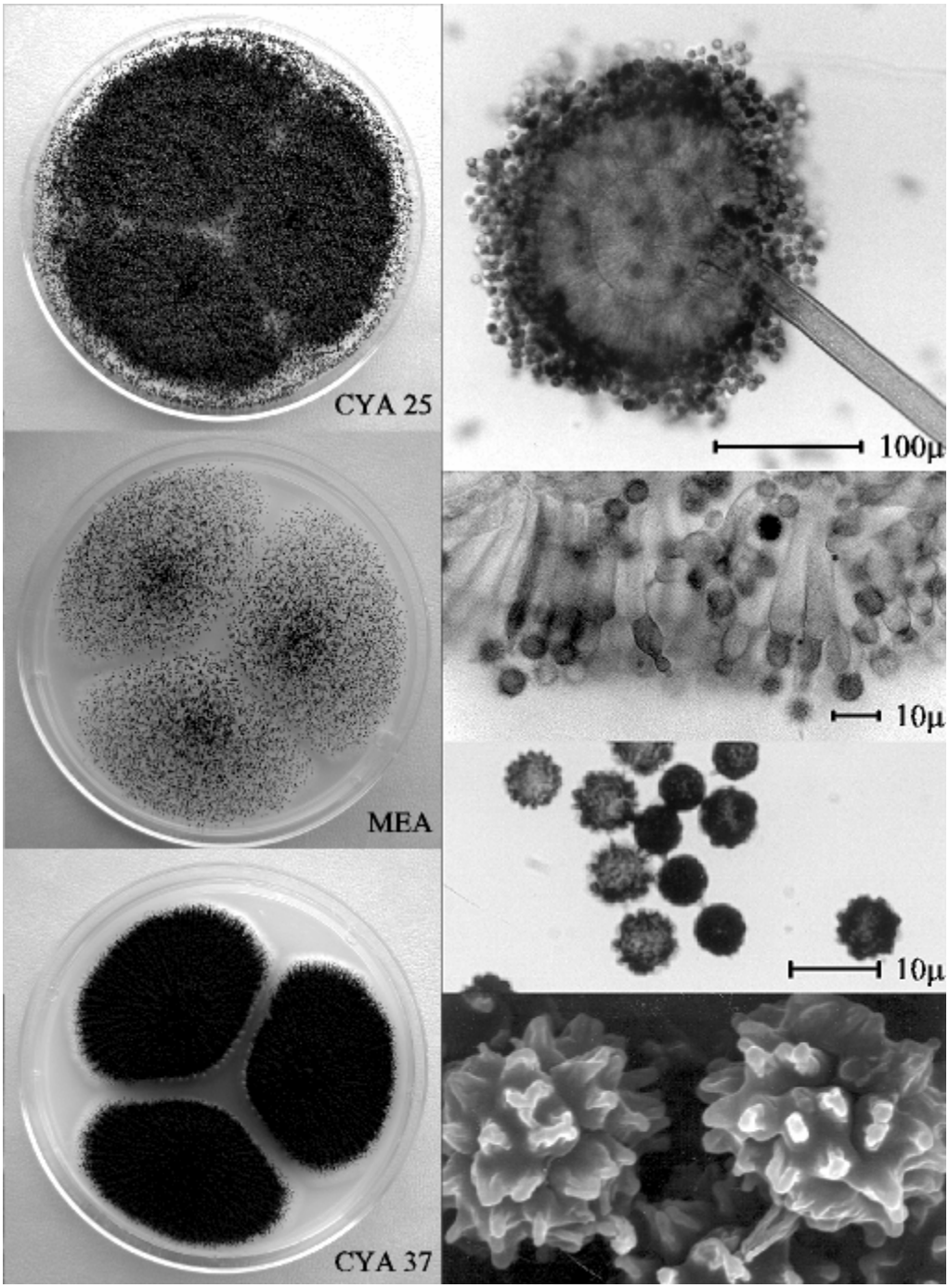

Fig. 12. *Aspergillus carbonarius*: left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, metulae and phialides, conidia, and SEM of conidia (x 8000).

Aspergillus carneus Blochwitz — Fig. 13.

Ann. Mycol. 31: 81. 1933. Neotype IMI 135818

Subgenus: ***Nidulantes*** **Section:** ***Flavipedes***

Colony Diameters at 7 days, in mm: **CYA25** 16-30 (36); **MEA** 20-42; **CY20S** 30-45; **CYA37** 0-53; **CZ** 17-23.

Colony Colors and Textures. Conidia on **CYA25** 'flesh' (6B3), dull pink (9A-B2-3) to pale greyish red (8C4, 7-9B3); mycelium yellow to white; exudate, when present, uncolored to brown; reverse uncolored, yellow orange or brown; soluble pigment sometimes present, brown to yellow; colony velutinous to lanose, plane or sulcate. On **MEA** conidia white to Venetian pink (10A3) to pale greyish orange or brownish orange (6BC3); mycelium white, inconspicuous; reverse uncolored or sometimes pale brown or yellow; soluble pigment yellow to yellow-brown, when present; colony low, granular, plane. Colony diameter on **CY20S** 24-40 mm, colonies otherwise similar to those on CYA25 in appearance. Growth on **CYA37** variable, when present, colony features similar to those on CYA25. Conidia on **CZ** dull pink (8B2, 9B3); mycelium white; reverse tan to red-brown (8-9E8); soluble pigment red-brown; colony low dense and velutinous.

Microscopic Characteristics. **Conidial heads** radiate to loosely columnar. **Stipes** 80-500 (700) x 3.5-7 µm, smooth-walled, hyaline to very pale brown; **vesicles** ranging from almost clavate to nearly spherical, predominantly pyriform (5.5) 9-15 µm wide; **biseriate**, metulae (4) 5-6 (10) x 2-3 µm, covering the upper third to half (rarely more) of the vesicle; phialides 5-7 x 2-2.5 (3) µm. **Conidia** (2) 2.5-3 (3.5) µm in diameter, smooth-walled, spherical, occasionally broadly ellipsoidal. Irregular branching elements or globose lateral cells sometimes present on the hyphae.

Distinguishing Features. Pale tan to pink conidia with white to yellow mycelium and biseriate conidial heads fertile over only the upper one third to one half of the vesicle are distinguishing characteristics of *A. carneus*.

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980; Klich & Pitt, 1988; Tzean *et al*., 1990.

Common Synonyms. *Aspergillus carneus* (van Tiegh.) Blochwitz. Domsch *et al*. (1980) and Samson & Gams (1985) noted that the authority for this name, used by Raper and Fennell (1965), is incorrect.

Note. Both morphological and molecular evidence (Peterson, 2000) indicates that there may be two species here, one with much faster growth rates than the other.

Habitats. This species has been isolated predominantly from soils in tropical and subtropical areas (Domsch *et al*., 1980; Klich, 2002)

Major Mycotoxins. Citrinin.

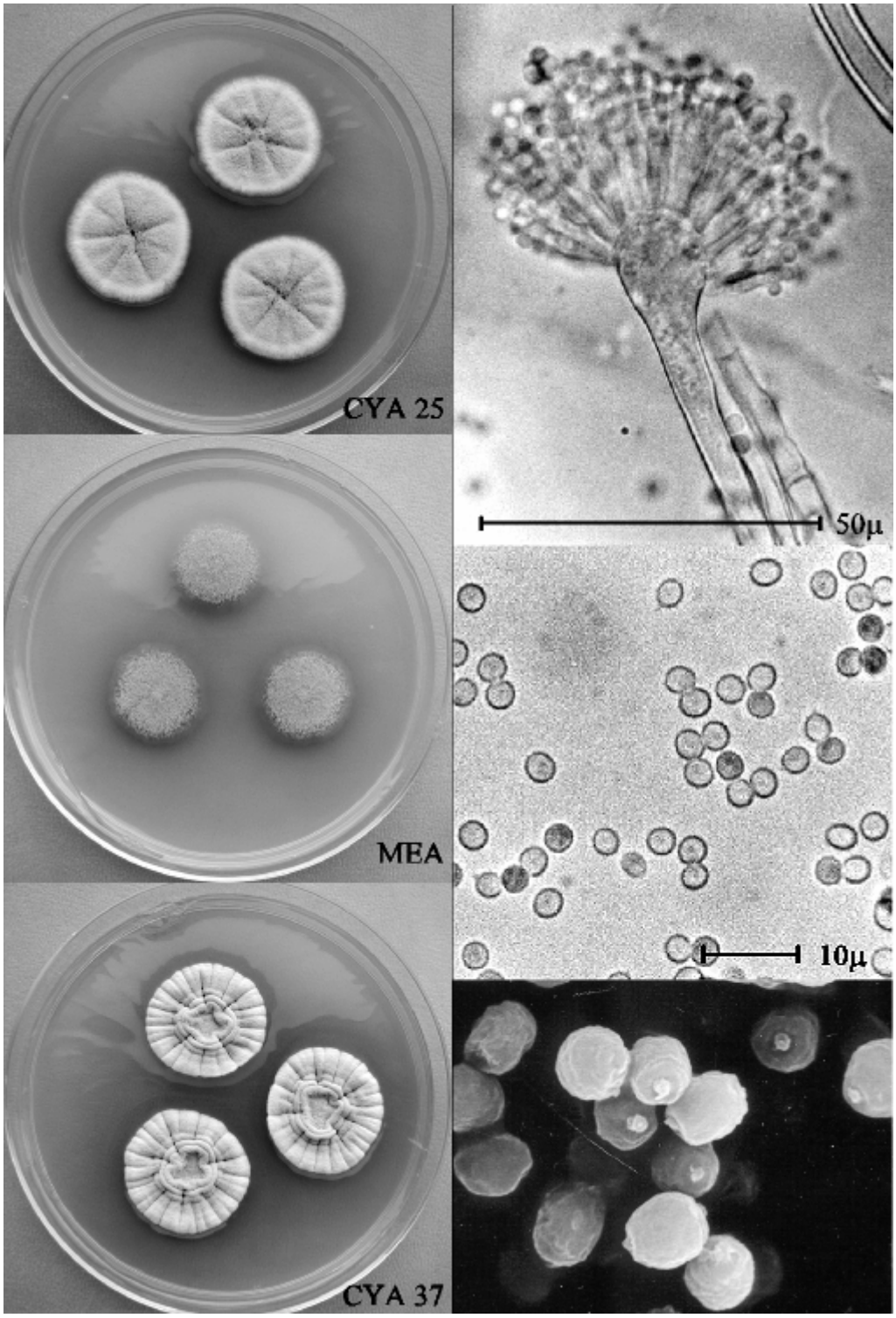

Fig. 13. *Aspergillus carneus* : left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, conidia, and SEM of conidia (x 3000).

Aspergillus cervinus Massee — Figs. 14 and 3h.

Kew Bull., Misc. Inf. 4: 158. 1914. Neotype WT 540 (herb. Wisc.).

Subgenus: *Fumigati* **Section: *Cervini***

Colony Diameters at 7 days, in mm: **CYA25** (10) 12-20 (22); **MEA** (53) 57-61 (65); **CY20S** 10-19; **CYA37** 0-12; **CZ** (8) 11-22.

Colony Colors and Textures. Conidia on **CYA25** orange white to light orange (4-5A2-4), relatively sparse; mycelium white, inconspicuous; reverse uncolored to light yellow or peach; texture granular, plane. On **MEA**, conidia abundant, pale orange to greyish orange (5-6A-B3-4); mycelium white, inconspicuous; reverse uncolored, dull yellow or pale brown; colony low velutinous to granular, plane. On **CY20S**, colonies similar in color and texture to CYA25. When colonies form on **CYA37**, they consist of low, dense, non-sporulating white colonies with no other colors present. Colonies on **CZ** consist of thin mycelium which is almost invisible unless the plate is held up to the light.

Microscopic Characteristics. **Conidial heads** radiate; **stipes** smooth, thick-walled, uncolored to slightly brown near the vesicles, 100-300 (600) x 4-9 µm; **vesicles** globose 10-20 (32) µm in diameter. **Diminutive heads** sometimes present; stipes 20-90 x 3-5 µm long, and vesicles 6-13 µm wide; **uniseriate**; phialides (4) 5-7 x 2.5-3 µm, tightly packed over the entire vesicle surface. **Conidia** smooth-walled, spherical, (2.5) 3-3.5 (4) µm in diameter.

Distinguishing Features. This species grows much more rapidly on MEA than on CYA25 or CY20S. It produces pale orange to greyish orange conidia on tightly packed phialides which cover most of the surface of the vesicle, and stipes in most isolates shorter than 300 µm. This species may be distinguished from the very similar species *A. kanagawaensis* by its generally shorter stipes (most under 300 µm), which are relatively consistent in length, thick stipe walls, and consistently erect conidial heads.

Taxonomic References. Christensen & Fennell, 1964; Raper & Fennell, 1965; Klich & Pitt, 1988.

Habitats. This species is not common, but has been isolated from tropical rainforest soils in Malaya, soils in Puerto Rico, New Zealand, Wisconsin USA, and India (Christensen & Fennell, 1964; Kamal & Kumar, 1979), and the rhizoplane of Cyperaceae in Australia (Yip & Weste, 1985). It has been reported at higher than expected relative frequencies from studies of cultivated soils, and from latitude ranges of 0-15 and 36-45 degrees (Klich, 2002).

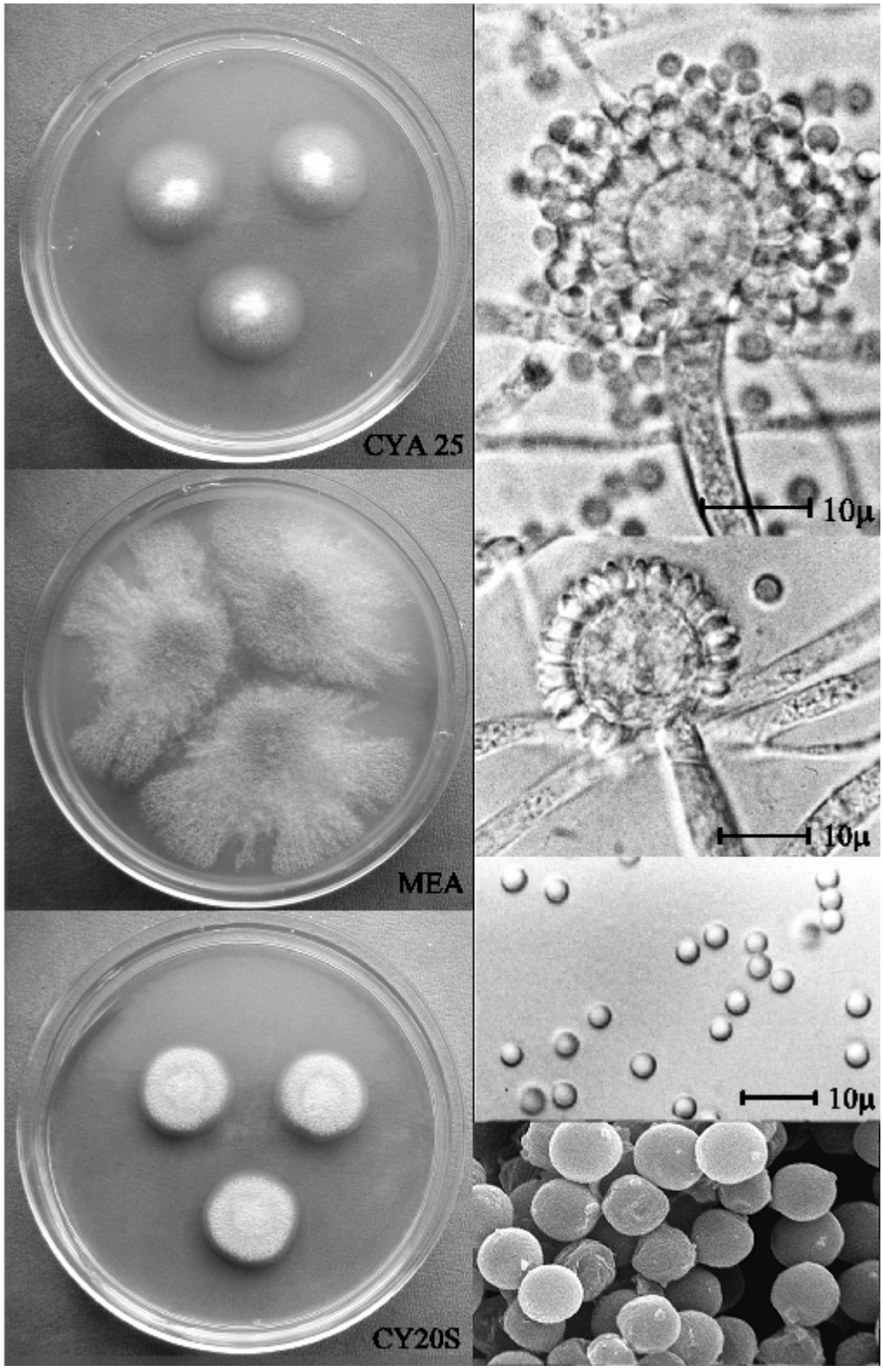

Fig. 14. *Aspergillus cervinus*: left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial head, young conidial head, conidia, and SEM of conidia (x 8000).

Eurotium chevalieri L. Mangin — Fig. 15.

Ann. Sci. Nat., Bot., Ser. 9, 10: 361. 1909. Neotype IMI 211382.
Anamorph: *A. chevalieri* ibid., p 362. Neotype IMI 211382.

Subgenus: *Aspergillus* Section: *Aspergillus*

Colony Diameters at 7 days, in mm: **CYA25** (16) 18-23 (28); **MEA** 16-25; **CY20S** (40) 45-68; **CYA37** 0-10 (11); **CZ** 16-20.

Colony Colors and Textures. Conidial areas on **CYA25** brown (4C-F5-8) or dull grey green (27E5); mycelium and cleistothecia yellow (3-4A6-7); reverse yellow to brown; colonies low, dense plane to sulcate. Conidia on **MEA** yellow olive, olive or olive brown (3-4D-E5-7); white to yellow mycelium, and yellow cleistothecia; reverse yellow to brown (sometimes orange or olive); colony low, velutinous, granular, or floccose, plane. On **CY20S**, conidia dull green (25-28E3-4); yellow mycelium and cleistothecia; reverse yellow, orange or brown; colony dense, plane to sulcate, velutinous. When growth occurs on **CYA37**, conidia are absent, mycelium is white to yellow; reverse in black to carmel colors; soluble pigment grey to orange-brown, colonies low, with raised central areas. On **CZ**, conidia dull olive to olive brown (3-4C-E4-8); mycelium white to yellow, reverse dull green to yellow; colonies velutinous to granular.

Microscopic Characteristics. **Conidial heads** on CY20S generally radiate; **stipes** (100) 300-500 (1000) x 7-12 (15) µm, uncolored to slightly brown, smooth-walled, broadening into pyriform, globose or clavate **vesicles** (17) 25-35 (37) µm in diameter; **uniseriate**; phialides (5) 6-8 (12) x (2) 3-4 (5) µm covering at least the upper two thirds of the vesicle surface. **Conidia** (3) 4-5 (7) x 3-4 µm, variable in shape, subspherical, ovoid, dolioform or pyriform with connectives sometimes visible, surface very finely roughened to rough and spinose. **Cleistothecia** (60) 90-150 (180) µm in diameter, globose to subglobose, yellow; wall consisting of a single cell layer composed of angular pseudoparenchymatous tissue. Asci 8-spored, dehiscent, maturing in one to two weeks. **Ascospores** lenticular, 4.5-5.5 (7) x 3.5-4.0 µm, smooth-walled with two prominent longitudinal flanges. These spores were aptly described by Mangin as 'pulley-form'.

Distinguishing Features. Colony diameter on CY20S at least twice that on CYA25, and yellow cleistothecia containing smooth-walled lenticular ascospores with two longitudinal flanges distinguish this species from others.

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980; Pitt, 1985; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Habitats. Like other *Eurotium* species, *E. chevalieri* is an ubiquitous xerophile. In soils it is most commonly isolated from tropical to subtropical zones, reported at greater than expected frequencies from studies on desert soils and from latitudes of 26-35 degrees (Klich, 2002). Some of its primary habitats are dried or concentrated substrates just above safe moisture levels including leather goods, cotton, seeds, and various kinds of dried foods, (Domsch *et al*., 1980) and indoor environments (Samson *et al*., 2001).

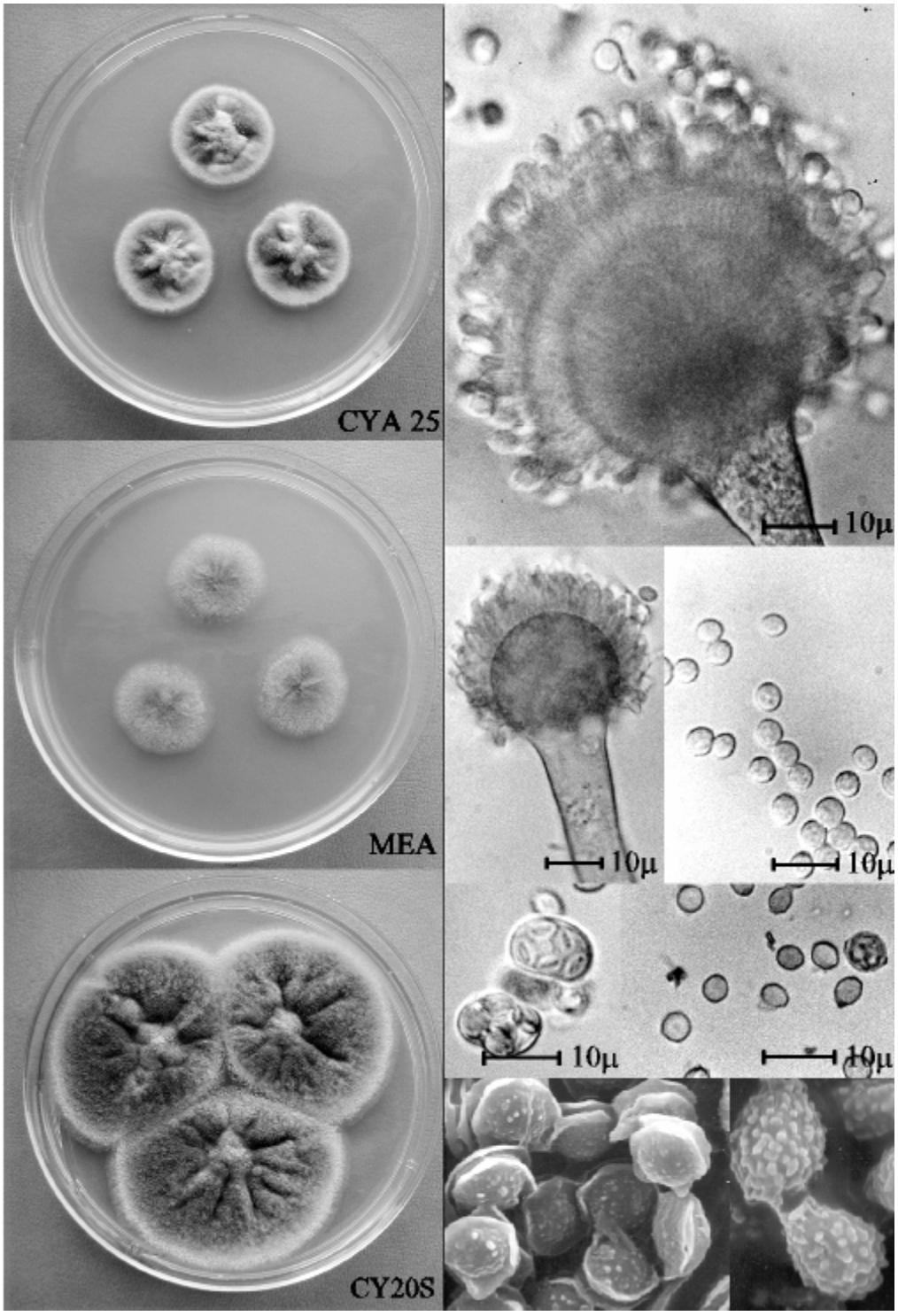

Fig. 15. *Eurotium chevalieri*: left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom, left to right), conidial head, conidial head, conidia, asci, ascospores, SEM of ascospores (x 3000) and SEM of conidia (x 8000).

Aspergillus clavatus Desm. — Figs. 16, 4e and 5c.

Ann. Sci. Nat. Bot., ser. 2, 2: 71. 1834. Neotype IMI 15949.

Subgenus: *Clavati* Section: *Clavati*

Colony Diameters at 7 days, in mm: **CYA25** (32) 37-48 (50); **MEA** (30) 35-45; **CY20S** (29) 35-54; **CYA37** 8-30; **CZ** 25-35.

Colony Colors and Textures. On **CYA25** conidia dull green, greyish turquoise, dark turquoise or dull green (24F7, 25E4-6, 26E3); mycelium white, inconspicuous to floccose; exudate, when present, uncolored; reverse uncolored or in dull yellow to brownish colors; colonies dense, plane to radially furrowed. Conidia on **MEA** in dull green, grey green or greyish turquoise shades (24-25D-E3-6, 24F7); mycelium white, inconspicuous; colony thin and low except for conidial areas which are more floccose and tend to be irregularly distributed. Colony colors and textures on **CY20S** like those on CYA25 except exudate not observed. Conidia less abundant on **CYA37** than on CYA25, absent in some isolates, colors and textures similar to those on CYA25. Colonies on **CZ** similar in appearance to those on CYA25, reverse colors less intense.

Microscopic Characteristics. **Conidial heads** radiate, or splitting into columns in age; **stipes** (300) 500-2000 (3000) x (5) 10-30 µm, smooth-walled, colorless to slightly brown near the apices, expanding gradually into clavate **vesicles** (8) 10-75 (90) µm wide, smaller vesicles sometimes pyriform, conidial zone extending from 12-250 µm down from the apices of the vesicles; **uniseriate**, phialides (6) 7-10 (14) x 2-3.5 (4) µm. **Conidia** smooth-walled, ellipsoidal, occasionally pyriform, apiculate or almost cylindrical, 3-6 x 2.5-4 µm.

Distinguishing Features. The most distinctive feature of *A. clavatus* is the formation of large, club shaped vesicles with fertile areas up to 250 µm long. The conidial heads are uniseriate with closely packed phialides. The conidia are dull turquoise, dark turquoise, or dull green.

Taxonomic References. Raper & Fennell, 1965; Klich & Pitt, 1988; Tzean *et al*., 1990; ; Pitt & Hocking, 1997; Samson *et al*., 2000.

Related Species. *A. giganteus* Wehmer, a closely related species, is characterized by very long stipes (up to several cm), and slightly larger colony diameters; CYA25 40-50 (65) mm, CY20S (33) 40-70 mm, and MEA 45-70 mm. This species is not as common as *A. clavatus*, is more tropical in distribution, and has been reported from dung, soil, and sorghum malt (Raper & Fennell, 1965; Kamal & Kumar, 1979; Rabie & Lübben, 1984; Klich, 2002).

Habitats. *A. clavatus* is a soil fungus with very widespread distribution in soils in warmer climates (Domsch *et al*., 1980). It has been reported at higher than expected frequencies from studies conducted in forest, desert and cultivated soils and at latitudes between 25 and 36 degrees (Klich, 2002). It is also quite widely distributed in some kinds of foods, especially cereals (Pitt & Hocking, 1997; Flannigan, 1986) and in indoor environments (Samson *et al*., 2001).

Major Mycotoxins. Patulin, cytochalasin E.

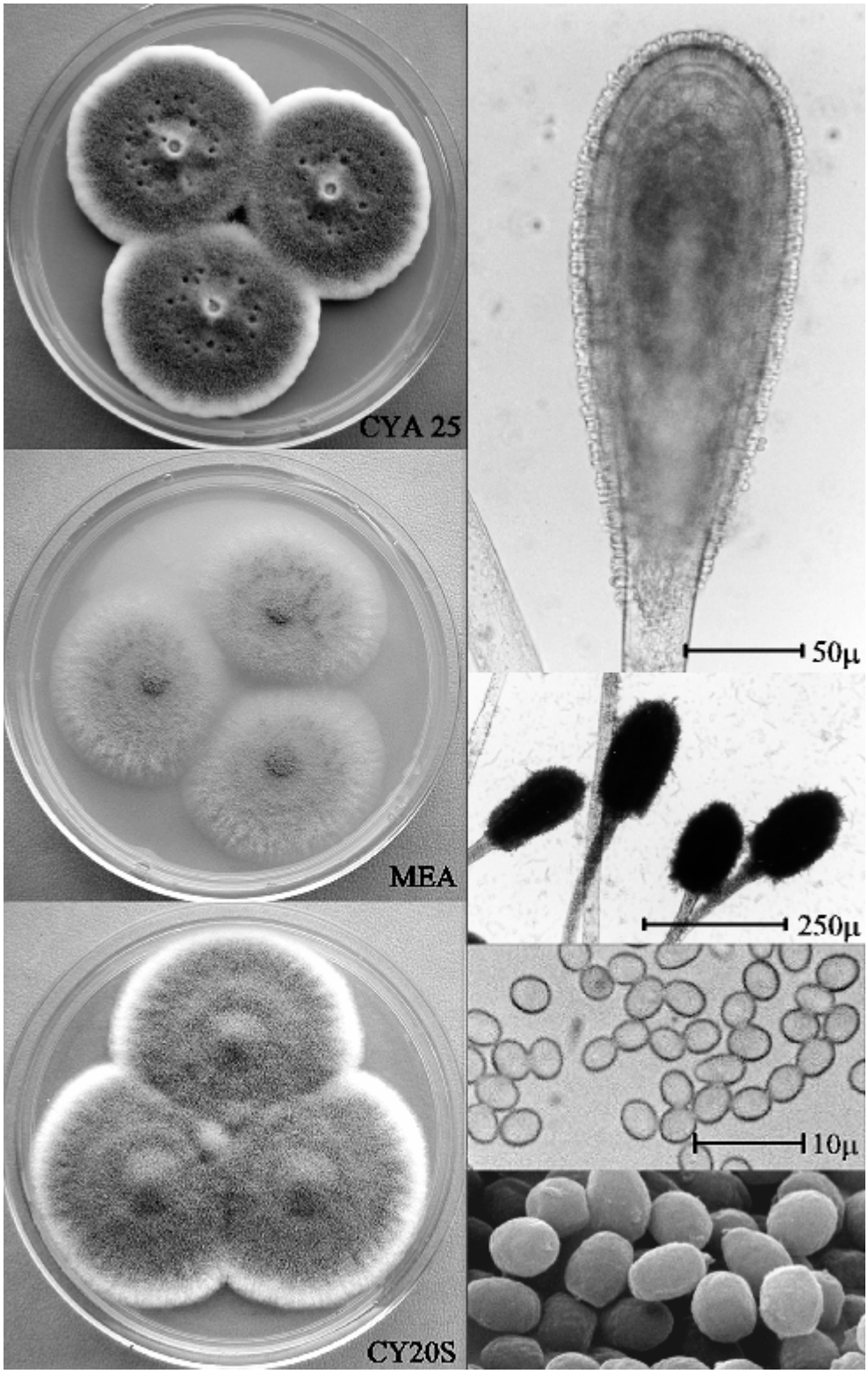

Fig. 16. *Aspergillus clavatus:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial head, conidial heads, conidia, and SEM of conidia (x 8000).

Chaetosartorya cremea (Kwon-Chung & Fennell) Subram. — Fig. 17.

Curr. Sci. 41: 761. 1972. Neotype IMI 123749ii
Anamorph: *A. cremeoflavus* Samson & W. Gams apud Samson & Pitt, Adv. *Penicillium Aspergillus* System.: 37. 1985. Holotype IMI 123749ii.

Subgenus: *Circumdati* Section: *Cremei*

Colony Diameters at 7 days, in mm: **CYA25** 10-25; **MEA** 18-25 (30); **CY20S** 35-55 (57); **CYA37** no growth; **CZ** 17-18.

Colony Colors and Textures. Conidia usually absent on **CYA25**; mycelium dense, white to pale yellow (4A-B4); cream to buff colored cleistothecia sometimes visible; exudate uncolored when present; reverse dull yellow to yellow brown (5C5); colony velutinous, radially sulcate. On **MEA**, conidia absent; mycelium dense, white to pale yellow (2A3-4); reverse cream to pale orange; cleistothecia yellow to dull orange. Colonies on **CY20S** similar in appearance to those on CYA25 except sparse, pale blue-green conidia usually present, and cleistothecia sometimes pale orange. Colony morphology on **CZ** similar to that on CYA25. Exposure to light enhances sporulation.

Microscopic Characteristics. **Conidial heads** radiate, **stipes** very long, 4000-8000 x10-25 µm, smooth-walled, uncolored or slightly yellowish, constricted beneath the vesicles; **vesicles** globose to subglobose, (40) 60-75 (100) µm in diameter; **biseriate**; metulae (7) 9-12 (13) x (3) 4-6 (6.5) µm covering the entire surface of the vesicle; phialides 9-12 (18) x 3-5.5 µm. **Conidia** variable in shape, subglobose to ellipsoidal, 5-8 x 3.5-5 µm, spinose. **Cleistothecia** globose, cream to buff colored, 70-600 µm in diameter, wall consisting of irregularly flattened cells. Asci globose, 12-14 µm, 8-spored, dehiscent. **Ascospores** mature within two weeks, lenticular, hyaline, 4.5-5.5 x 4-4.5 µm excluding the two longitudinal crests which are up to 1.5 µm wide; convex walls usually have one to several thin spikes which look almost like small crests.

Distinguishing Features. *C. cremea* is xerophilic, producing few conidia on CYA25 and MEA. The conidia are very large (5-8 µm) and have distinct spines. This fungus usually produces cream to buff colored cleistothecia containing mature ascospores within two weeks. The hyaline ascospores have two longitudinal crests and spikes on the convex walls.

Common Synonyms. *A. cremeus* Kwon-Chung & Fennell. This name is not valid because the description included the teleomorph.

Taxonomic References. Raper & Fennell, 1965; Subramanian, 1972; Malloch & Cain, 1972; Klich & Pitt, 1988.

Habitats. *C. cremea* is not a commonly isolated species, but has been reported from soils (Raper & Fennell, 1965).

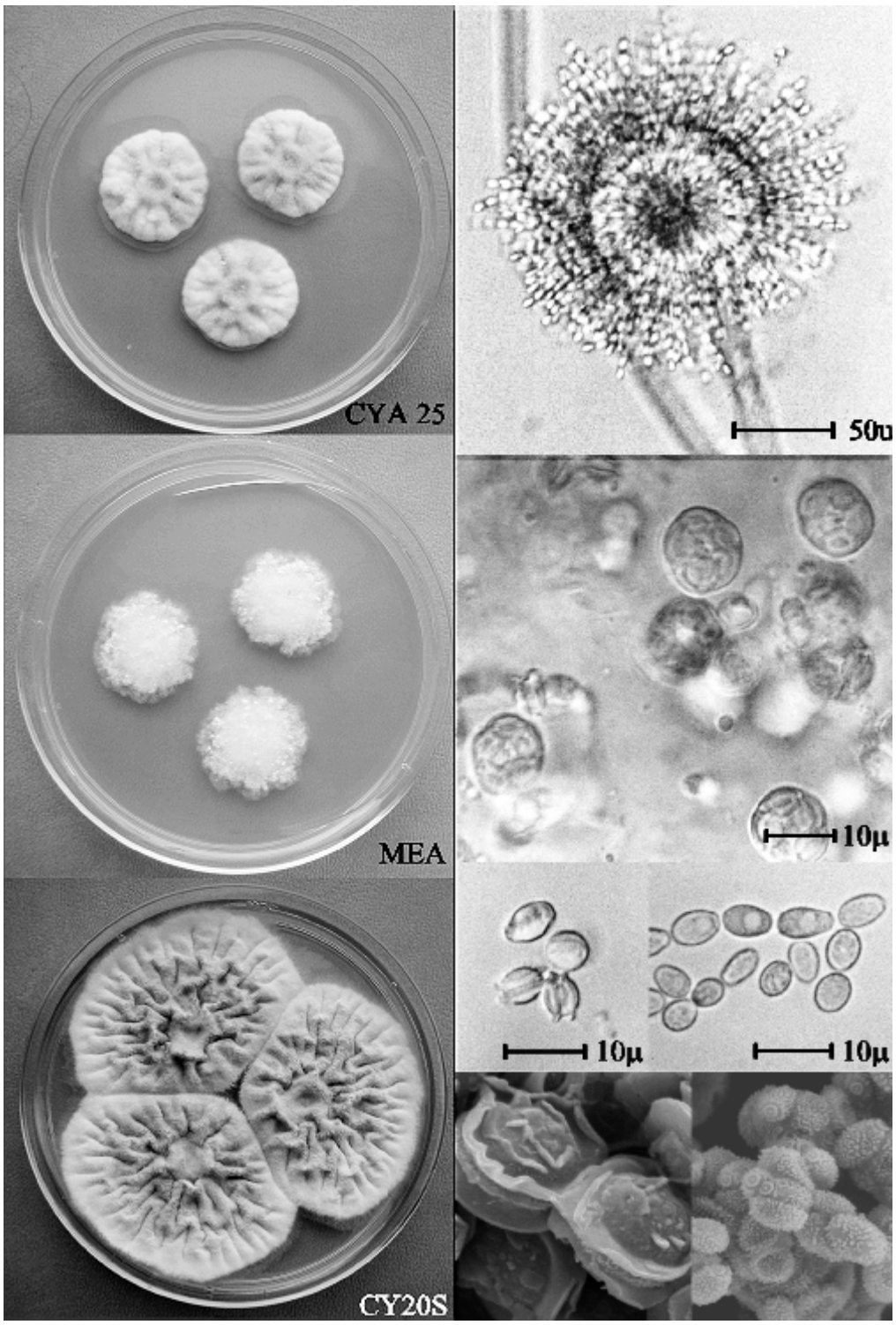

Fig. 17. *Chaetosartorya cremea*: left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom, left to right), conidial head, asci, ascospores, conidia, SEM of ascospores (x 8000) and SEM of conidia (x 3000).

Neosartorya fischeri (Wehmer) Malloch & Cain — Figs. 18 and 5b.

Can. J. Bot. 50: 2621. 1972. Neotype IMI 21139ii.
Anamorph: *A. fischerianus* Samson & W. Gams apud Samson & Pitt, Adv. *Penicillium Aspergillus* System.: 39. 1985. Holotype IMI 21139ii.

Subgenus: *Fumigati* Section: *Fumigati*

Colony Diameters at 7 days, in mm: **CYA25** (50) 60-70; **MEA** (60) 65-70; **CY20S** 60-70; **CYA37** 60-70; **CZ** 53-60.

Colony Colors and Textures. On **CYA25**, conidia sparse grey green to pale blue green (25D-E4-5, 26-27C-E3); mycelium white to cream with cream colored cleistothecia; exudate, when present, uncolored to pale brown; reverse uncolored, yellow, or brown; soluble pigment absent; texture velutinous to floccose, plane or somewhat sulcate. Sporulation on **MEA** sparse or absent, in colors similar to those on CYA25; mycelium white to cream, cleistothecia light cream; reverse uncolored to pale dull yellow; texture thin, plane or somewhat floccose. Colonies on **CY20S** colored as on CYA25, with similar textures. Conidia abundant on **CYA37**, colors similar to those on CYA25, colonies low, dense, usually radially sulcate. On **CZ**, conidia very sparse in dull blue green colors, reverse colors pale yellow to peach (5A-B3), other characters similar to those on CYA25.

Microscopic Characteristics. These characters are best observed on mounts from CYA37 plates. **Conidial heads** radiate to columnar, **stipes** uncolored, smooth-walled, (100) 150-350 (1000) x 5-9 µm, enlarging to pyriform **vesicles** (8) 10-20 (25) µm in diameter; **uniseriate**; phialides 5-8 x 2-3 µm covering the upper half to two-thirds of the vesicle. **Conidia** smooth to finely roughened, spherical to ellipsoidal, 2.5-3 (4) x 2-3 µm. **Cleistothecia** globose (100) 150-350 (1000) µm, soft-walled, mycelial, often with pseudoparenchymatous wall several layers thick, white to cream in color. Asci 9-15 µm, dehiscent, with 8 inordinately arranged uncolored ascospores which mature in 7-14 days. **Ascospores** lenticular to almost spherical, 5-8 µm in length, including flanges, 4-5 (6) µm in width; walls slightly to very rough, with two longitudinal, thin, ruffled flanges.

Distinguishing Features. This species is characterized by rapidly growing colonies, sparsely sporulating on all three media, with soft-walled, white to cream colored cleistothecia containing hyaline, rough-walled ascospores with two sinuous longitudinal flanges.

Taxonomic References. Raper & Fennell, 1965; Samson, 1979; Domsch *et al*., 1980; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Common Synonyms. *A. fischeri* Wehmer. This name is invalid because the species description included the teleomorph.

Related Species. Raper & Fennell (1965) recognized two varieties of this species, *A. fischeri* var. *glaber* [= *N. fischeri* var. *glabra* (Raper & Fennell) Malloch & Cain] and *A. fischeri* var. *spinosus* [= *N. fischeri* var. *spinosa* (Raper & Fennell) Malloch & Cain]. The first named has ascospores with smooth convex walls, while the latter has spinose convex walls. Both species are uncommon. A number of other *Neosartorya* species have been described (see Pitt *et al*., 2000), most are quite rare.

Habitats. *N. fischeri* is a thermotolerant soil fungus of widespread distribution (Domsch *et al*., 1980). It has been reported at greater than expected frequencies from studies in wetland soils and soils in the 0-15 and 26-35 degree latitude ranges (Klich, 2002). It has been isolated from agricultural products and is sometimes pathogenic to mammals, including humans (Samson *et al*., 2000).

Major Mycotoxins. Verrucologen, fumitremorgin A & B.

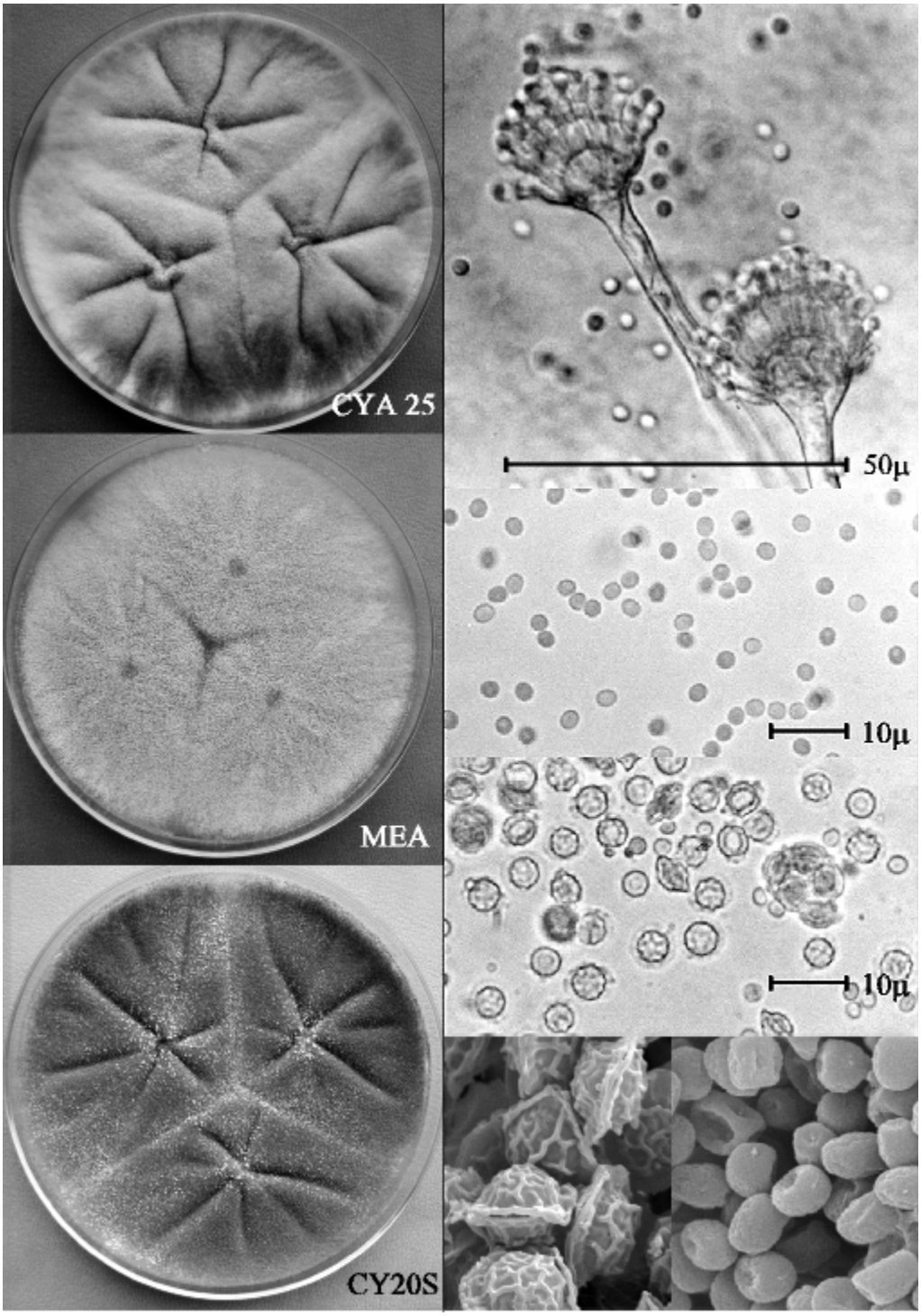

Fig. 18. *Neosartorya fischeri:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom, left to right), conidial heads, conidia, ascospores, SEM of ascospores (x 8000),and SEM of conidia (x 8000).

Aspergillus flavipes (Bainier & Sartory) Thom & Church — Fig. 19.

The Aspergilli: 155. 1926. Neotype. IMI 171885
Teleomorph: *Fennellia flavipes* Wiley & Simmons. Mycologia 65: 937. 1973. Holotype QM 9131.

Subgenus: *Nidulantes* Section: *Flavipedes*

Colony Diameters at 7 days, in mm: **CYA25** (19) 24-33 (40); **MEA** 28-31 (37); **CY20S** 23-39; **CYA37** 8-20 (25); **CZ** 20-17 (29).

Colony Colors and Textures. Conidia on **CYA25** orange grey to greyish orange (5-6B-C2-3); mycelium white to cream, dense; exudate, when present, yellow, brown or uncolored; reverse uncolored, pale yellow, light brown (5D6), yellowish brown (5E-F8) or brown (6-7D-E8); colonies radially sulcate, velutinous, occasionally with a tufted overlay of white mycelium. Conidia orange white (5A2) to reddish blond (5C3-4) on **MEA**; mycelium white, inconspicuous; reverse greyish yellow (4B5) to golden brown (5D7); colonies velutinous to slightly granular, occasionally forming sectors of sterile floccose mycelium. On **CY20S**, colors similar to those on CYA25, no exudate observed, texture generally granular or lanose, wrinkled. On **CYA37**, and **CZ** colors and textures similar to those on CYA25, however, no exudate was observed on CYA37.

Microscopic Characteristics. **Conidial heads** radiate to loosely columnar; **stipes** (150) 200-800 (1200) x 4-8 µm, uncolored to pale brown, walls smooth to slightly roughened, broadening gradually into spathulate to subglobose **vesicles** (7) 10-18 (20) µm wide; **biseriate**; metulae (4) 5-6 (8) x 2.5-3.5 (4.5) µm, covering at least the upper half of the vesicle; phialides 5-8 x 2-3 µm. **Conidia** globose, 2-3 µm in diameter, smooth-walled. Lateral globose cells are occasionally produced on the vegetative hyphae. **Cleistothecia** were not developed by the isolates examined. *Fide* Wiley and Simmons (1973): cleistothecia yellow, embedded in discrete clumps of rounded to elongate Hülle cells; asci globose, 10-12.5 µm in diameter, dehiscent and usually 4-spored; **ascospores** mature in about 3 weeks, hyaline, subglobose, 6.4-8.0 x 5.6-6.4 µm, smooth walled, with an inconspicuous longitudinal groove.

Distinguishing Features. Pale greyish orange conidia on loosely columnar to radiate biseriate conidial heads with small (2-3 µm) smooth-walled globose conidia make this species distinctive.

Taxonomic References. Raper & Fennell, 1965; Wiley & Fennell, 1973; Wiley & Simmons, 1973; Domsch *et al*., 1980; Klich & Pitt, 1988; Tzean *et al*., 1990; Pitt & Hocking, 1997.

Habitats. *A. flavipes* is a very common soil fungus (Domsch *et al*., 1980), occurring at high relative frequencies in studies conducted in the 26-35 degree latitude range (Klich, 2002). It has been isolated from indoor environments but is relatively uncommon in foods (Pitt & Hocking, 1997; Samson *et al*., 2001).

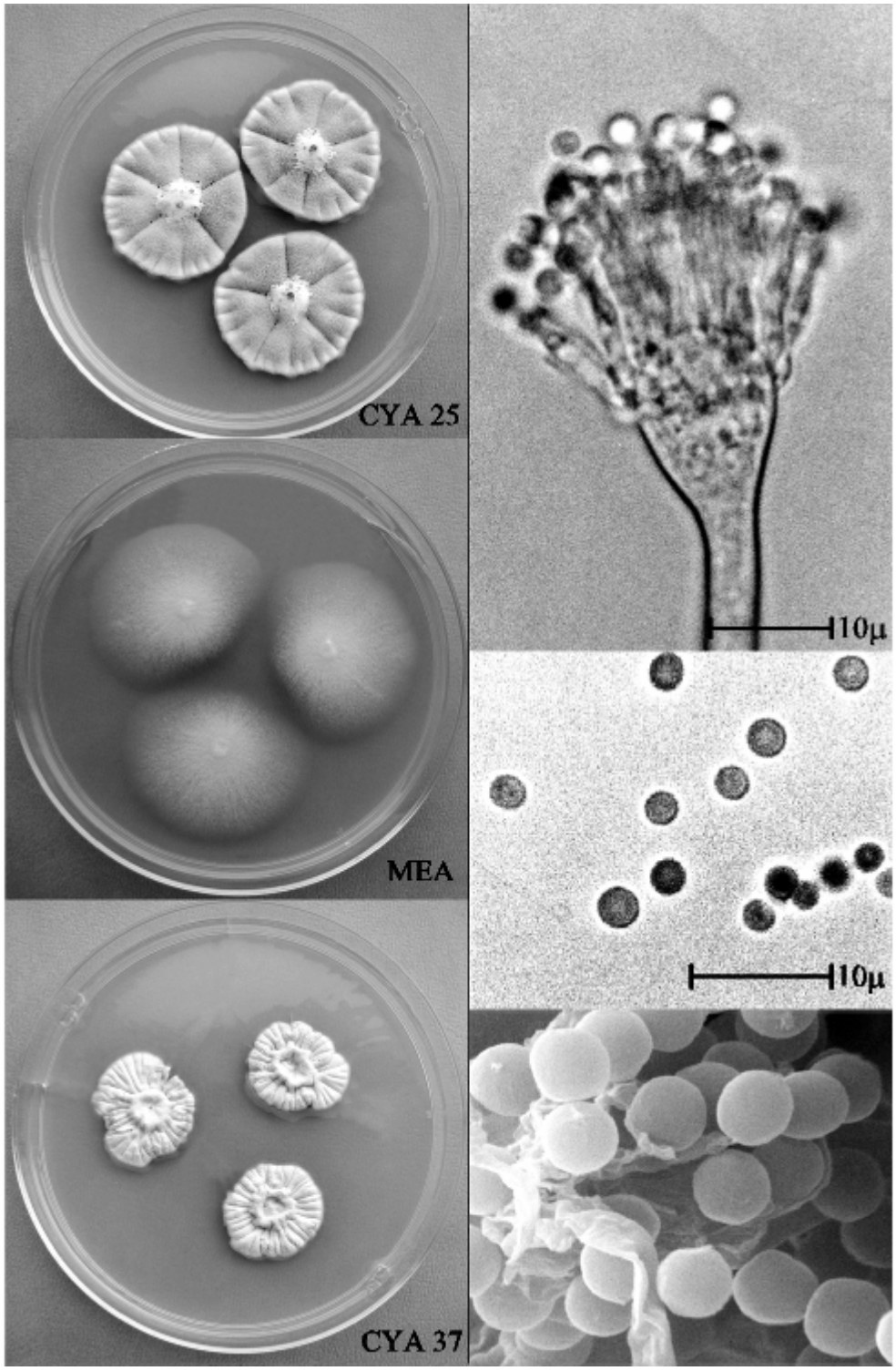

Fig. 19. *Aspergillus flavipes:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus flavus Link — Figs. 20 and 3j.

Ges. Naturf. Freunde Berlin Mag. Neuesten Entdeck. Gesammten Naturk 3: 16. 1809. Neotype IMI 124938.

Subgenus: *Circumdati* Section: *Flavi*

Colony Diameters at 7 days, in mm: **CYA25** (45) 65-70; **MEA** (50) 65-70; **CY20S** 65-70; **CYA37** (50) 55-65 (70); **CZ** 55-65.

Colony Colors and Textures. Conidia on **CYA25** deep green (28-30D-E8), olive green (1-3D-E6-7), or olive (3E6-8), sometimes overlaid with greyish yellow to olive yellow (2-4B-C6) areas; mycelium white; sclerotia, when present, dark brown to black variable in shape and size; exudate, when present, uncolored to brown; reverse uncolored, dull brown or orangish; variable in colony texture, generally 2-3 mm deep, lanose to floccose. On **MEA**, conidia olive (1-3D-E5-8) or occasionally dark green (30E-F7-8); mycelium white, inconspicuous; sclerotia sometimes present, brown to black, variable in shape and size; reverse generally uncolored, sometimes in dull yellow colors; colonies floccose, especially centrally. Colony characters on **CY20S** similar to those on CYA25 except exudate absent and bright yellow (3A3-8) reverse colors occasionally produced. Conidia on **CYA37** olive to olive brown (3-4E8), other colors and textures as on CYA25. Colony morphology on **CZ** similar to that on CYA25.

Microscopic Characteristics. **Conidial heads** radiate to columnar. **Stipes** (250) 400-800 (2500) x 8-17 µm in length, walls usually quite rough, occasionally finely roughened, generally uncolored, sometimes very pale brown; **vesicles** spherical to elongate (12) 20-45 (85) µm wide; variable in seriation, most isolates with at least 20% **biseriate** on CYA25, some almost entirely **uniseriate** on MEA; metulae covering three quarters to the entire surface of the vesicle, (6) 8-10 (16) x (4) 5-7 (9) µm; phialides 7-12 x (2.5) 3-4 (5) µm. **Conidia** globose to ellipsoidal 3-6 (8) µm, with smooth to finely roughened walls.

Distinguishing Features. Spreading yellow-green colonies with rough-walled stipes, and smooth to finely roughened conidia 3-6 µm in diameter are the most distinctive features of this species. *A. flavus* may be distinguished from *A. oryzae* by its less floccose texture, greener colors and smaller conidia, and from *A. parasiticus* by its smooth spores.

Taxonomic References. Raper & Fennell, 1965; Christensen, 1981; Klich & Pitt, 1985; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Related Species. *A. nomius* may be distinguished from *A. flavus* by production of both B and G aflatoxins. A new rare species, *A. bombycis* (Peterson *et al*., 2001) grows slowly on CYA37 (0-37 mm at one week) and has smooth stipe walls.

Habitats. *A. flavus* is worldwide in distribution. It is the most widely reported food-borne fungus, it also colonizes decaying vegetation, crop seeds and many other substrates in indoor and outdoor environments (Pitt & Hocking, 1997 Samson *et al*., 2001). It has been reported as an insect and animal pathogen. About half of the isolates form aflatoxins, very potent carcinogens (Domsch *et al*., 1980; Christensen, 1981; Diener *et al*., 1987). It has been reported in a greater than expected proportion of studies conducted in the 26-35 degree latitude range (Klich, 2002).

Major Mycotoxins. Aflatoxin B_1, cyclopiazonic acid, 3-nitropropionic acid.

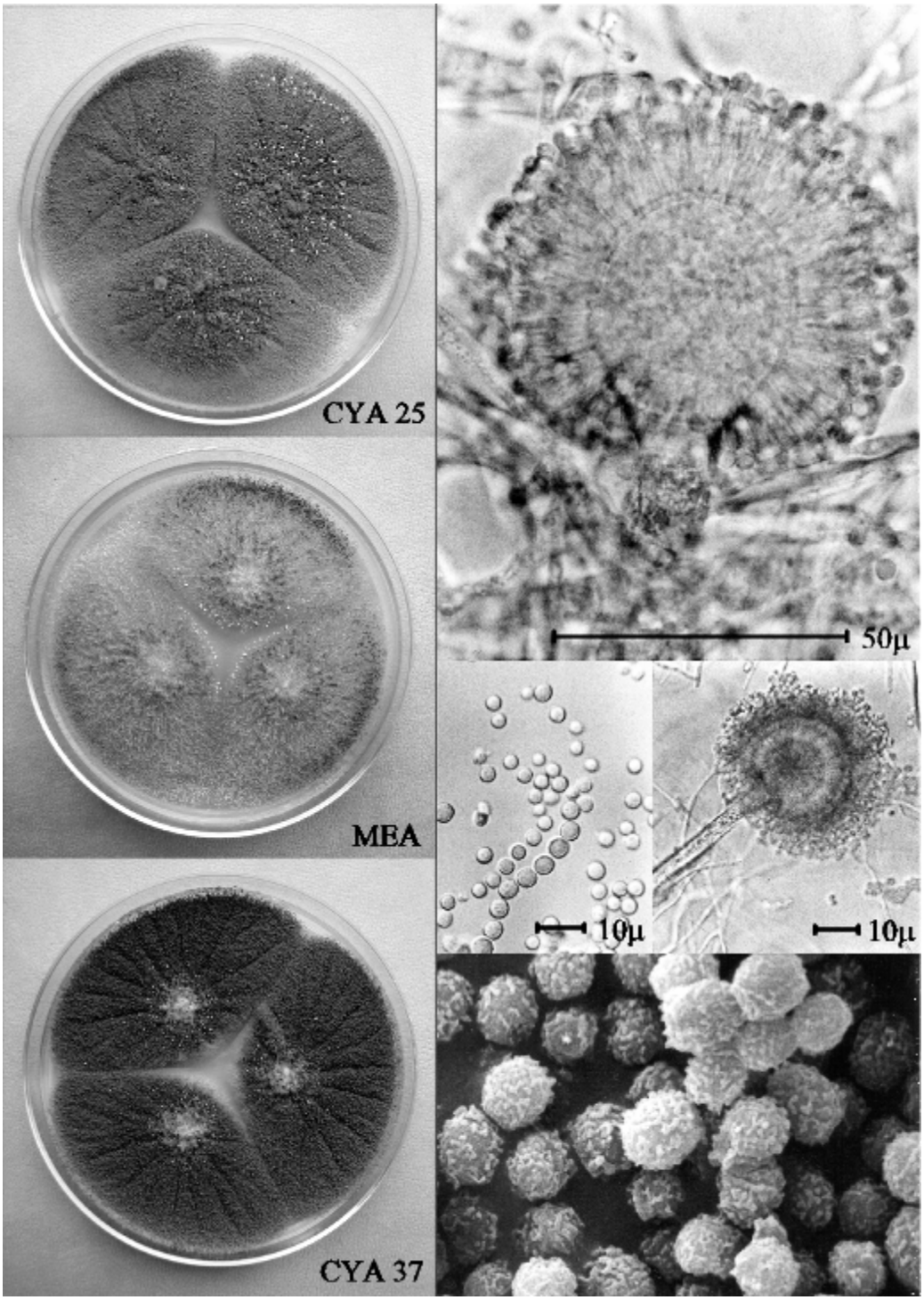

Fig. 20. *Aspergillus flavus*: left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom, left to right), conidial head, conidia, conidial head, and SEM of conidia (x 3000).

Aspergillus foetidus Thom & Raper — Figs. 21, 4h and 5g.

Manual of the Aspergilli: 219. 1945. Neotype CBS 121.28.

Subgenus: *Circumdati* Section: *Nigri*

Colony Diameters at 7 days, in mm: **CYA25** (40) 45-60 (65); **MEA** 55-65 (70); **CY20S** 55-70; **CYA37** 48-65; **CZ** 30-40 (45).

Colony Colors and Textures. Conidial areas on **CYA25** dark brown to black; mycelium dull white to bright yellow; reverse grey to brown centrally, yellow or greenish brown at the margin; yellow soluble pigment sometimes produced; colonies velutinous, occasionally floccose centrally, generally sulcate. On **MEA**, conidia black to dark brown, uncrowded; hyphae inconspicuous; reverse uncolored or slightly yellow. Colonies on **CY20S** similar to those on CYA25. On **CYA37**, mycelium inconspicuous, exudate not formed, soluble pigment yellow but not abundant, other characters similar to those on CYA25. Colony morphology on **CZ** similar to that on CYA25.

Microscopic Characteristics. **Conidial heads** radiate, splitting into columns in age; **stipes** (250) 400-800 (1000) x 7-17 µm, smooth-walled, uncolored or slightly brown near the apices; **vesicles** globose to slightly elongate, (19) 30-50 (70) µm wide; predominantly **biseriate**, metulae over at least the upper half of the vesicle; metulae 5-18 (20) x 3-6 (7) µm, phialides 7-9 (10) x 3-3.5 (4) µm. **Conidia** spherical, 4-5 (6) µm in diameter, delicately spinose when formed, appearing smooth-walled at maturity.

Distinguishing Features. Colonies of *A. foetidus* are often dark brown rather than black. This species is biseriate and has relatively short stipes. The small smooth to delicately roughened conidia make this species quite distinctive.

Taxonomic References. Raper & Fennell, 1965; Al-Musallam, 1980; Klich & Pitt, 1988; Kozakiewicz, 1989.

Habitats. This is an uncommon species in nature, but it is used in several industrial processes including koji for shochu, and enzyme production (Raper & Fennell, 1965).

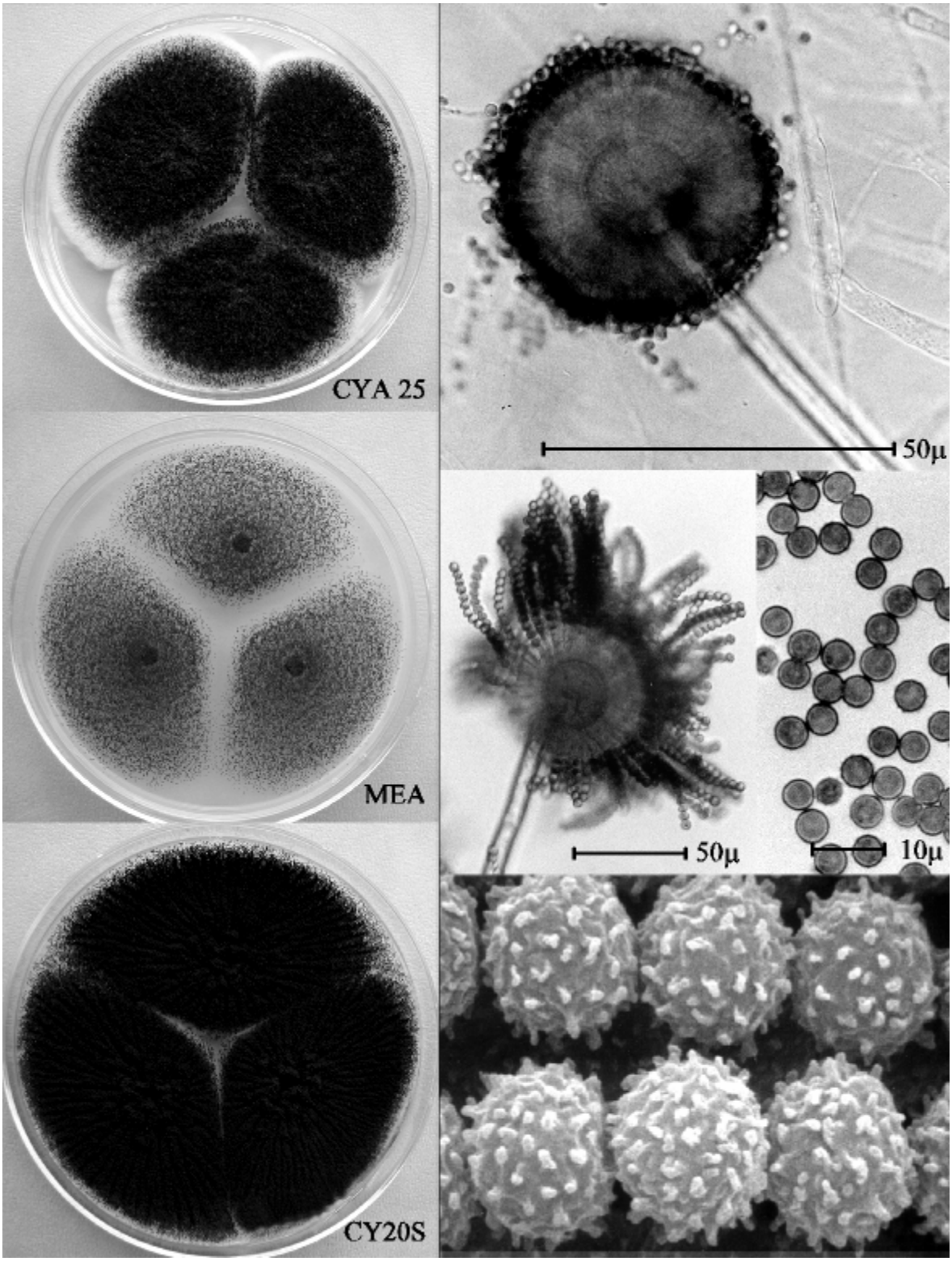

Fig. 21. *Aspergillus foetidus:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days, right column (top to bottom, left to right), conidial head, conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus fumigatus Fresen. — Figs. 22, 4f and 5d.

Beitr. Mykol.: 81. 18. 1863. Neotype IMI 16152.

Subgenus: *Fumigati* Section: *Fumigati*

Colony Diameters at 7 days, in mm: **CYA25** (35) 40-70; **MEA** (30) 45-70; **CY20S** (30) 40-70; **CYA37** (57) 60-70; **CZ** 45-60.

Colony Colors and Textures. Conidia on **CYA25** greyish turquoise or dark turquoise to dark green or dull green (24-26E-F3-8); mycelium white; exudate, when present, uncolored; reverse uncolored, yellowish, red brown or green; soluble pigment usually absent, occasionally in reddish brown colors; texture velutinous to floccose, plane or radially furrowed. On **MEA,** conidia colored as on CYA25; mycelium white, inconspicuous; reverse uncolored, dull yellow or grey; soluble pigment, when present, colored as reverse; texture as on CYA25 except consistently plane. On **CY20S**, exudate absent, otherwise colors and textures as on CYA25. Conidia on **CYA37** as on CYA25 or greyish brown (7E3-4), other characters as on CYA25. Colony characters on **CZ** similar to those on CYA25.

Microscopic Characteristics. **Conidial heads** predominantly columnar; **stipes** uncolored or greyish near the apices, smooth-walled (100) 200-400 (580) x 5-11 µm, expanding gradually into pyriform or spathulate **vesicles** (10)15-30 (40) µm in diameter; **uniseriate**; phialides 5-9 x 2-3 µm, over upper half to two-thirds of the vesicle, usually curving such that all phialides are parallel to each other and the stipe axis. **Conidia** globose to broadly ellipsoidal, smooth to finely roughened or spinose, 2-3 (3.5) µm in diameter.

Distinguishing Features. This species is distinguished by rapidly growing colonies in turquoise to dark green shades, phialides curving to be roughly parallel to each other and the axis of the stipe, and small conidia borne in columns.

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Habitats. *A. fumigatus* is a very common, ubiquitous species. It grows well over a relatively wide temperature range. It is a human and animal pathogen, responsible for systemic mycoses usually resulting from invasion of the lungs or respiratory tract. It has been reported from a wide range of substrates in both indoor and outdoor environments including soils, plants, seeds, sludge, wood chips, compost, cotton, and even penguin excreta (Domsch *et al*., 1980; Ellis, 1980; Samson *et al*., 2001; Klich, 2002).

Note. Medical isolates often sporulate poorly.

Major Mycotoxins. Gliotoxin, verrucologen, fumitremorgin A & B.

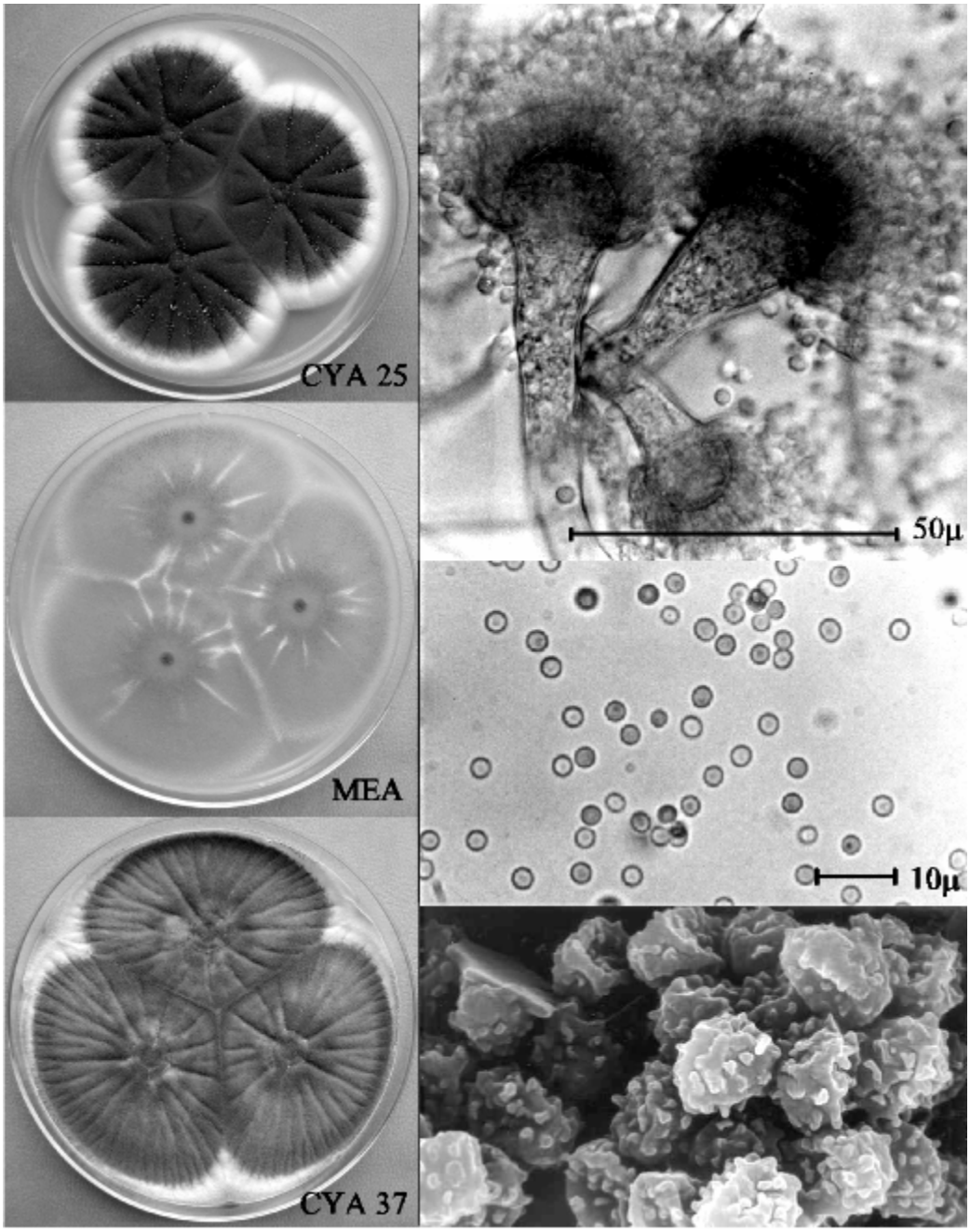

Fig. 22. *Aspergillus fumigatus:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial heads, conidia, and SEM of conidia (x 8000).

Eurotium herbariorum Link — Fig. 23.

Ges. Naturf. Freunde Berlin Mag. Neuesten Entdeck. Gesammten Naturk. 3: 31. 1809. Neotype DAOM 137960.
Anamorph: *A. glaucus* Link. Ges. Naturf. Freunde Berlin Mag. Neuesten Entdeck. Gesammten Naturk. 3: 16. 1809. Neotype IMI 211383.

Subgenus: *Aspergillus* Section: *Aspergillus*

Colony Diameters at 7 days, in mm: **CYA25** 3-20 (25); **MEA** 0-17 (20); **CY20S** (25) 30-45 (60); **CYA37** no growth; **CZ** 0-13.

Colony Colors and Textures. On **CYA25** conidial heads sparse, grey-green (30B-C4) to dull green; mycelium and cleistothecia forming a yellow to orange felt; exudate, when formed, brown; reverse yellow, orange or brown; soluble pigment absent or yellow; colony velutinous to floccose, plane or wrinkled, often with umbonate center. Some isolates not growing on **MEA**, when present, conidial heads grey green, often sparse or absent; mycelium yellow gold or sometimes orange; cleistothecia and colony reverse generally yellow to gold; colony granular or tufted. On **CY20S,** conidia variable in abundance, in grey green shades (30C-E3-5); mycelium usually in yellow to orange-gold shades (3A4 to 5A4) in the colony center, yellow at the margin, rarely white; cleistothecia yellow; reverse bright yellow to orange or brown to almost black in age; colonies plane or radially sulcate, velutinous or with a floccose overlay. When growth occurs on **CZ**, conidia sparse, grey green; mycelium white to bright yellow gold; reverse yellow to gold; colonies low, dense, plane.

Microscopic Characteristics. Best observed on CY20S. **Conidial heads** on CY20S radiate; **stipes** colorless, walls smooth to rough, (200) 300-700 (800) x (8) 9-15 µm, expanding into subglobose to pyriform **vesicles**, (12) 18-36 (50) µm wide; **uniseriate**; phialides 7-11 x 3-7 µm, covering most of the vesicle. **Conidia** variable in shape, spherical, ellipsoidal or apiculate, spinose, (4.5) 5-8 (11) x 5-7 µm. **Cleistothecia** yellow, globose to subglobose, 60-150 µm in diameter; wall consisting of a single layer of angular pseudoparenchymatous tissue, frequently surrounded by orange encrusted hyphae. Asci dehiscent, globose, 10-15 (20) µm, 8-spored. **Ascospores** mature at 14 days, lenticular, 5-6.5 x 3-5 µm, often with a slight to definite furrow, and a smooth surface texture.

Distinguishing Features. Colony diameter on CY20S at least twice that on CYA25, large spinulose conidia, yellow ascocarps surrounded by yellow to orange encrusted hyphae, and smooth-walled, lenticular ascospores, each with a shallow longitudinal furrow, are the main distinguishing characteristics for this species.

Taxonomic References. Raper & Fennell, 1965; Pitt, 1985; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Samson *et al*., 2000.

Related Species. *Eurotium repens* and *E. rubrum* are species closely related to *E. herbariorum*. *E. repens* differs from *E. herbariorum* by the formation of ascospores without a distinct furrow. *E. rubrum* has ascospores with a more distinct furrow, and the hyphae tend to turn brick red in age. Domsch *et al*. (1980) considered these three species to be conspecific, referring to all of them as *E. herbariorum*.

Habitats. *Eurotium herbariorum* is world wide in distribution but more common in tropical and subtropical regions than in temperate zones. It has been isolated from soils and a wide range of saprophytic habitats both indoors and outdoors. It is xerophilic and is especially common on dry or concentrated substances. (Domsch *et al*., 1980; Samson *et al*., 2001; Klich, 2002).

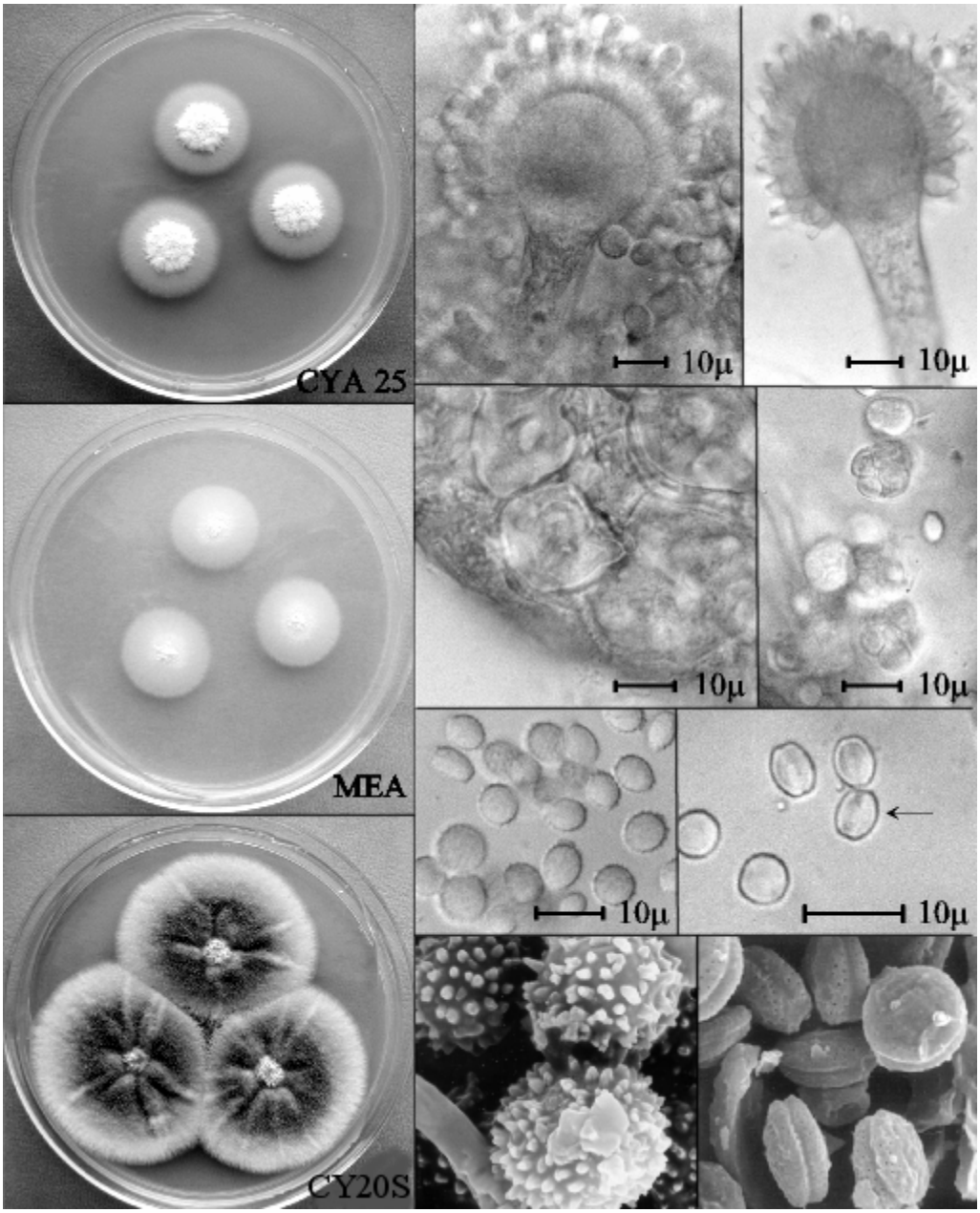

Fig. 23. *Eurotium herbariorum:* left column (top to bottom), colonies on CYA25, MEA, CY20S, 7 days; right column (top to bottom, left to right), conidial head, conidial head, ascocarp wall, developing asci, conidia, ascospores, SEM of conidia (x 8000), and SEM of ascospores (x 3000).

Aspergillus japonicus Saito — Figs. 24, 4g and 5k.

Bot. Mag. (Tokyo) 20: 61. 1906. Neotype CBS 114.51.

Subgenus: *Circumdati* Section: *Nigri*

Colony Diameters at 7 days, in mm: **CYA25** (49) 60-70; **MEA** (53) 60-70; **CY20S** -70; **CYA37** (5) 20-50 (53); **CZ** 30-70.

Colony Colors and Textures. Conidial areas on **CYA25** very dark brown to purple brown or purple black (5-6F4); mycelium white; sclerotia, when present, white to cream colored; reverse dull brown, dark purplish brown, brownish orange or slightly yellow-green; exudate clear when present; soluble pigment absent or slightly brown; colonies velutinous to slightly floccose, plane to radially sulcate. On **MEA**, conidia dark brown to black; mycelium white; exudate absent; reverse uncolored to slightly yellow-grey; plane, not dense. Colonies on **CY20S**, similar to those on CYA25 except exudate not produced and reverse uncolored, grey-black or yellow/yellow green in color. On **CYA37** reverse brown to black, abundant yellow to brown soluble pigment present; colonies low, radially sulcate, other characters as on CYA25. On **CZ**, morphological characters as on CYA25.

Microscopic Characteristics. **Conidial heads** radiate; **stipes** (150) 300-600 (1400) µm, smooth-walled, uncolored or somewhat pigmented near the apex; **vesicles** 14-30 (47) µm wide, globose to elongate; **uniseriate;** phialides 5-9 (10) x 3.5-4 (5) µm, covering at least the upper half of the vesicle. **Conidia** globose to subglobose, occasionally ellipsoidal, measuring (3.5) 4-5 (6) or 4-5 x 3-4 µm, surface echinulate with evenly spaced spines.

Distinguishing Features. *A. japonicus* is uniseriate and produces black spinose conidia.

Taxonomic References. Raper & Fennell, 1965; Al-Musallam, 1980; Domsch *et al*., 1980; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Parenicova, 2000.

Related Species. The taxonomic status of *A. aculeatus* is still in question (see taxonomic references). Like *A. japonicus* it is uniseriate and produces spiny black conidia. *A. aculeatus* usually produces larger vesicles [(15) 25-55 (100) µm] and more consistently ellipsoidal conidia.

Habitats. This species has been isolated from soils, plant rhizospheres, and leaf litter, predominantly in tropical zones (Domsch *et al*., 1980; Klich, 2002).

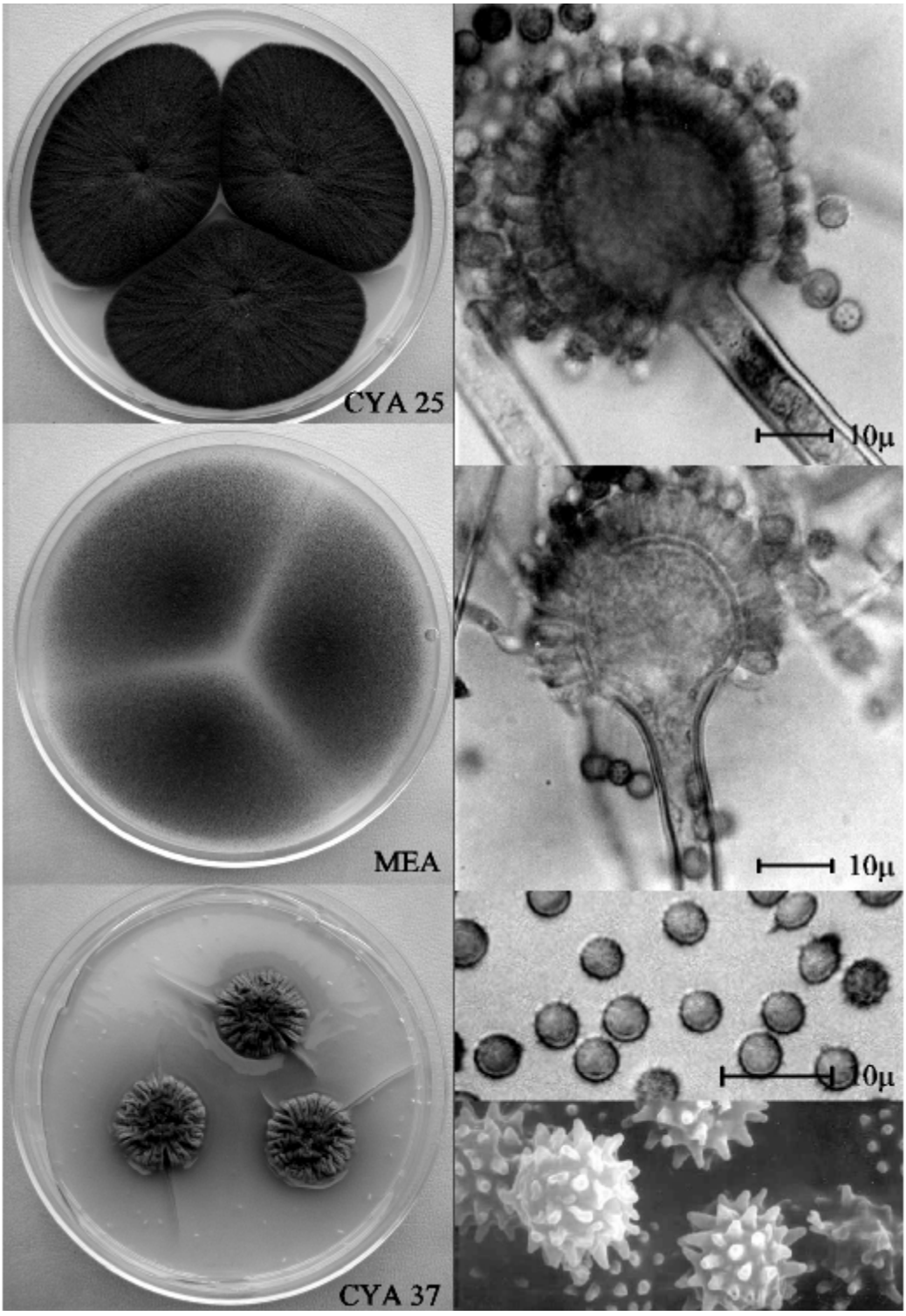

Fig. 24. *Aspergillus japonicus:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus kanagawaensis Nehira — Fig. 25.

J. Jap. Bot. 26: 109. 1951. Neotype IMI 126690.

Subgenus: *Fumigati* **Section: *Cervini***

Colony Diameters at 7 days, in mm: **CYA25** (3) 7-13; **MEA** (39) 45-58; **CY20S** 5-11; **CYA37** 0-10; **CZ** 4-14.

Colony Colors and Textures. Few conidia produced on **CYA25**, in pale white orange to greyish orange shades (5-6A-B2-3); mycelium white; reverse uncolored to yellowish or yellow brown (4C3, 5C5); colony low and plane. On **MEA**, conidia abundant, greyish yellow, white orange to greyish orange, peach (5-6A2, 6B4); mycelium white; reverse yellowish to brownish gold; yellowish soluble pigment occasionally present; colonies low, plane, velutinous, granular to slightly floccose. Colonies on **CY20S** sometimes yeasty, otherwise similar in appearance to colonies on CYA25. When growth occurs on **CYA37**, colonies small, low and white. On **CZ**, thin inconspicuous white mycelium, with few central pale peach colored conidia.

Microscopic Characteristics. **Conidial heads** radiate; **stipes** often variable in length (80) 150-700 (1000) x 4-7 µm, walls smooth uncolored to slightly brownish; **vesicles** (6) 11-22 (27) µm, globose to subglobose, often slightly colored; **uniseriate**, phialides tightly packed covering at least the upper three-fourths of the vesicle, 4-6 (8) x 2.5-3.5 µm. **Conidia** smooth-walled, globose to subglobose, 2.5-3.5 (4.5) µm in diameter.

Distinguishing Features. *A. kanagawaensis* grows much more rapidly on MEA than on CYA or CY20S, produces greyish yellow, white orange or greyish orange conidia, with tightly packed phialides covering the majority of the vesicle. *A. kanagawaensis* is distinguished from the morphologically similar species *A. cervinus* by its longer stipes (up to 700 µm or more) of varying lengths in any one isolate.

Taxonomic References. Christensen *et al*., 1964; Raper & Fennell, 1965; Klich & Pitt, 1988.

Habitats. The type isolate came from soil in Japan. *A. kanagawaensis* has also been isolated from soils in hemlock and jack pine forests in Wisconsin USA (Christensen *et al*., 1964).

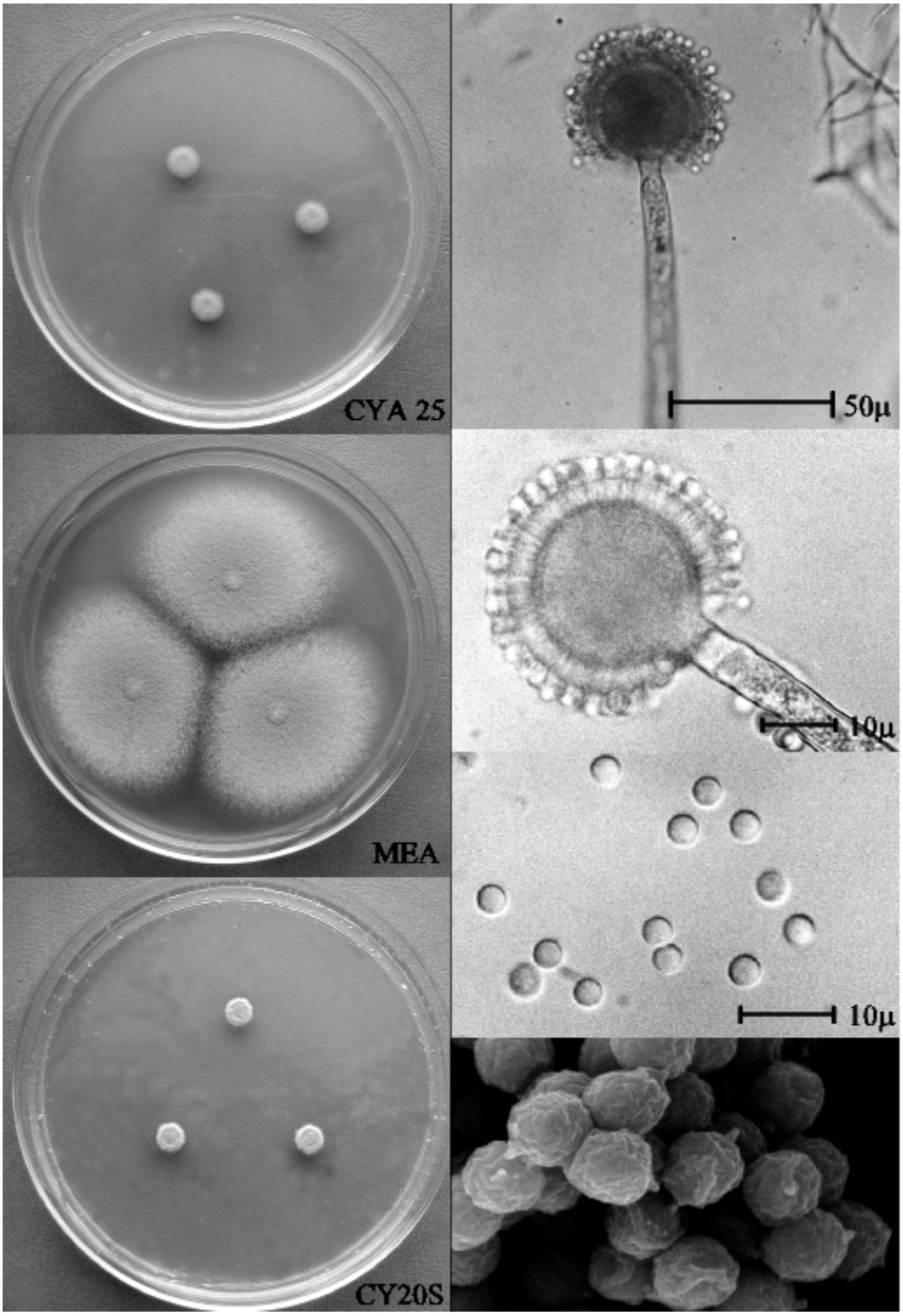

Fig. 25. *Aspergillus kanagawaensis:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial head, young conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus melleus Yukawa — Figs. 26 and 3e.

J. Coll. Agric. Imp. Univ. Tokyo 1: 358. 1911. Neotype CBS 546.65.

Subgenus: *Circumdati* Section: *Circumdati*

Colony Diameters at 7 days, in mm: **CYA25** 30-50; **MEA**, 33-60; **CY20S**, (41) 58-70; **CYA37** (17) 25-35 (38); **CZ** 15-35.

Colony Colors and Textures. On **CYA25** conidia sparse or absent, light golden yellow to pale straw (4A4); mycelium white to yellow, inconspicuous; exudate, when present, uncolored to yellow; reverse yellow to apricot or brown (4-6A-B6); soluble pigment when present yellow to brown; colonies low, velutinous, often radially sulcate, dominated by abundant sclerotia in yellow, buff to light brown colors (5B3-5, 6CD5, 7B3). Conidia generally abundant and pale golden yellow to cream (3-4A3-4) on **MEA**, mycelium inconspicuous, exudate absent, reverse in pale yellow to pale brown colors, sclerotia scattered or absent, pinkish buff to dull orange to pale brown. Colonies on **CY20S** producing light yellow conidia (4A4-5), white to yellow mycelium ranging from inconspicuous to floccose, no exudate observed, sclerotial colors similar to those on CYA25. On **CYA37** colonies similar in appearance to those on CYA25, except no exudate observed and reverse sometimes reddish brown to dark brown. On **CZ** colony characters similar to those on CYA25.

Microscopic Characters. **Conidial heads** radiate; **stipes** (200) 350-700 (720) x (4)7-10 µm, uncolored to slightly brown near the apex, walls rough or warted; **vesicles**: (12) 20-35 (38) µm, globose to spathulate or pyriform; conidial heads **biseriate**, metulae (5) 6-9 (10) x 3-4 µm, covering almost all of the vesicle; phialides (5) 7-8 (9) x 2.5-3 µm. **Conidia** spherical to broadly ellipsoidal, 3-3.5 (4) µm, walls smooth to finely roughened. **Sclerotia** spherical to elongate (200) 300-600 µm.

Distinguishing Features. *A. melleus* is characteristically dominated by sclerotia in yellow, buff to brown colors. This along with the pale yellow/gold or cream colored conidia make it a distinctive species

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980; Christensen, 1982.

Habitats. *A. melleus* has been reported predominantly from tropical to warm temperate soils (Klich, 2002). It has also been reported from peanuts and a variety of other crop seeds (Domsch *et al*., 1980).

Major Mycotoxins. Ochratoxin A, penicillic acid, xanthomegnin, viomellein, vioxanthin.

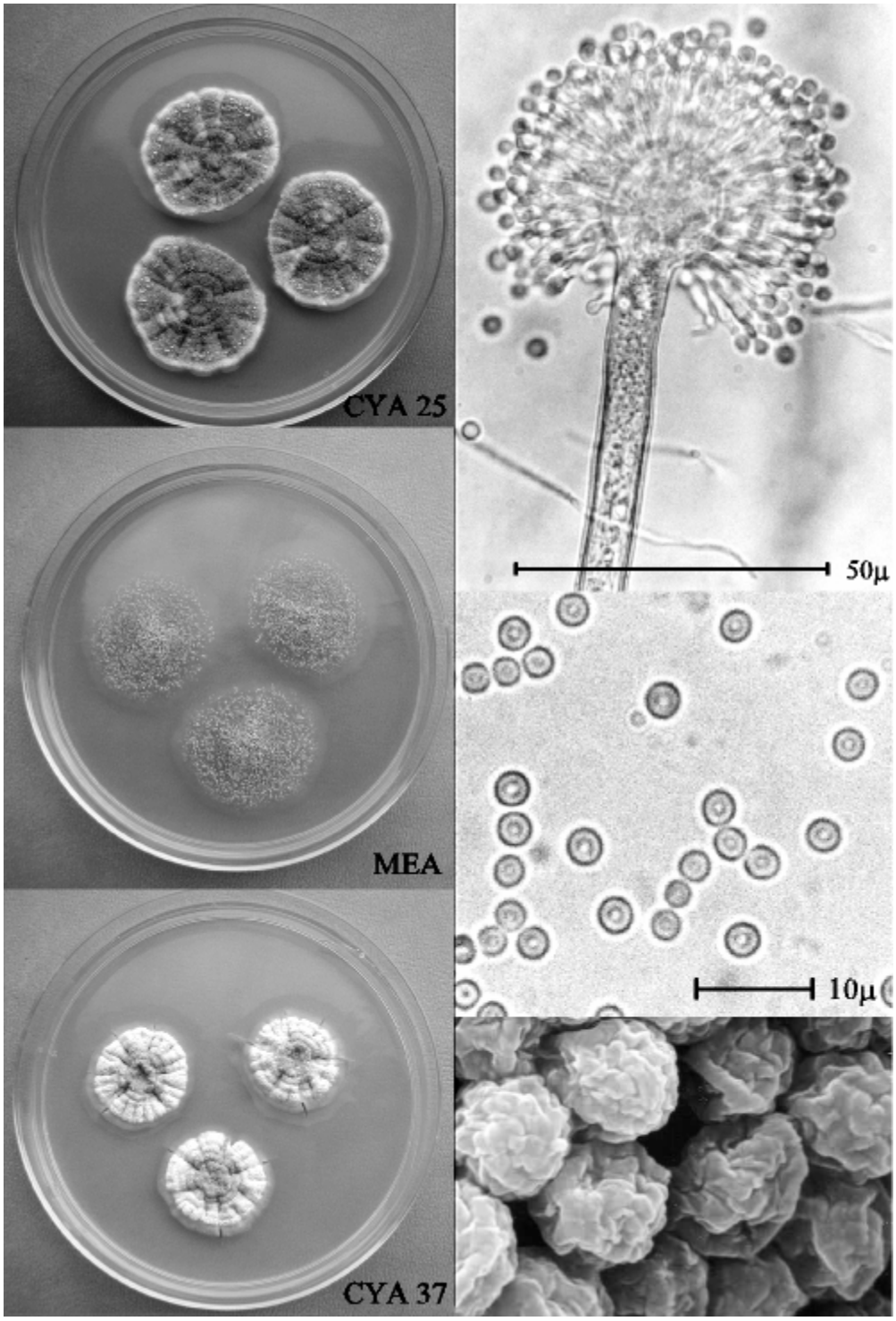

Fig. 26. *Aspergillus melleus:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, conidia, and SEM of conidia (x 8000).

Emericella nidulans (Eidam) Vuill. — Figs. 27, 4b and 5j.

Compt. Rend. Seances Acad. sci. Paris 184: 137. 1927. Neotype IMI 86806.
Anamorph: *A. nidulans* (Eidam) G. Winter in Rabenh. Krypt-Fl ed 2 1(2) 62. 1884. Neotype IMI 86806.

Subgenus: *Nidulantes* **Section: *Nidulantes***

Colony Diameters at 7 days, in mm: **CYA25** 40-60 (62); **MEA** 53-65; **CY20S** (38) 40-60; **CYA37** 50-70; **CZ** 38-43.

Colony Colors and Textures. Conidia on **CYA25** sparse to abundant, green, deep green or dark green (27-30E-F5-8); mycelium white to cream or greyish; cleistothecia appearing dull yellow to buff from the presence of abundant Hülle cells; exudate dull red to brown, when present; reverse uncolored to brownish orange or deep purple red (6C2, 8E7, 10D6); soluble pigment similarly colored or pink; colony velutinous or with a floccose overlay, dense, plane or sulcate. Colonies on **MEA** usually heavily sporulating with dark green (26-29F5-7) conidia; mycelium white, inconspicuous; cleistothecia appearing dull yellow to buff from surrounding Hülle cells; reverse uncolored to red brown or dark brown; soluble pigment absent; colony low, velutinous, plane. On **CY20S** conidial colors and mycelial colors similar to those on CYA25; exudate lacking; reverse dull brown to red brown or dark green; soluble pigment absent or pink to brown; colonies velutinous, slightly sulcate to wrinkled. Conidia olive (1-2E6-8) on **CYA37**, mycelium inconspicuous; exudate usually absent, brownish when present; cleistothecia in buff grey shades; reverse dark brown to red brown (9E5 to 10F8); purple-pink soluble pigment; colonies low velutinous and radially sulcate. On **CZ,** morphology generally similar to that on CYA25, but cleistothecia more buff in color.

Microscopic Characteristics. **Conidial heads** radiate to loosely columnar on CYA25, columnar on MEA; **stipes** (35) 70-150 (210) x 3-6 (7) µm, smooth-walled, becoming brown in age, expanding into spathulate to pyriform **vesicles** (7) 8-12 (16) µm in width; **biseriate**, metulae covering only the upper half of the vesicle, 5-7 (9) x 2-3 (4) µm wide; phialides 5-8 (9) x 2-3 µm. **Conidia** spherical, usually smooth to slightly rough, 3-4 µm in diameter. **Cleistothecia** globose (80) 100-250 (280) µm, wall hyphal, dark red at maturity; surrounded by globose to subglobose Hülle cells 10-25 µm in diameter, dull yellow to buff en masse. Asci 8-spored, dehiscent. **Ascospores** maturing within 2 weeks, lenticular, red to purple, smooth-walled, 4-6 x 3-4 µm, with 2 thin longitudinal flanges about 1 µm long, somewhat wrinkled, but with entire margins.

Distinguishing Features. *E. nidulans* is a relatively fast growing species, producing red-purple lenticular smooth-walled ascospores with two longitudinal, pleated but entire flanges. The closely related species *E. quadrilineata* has ascospores with 4 longitudinal flanges, and *E. rugulosa* grows more slowly (see *E. rugulosa* description for details).

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980; Christensen & States, 1982; Klich & Pitt, 1988; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000; Klich *et al*., 2001.

Related Taxa. Four varieties of *E. nidulans* have been described; var. *acristata* lacks longitudinal flanges on the ascospores; var. *dentata* has ascospores with dentate flanges; var. *echinulata* has ascospores with echinulate convex walls; and var. *lata* has dull colored cleistothecial walls. All are relatively rare.

Habitats. An ubiquitous soil fungus, *E. nidulans* has been isolated most frequently from tropical and subtropical climates (Domsch *et al*., 1980; Klich, 2002). This species has been used extensively in genetic studies. It has been isolated from a wide variety of foods and from indoor environments (Pitt & Hocking, 1997; Samson *et al*., 2001).

Major Mycotoxins. Sterigmatocystin.

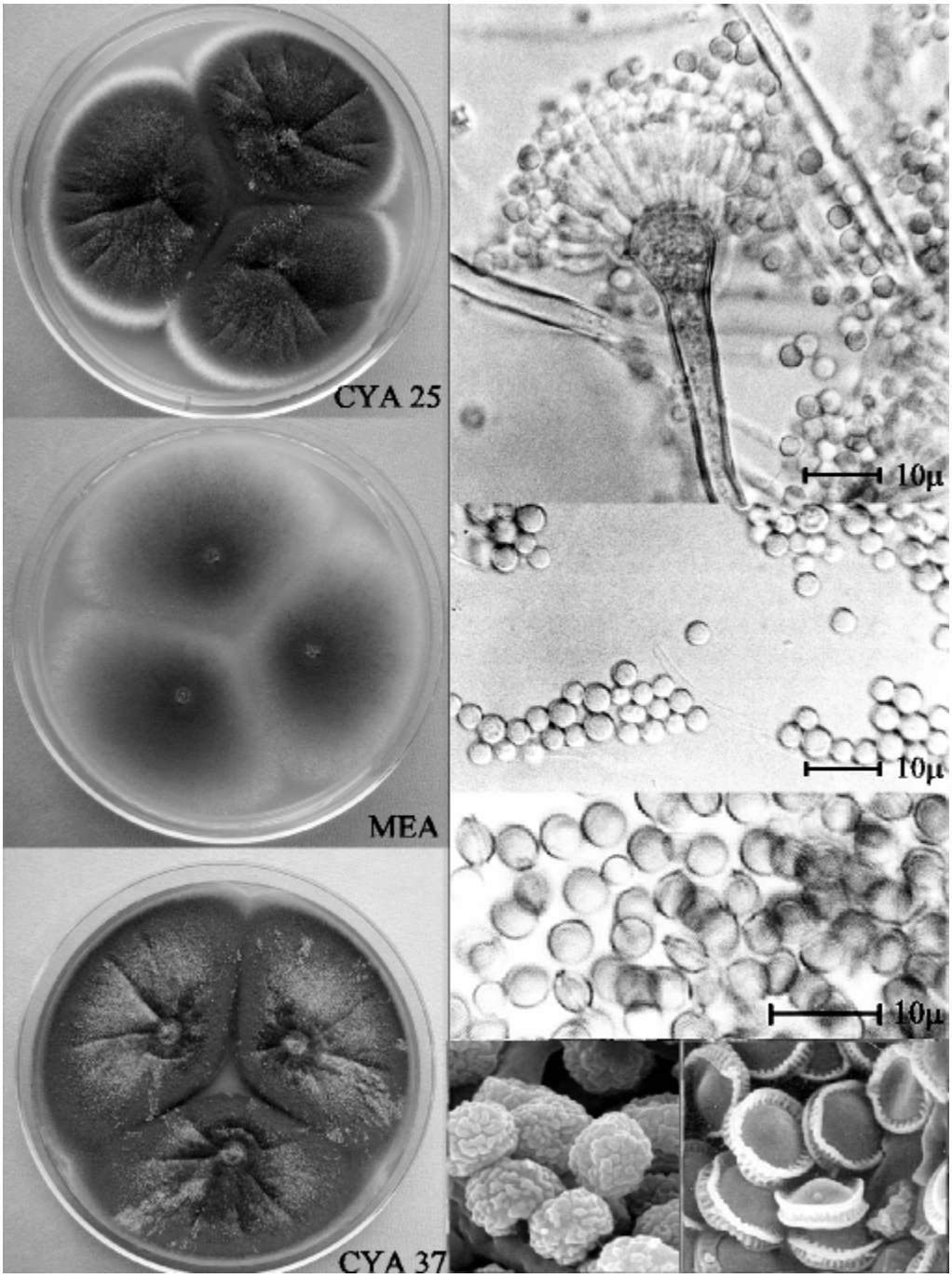

Fig. 27. *Emericella nidulans:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom, left to right), conidial head, conidia, ascospores, SEM of conidia (x 8000), and SEM of ascospores (x 5000).

Aspergillus niger Tiegh. — Figs. 28 and 4i.

Ann. Sci. Nat. Bot sér. 5, 8: 240. 1867. Neotype CBS 554.65.

Subgenus: *Circumdati* Section: *Nigri*

Colony Diameters at 7 days, in mm: **CYA25** 55-70; **MEA** (30) 50-70; **CY20S** 68-70; **CYA37** 50-70; **CZ** 40-62.

Colony Colors and Textures. Conidial areas black to very dark brown and densely packed on **CYA25**; hyphae usually inconspicuous, white to dull yellow; sclerotia, when present, cream or buff to dull faint pink; exudate uncolored when present; reverse uncolored to yellow; soluble pigment not observed colony granular to floccose, sometimes radially sulcate. On **MEA**, conidial areas black; mycelium white and inconspicuous; reverse uncolored; colonies granular to floccose. Colonies on **CY20S** similar to those on CYA25 in appearance, but reverse colors generally more intense. Colonies on **CYA37** and **CZ** similar to CYA25 in appearance.

Microscopic Characteristics. **Conidial heads** radiate; stipes (300) 400-3000 x (7) 12-17 (20) µm, walls thick, smooth, hyaline to yellowish or slightly brown especially near the apices; **vesicles** (20) 30-75 (85) µm wide, nearly spherical; **biseriate** (very rarely uniseriate); metulae covering virtually the entire surface of the vesicle, measuring 12-20 (40) x 3-6 µm, sometimes with a single septum; phialides 7-10 x 3-4 µm. **Conidia** globose, (3) 3.5-4.5 (5) µm in diameter, usually very rough with irregular ridges and bars, occasionally only finely roughened.

Distinguishing Features. This common species is characterized by its very dark brown to black colonies, biseriate conidial heads with large vesicles, fairly long metulae, and irregularly roughened conidia.

Taxonomic References. Raper & Fennell, 1965; Al-Musallam, 1980; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Related Species. *A. ficuum* (Reich.) Thom & Church and *A. tubingensis* Mosseray were placed in synonymy with *A. niger* by Al-Musallam (1980). Molecular data indicate that *A. tubingensis* is a separate taxon (see Samson, 1994 for summary). Recent data on the validity of closely related species such as *A. foetidus* and *A. awamori* are conflicting. Until these conflicts are resolved, I have retained them as separate species.

Habitats. This ubiquitous species is commonly isolated from soils, plant litter, plant rhizospheres, seeds, dried fruits and nuts. It is one of the most commonly reported fungi from foods and indoor environments. (Domsch *et al*., 1980; Pitt & Hocking, 1997; Samson *et al*., 2001; Klich, 2002).

Major Mycotoxins. Ochratoxin A.

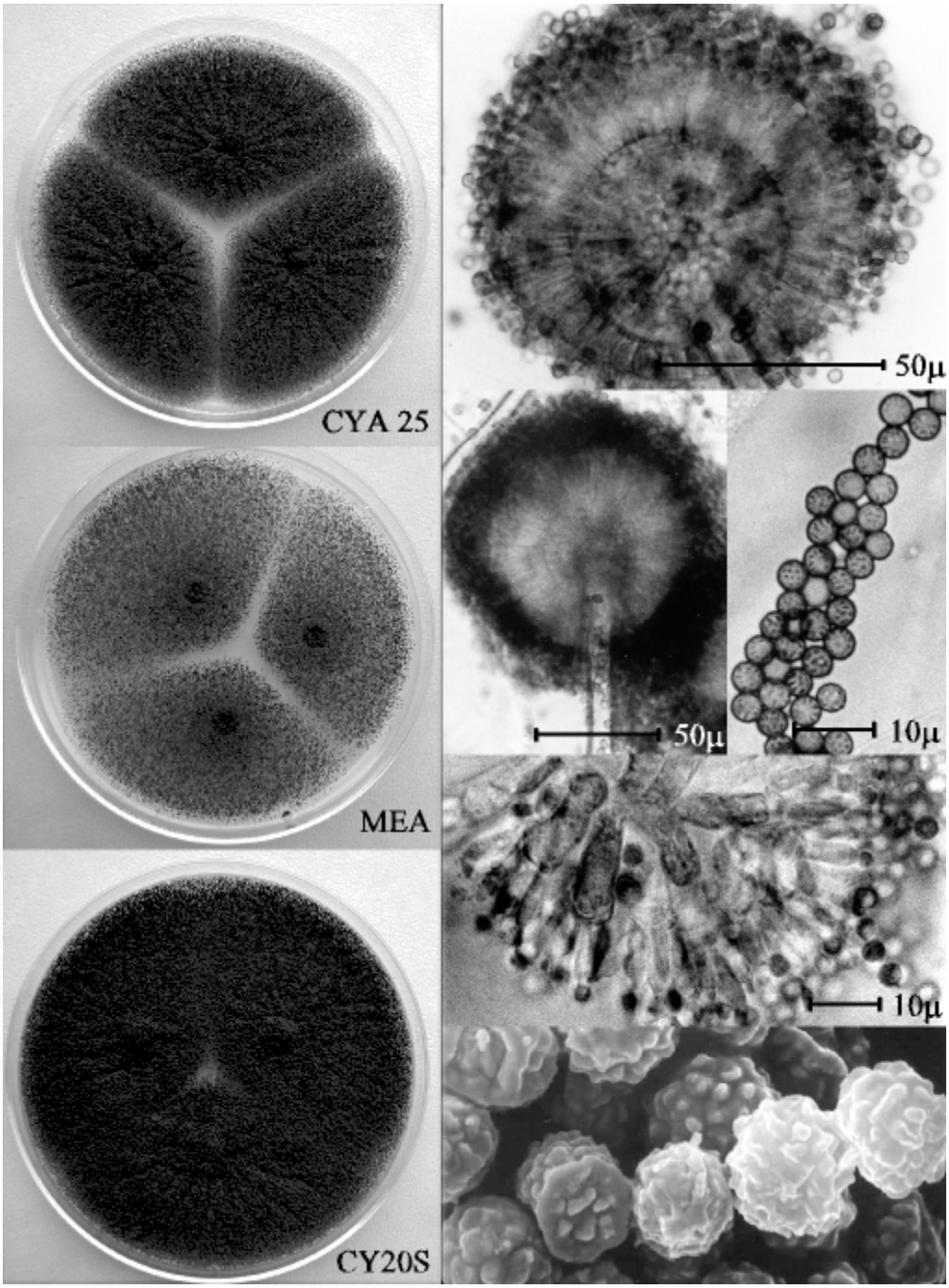

Fig. 28. *Aspergillus niger*: left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom, left to right), conidial head, conidial head, conidia, metulae and phialides, and SEM of conidia (x 8000).

Aspergillus niveus Blochwitz — Fig. 29.

Ann. Mycol. 27: 205. 1929. Neotype IMI 171878.
Teleomorph: *Fennellia nivea* (Wiley & Simmons) Samson Stud. Mycol. 18: 5. 1979. Holotype QM 8942.

Subgenus: ***Nidulantes*** **Section:** ***Flavipedes***

Colony Diameters at 7 days, in mm: **CYA25** (15) 20-38; **MEA** (10) 23-38; **CY20S** (17) 30-53 (60); **CYA37** 0 or 30-45 (57); **CZ** 16-30.

Colony Colors and Textures. Conidia on **CYA25** white, yellowish white or pale yellow (3A2-3) to cream colored; mycelium white, occasionally with bright yellow sectors, some with yellow Hülle cells; exudate uncolored, yellow gold, dull red, brown or green; reverse yellow brown to dark green; soluble pigment yellow when present; colonies velutinous, plane or radially sulcate, dense. On **MEA**, conidia white to dull orange white; mycelium white and inconspicuous or as a bright yellow basal felt, sometimes in radial sectors; exudate absent or uncolored; reverse uncolored or in dull yellow to brown shades; colony granular to floccose On **CY20S**, soluble pigment yellow to brown when present, no exudate observed, other characters similar to those on CYA25. Colony colors and textures on **CYA37** and **CZ** similar to those on CYA25.

Microscopic Characteristics. **Conidial heads** radiate to loosely columnar; **stipes** (80) 100-500 (1000) x 3-7 µm, uncolored, walls smooth, thick on MEA, but often thin on CYA25, expanding into spathulate to pyriform **vesicles** (5) 8-15 (18) µm wide; predominantly **biseriate**, occasionally uniseriate and biseriate condition on the same vesicle; metulae very crowded covering the upper one- to two-thirds of the vesicle, (4) 5-9 x 2-3.5 µm; phialides 5-8 x 2-3 µm. **Conidia** (2) 2.5-3.5 µm in diameter, smooth-walled to finely roughened, globose to subglobose. Hülle cells, when present, yellow, globose to elongate. Mature **cleistothecia** not observed: *fide* Wiley & Fennell, 1973; on MEA, ascocarps yellowish, consisting of one to several layers of thin-walled hyphae, asci 9.6-11.2 µm, **ascospores** lenticular, hyaline to faintly yellow, 4-5.6 x 3.2-4.8 µm, with spinose walls, inconspicuous longitudinal grooves and two very low longitudinal crests.

Distinguishing Features. *A. niveus* is one of two persistently white *Aspergillus* species. The most conspicuous difference between these two species is that the conidial heads of *A. niveus* are fertile only on the upper one-third to two-thirds of the vesicle, while those of *A. candidus* are fertile over the entire vesicle surface. Vesicle diameters are generally less than 15 µm in *A. niveus* and larger in *A. candidus.*

Taxonomic References. Raper & Fennell, 1965; Wiley & Fennell, 1973; Wiley & Simmons, 1973; Samson, 1979; Domsch *et al*., 1980; Klich & Pitt, 1988.

Common Synonym. *Emericella nivea* Wiley & Simmons. Samson (1979) transferred this species to *Fennellia.*

Habitats. *A. niveus* is predominantly a soil fungus which appears to be widely distributed (Domsch *et al*., 1980). The species has been reported at high relative frequencies from studies conducted at latitudes from 26-35 degrees and from wetland and desert soils (Klich, 2002).

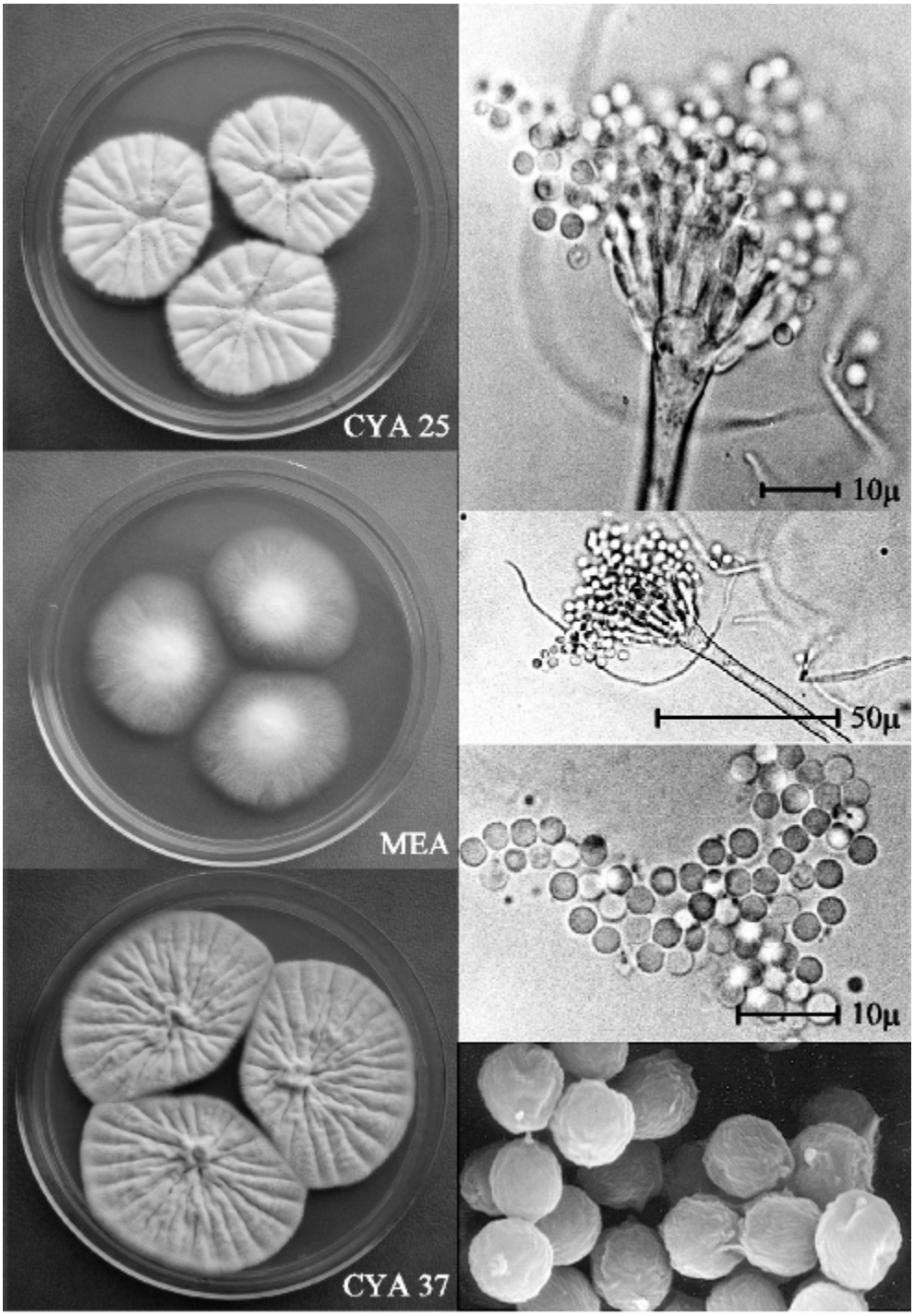

Fig. 29. *Aspergillus niveus:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus ochraceus K. Wilh. — Figs. 30 and 5e.

Beitr. Kenntn. *Aspergillus* 66. 1877. Neotype IMI 16247iv.

Subgenus: *Circumdati* Section: *Circumdati*

Colony Diameters at 7 days, in mm: **CYA25** 39-59; **MEA** 44-55 (57); **CY20S** 44-70; **CYA37** 0-35; **CZ** 22-42.

Colony Colors and Textures. Conidial colors on **CYA25** near wheat (4-5A-B4-5) to ochraceus or buff; mycelium white, inconspicuous to floccose; sclerotia, when present, in dull pink (flesh 6B3) to purplish colors; exudate sometimes formed, uncolored, yellow or dull red; reverse dull yellow, greyish red or brown; soluble pigment sometimes formed in colors similar to those of the reverse; colonies varying from loosely floccose and plane to quite low and sulcate. On **MEA**, conidia not dense usually pale to light yellow (3-4A3-5) or amber yellow (4B6); mycelium white, inconspicuous to floccose; reverse in yellow, pale orange to greyish gold shades; colonies not densely sporulating, variable in appearance. Colonies on **CY20S** similar to CYA25 in appearance except reverse usually in brown shades. On **CYA37**, conidiation frequently sparse, colony dense and wrinkled, other characters similar to those on CYA25. Colonies on **CZ** generally similar to those on CYA25 except soluble pigment not observed.

Microscopic Characteristics. **Conidial heads** radiate; **stipes** (100) 300-1700 µm, walls slightly to coarsely roughened, uncolored to yellowish or pale brown at the apices; **vesicles** globose to elongate (12) 25-55 (80) µm; **biseriate** with tightly packed metulae over the entire vesicle, measuring (5) 6-12 (30) x 2-6 µm; phialides 7-12 (14) x 2-3 µm. **Conidia** (2) 2.5-3.5 (4.5) µm, smooth to finely roughened, spherical to broadly ellipsoidal, occasionally apiculate.

Distinguishing Features. Yellow-buff colored colonies, small (2.5-3.5 µm) nearly smooth conidia, and pink to purple sclerotia are the major distinguishing characteristics for this species.

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980; Christensen, 1982; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Common Synonyms. The name *A. alutaceus* Berk. & Curt. predates *A. ochraceus* (Samson & Gams, 1985), however, grounds exist for the conservation of *A. ochraceus* because it is such a commonly used name, and because some doubt remains about the validity of the synonymy of these two species.

Habitats. The greatest proportion of reports of this common fungus are from tropical areas (latitudes 0-15 degrees) and desert soils, but it has also been reported from other soils, plant rhizospheres, stored seeds, a wide range of foods, and indoor environments (Domsch *et al*., 1980; Pitt & Hocking, 1997; Samson *et al*., 2001; Klich, 2002).

Major Mycotoxins. Penicillic acid, ochratoxin A, xanthomeginin, viomellein, vioxanthin.

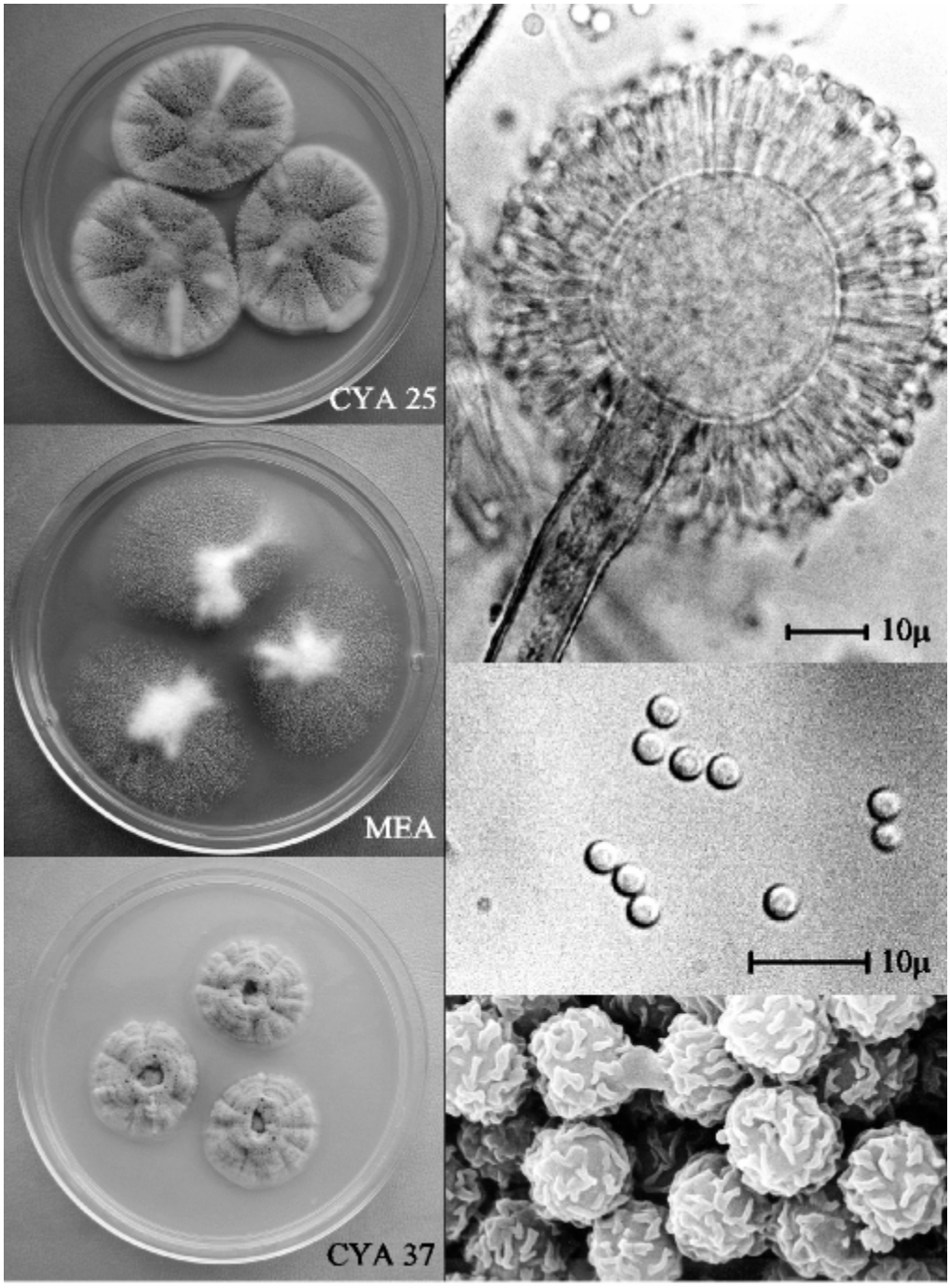

Fig. 30. *Aspergillus ochraceus:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, conidia, and SEM of conidia (x 8000).

Sclerocleista ornata (Raper *et al*.) Subram. — Figs. 31 and 3d.

Curr. Sci 41: 757. 1972. Neotype IMI 55295
Anamorph: *A. ornatulus* Samson & W. Gams. In Samson & Pitt, Adv. *Penicillium Aspergillus* System.: 45. 1985. Holotype. IMI 55295.

Subgenus: *Ornati* **Section: *Ornati***

Colony Diameters at 7 days, in mm: **CYA25** 8-27; **MEA** 40-70; **CY20S** 9-35; **CYA37** no growth; **CZ** 8-9.

Colony Colors and Textures. Conidia sparse on **CYA25** light greenish yellow to olive bronze (near 5D8); mycelium white; reverse uncolored or yellowish; colony very low, thin, plane, granular. On **MEA**, conidia variable in abundance, olive brown (4D8); mycelium white; cleistothecia white at one week, purple in age; exudate absent; reverse uncolored, pale yellow or dull brown. Colonies on **CY20S** similar to those CYA25 except conidia more abundant, olive yellow (3C5-6) to olive bronze (5D8) and reverse coloration often in deeper yellows. Colonies on **CZ** very thin, similar to CYA25

Microscopic Characteristics. **Conidial heads** radiate; **stipes** (150) 200-500 (850) x 7-15 (18) µm, uncolored, smooth-walled; **vesicles** usually spathulate to clavate, sometimes pyriform, 12-30(-35) µm wide; **uniseriate**, phialides 8-12 (15) x 4.5-6 (7) µm, relatively few in number, borne over at least the upper three fourths of the vesicle. **Conidia** ovoid, ellipsoidal, pyriform, or sometimes apiculate (6.5) 8-11 (12) x 5-7 µm, walls very rough. **Cleistothecia** (100) 200-500 (600) µm, initially white, becoming purple in 2-3 weeks, wall consisting of polyhedral cells enveloped in branching hyphae. Asci abundant at 2 weeks, globose, 12-15 µm, 8-spored, dehiscing slowly. **Ascospores** lenticular, uncolored to pale brown, 7.5-10 x 5-6 µm, with several thin irregularly arranged crests.

Distinguishing Features. Colony diameters on MEA twice those on CYA, very large (8-11 µm) ovoid to ellipsoidal rough-walled conidia and purple cleistothecia with ascospores producing several irregularly arranged crests are the distinctive characters for this species.

Taxonomic References. Raper & Fennell, 1965; Klich & Pitt, 1988.

Common Synonyms. *A. ornatus* Raper, Fennell & Tresner. This name is invalid because the species description included the teleomorph.

Habitats. This species is relatively rare, but has been isolated from soils (Raper & Fennell, 1965). Most reports are from forest soils in latitudes between 36 and 46 degrees (Klich, 2002).

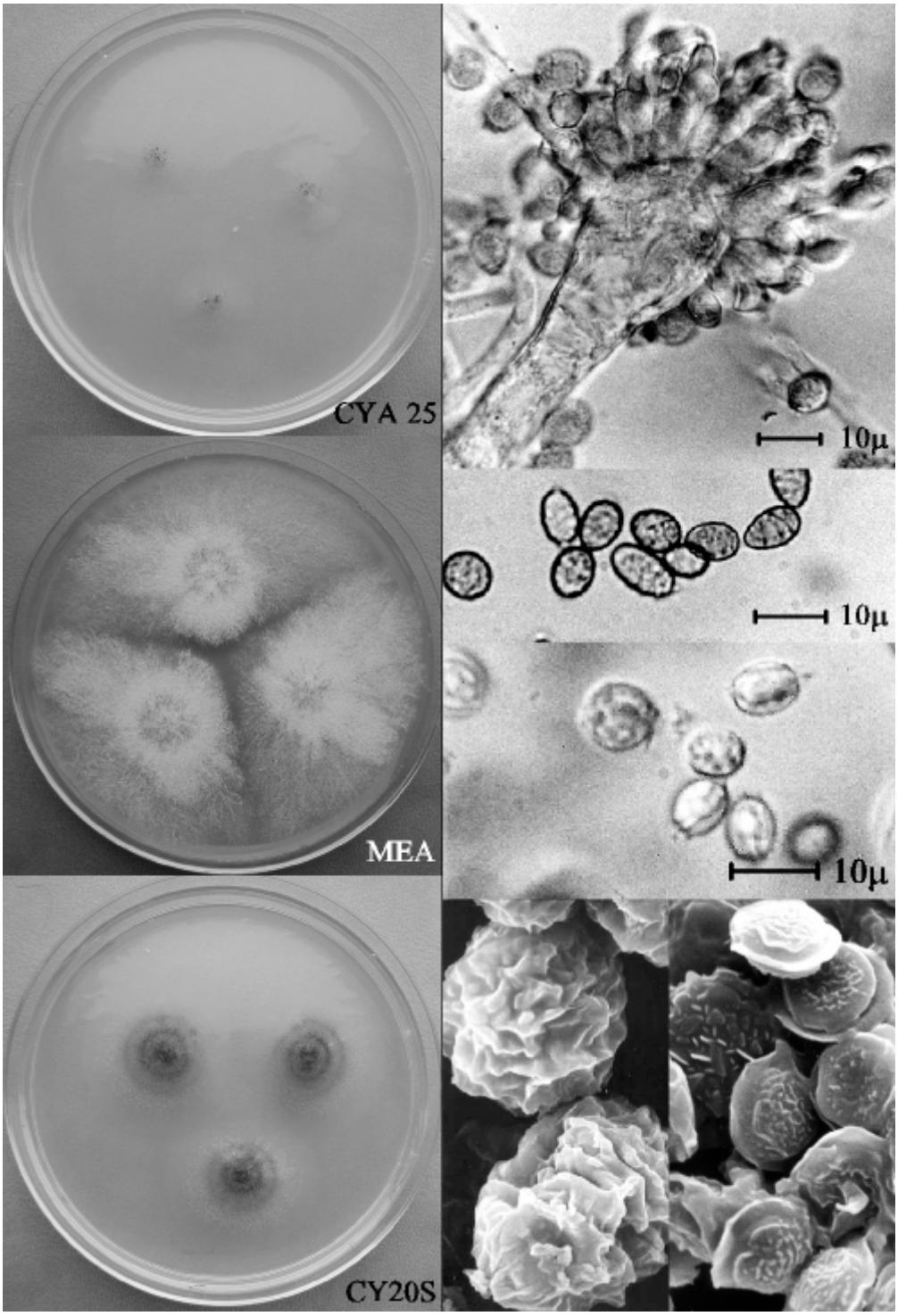

Fig. 31. *Sclerocleista ornata:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom, left to right), conidial head, conidia, ascospores, SEM of conidia (x 8000), and SEM of ascospores (x 8000).

Aspergillus oryzae (Ahlburg) Cohn — Figs. 32 and 3*l*.

Jahresber. Schles. Ges. Vaterl. Kult. 61: 226. 1884. Neotype IMI 167226.

Subgenus: *Circumdati* Section: *Flavi*

Colony Diameters at 7 days, in mm: **CYA25** 55-70; **MEA** 60-70; **CY20S** (50) 60-70; **CYA37** 50-65; **CZ** 39-65.

Colony Colors and Textures. Conidia on **CYA25** greyish yellow to olive brown (4C-D4-7); mycelium dense, white to cream; dark sclerotia occasionally formed; reverse uncolored pale brown or greyish yellow (4B-C5-6); colonies lanose to floccose. On **MEA**, conidia often sparse, greyish yellow (3C-D4-5); mycelium white; reverse uncolored or dull yellow; colonies floccose, mycelium not as dense as on CYA25. On **CY20S** conidia variable in abundance, olive yellow, greyish yellow or olive (3C-D3-5), occasionally olive brown (4D6); mycelium white, dense; reverse uncolored to yellow; colonies usually floccose. Colonies on **CYA37** usually forming few conidia, which are sometimes more brown than on CYA25 (5C-D4), colonies usually floccose, other characters similar to those on CYA25. Conidia on **CZ** olive to olive brown (3C-D4, 4B3-4), frequently floccose, other characters as on CYA25.

Microscopic Characteristics. **Conidial heads** radiate to loosely columnar; **stipes** 500-2500 (5000) x 10-25 (35) µm, walls uncolored, usually finely rough to rough; **vesicles** pyriform, clavate to subglobose, (8) 22-50 (90) µm wide; highly variable in seriation, some isolates predominantly **uniseriate**, others predominantly **biseriate**; metulae or phialides covering half or more of the surface of the vesicle; metulae (2) 8-12 (15) x 4-6 µm; phialides 8-12 (15) x 3-5 µm. **Conidia** smooth to finely roughened, occasionally spinose when first formed; globose to ovoid, sometimes ellipsoidal; (3.5) 4-8.5 (10) µm in length.

Distinguishing Features. Colonies of this species spread broadly on all media, and are usually floccose in greyish yellow to olive colors. *A. oryzae* may be distinguished from *A. flavus* by the floccose texture, more olive colors of conidial heads which are less dense than those of *A. flavus*, and generally larger conidia.

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980; Christensen, 1981; Klich & Pitt, 1985; Kurtzman *et al*., 1986; Klich & Mullaney, 1987; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Samson *et al*., 2000.

Note. *A. oryzae* (Ahlb.) Cohn var. *effusus* (Tiraboschi) Ohara was described as having an extremely flocculent growth habit and conidia predominantly 4.5-5.5 µm. The flocculent habit and smaller conidia represented the ends of a continuum rather than consistent, reliable differences between *A. oryzae* var. *oryzae* and *A. oryzae* var. *effusus*.

Habitats. *A. oryzae* has been reported from soils, vegetative plant parts, seeds, and cotton fabric. It is used in food fermentations in production of saki, shoyu, miso, and soy sauce and as a source of industrial enzymes (Domsch *et al*., 1980; Bennett and Klich, 1992). In soils it is tropical in distribution (latitudes 0-25) and is reported with high relative frequencies in studies of wetland soils (Klich, 2002).

Major Mycotoxins. Cyclopiazonic acid, 3 nitropropionic acid.

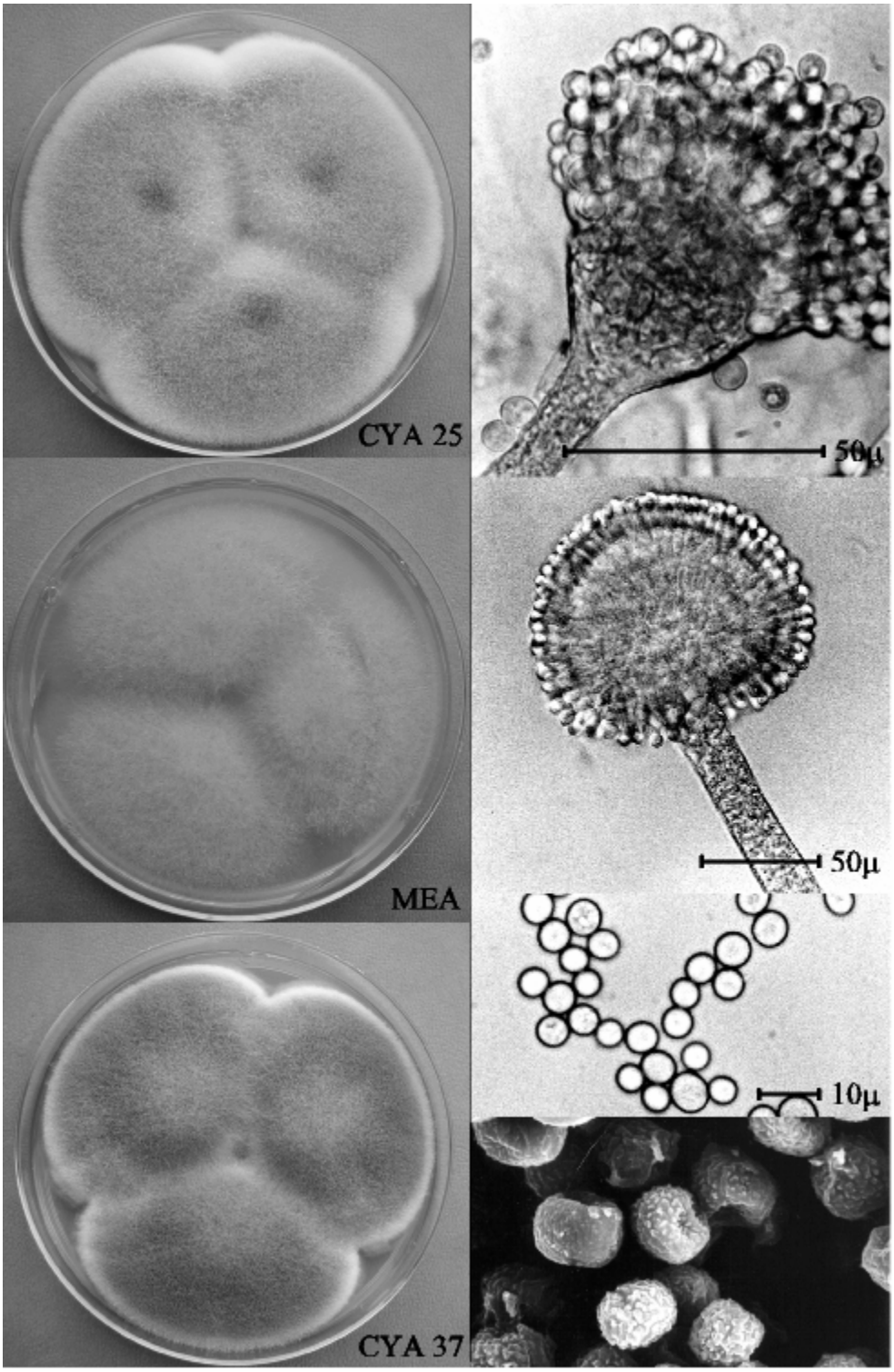

Fig. 32. *Aspergillus oryzae:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, conidial head, conidia, and SEM of conidia (x 3000).

Aspergillus ostianus Wehmer Figs. 33 and 3f.

Bot. Centbl. 80: 461. 1899. Neotype IMI 15960.

Subgenus: *Circumdati* Section: *Circumdati*

Colony Diameters at 7 days, in mm: **CYA25** 38-50 (52); **MEA** 40-50 (58); **CY20S** (48) 50-60 (70); **CYA37** 0-15 (35); **CZ** 20-30.

Colony Colors and Textures. Conidia on **CYA25** pale yellow near margin, centrally buff or reddish blond to clay (5C-D4-7); mycelium white; exudate uncolored to dark brown, produced by most isolates observed; sclerotia, when present, usually inconspicuous, white or colored as conidia; reverse uncolored, brownish orange (7C-E5-6), or shell pink (8A3); soluble pigment sometimes produced, pinkish to brown; colonies low velutinous, plane or radially sulcate. On **MEA,** conidia slightly more buff than pastel yellow (4A3), butter yellow (4A5) or amber yellow (4B6); mycelium white, inconspicuous; reverse usually near amber yellow (4B6); colonies low, conidial heads uncrowded. Conidia on **CY20S** gold to yellow buff; reverse brown; exudate absent; colonies granular to floccose, plane or wrinkled. On **CYA37**, conidia absent or sparse; exudate usually absent; colonies low dense mounds, sometimes wrinkled; other characters as on CYA25. On **CZ**, colony morphology similar to that on CYA25 except exudate and soluble pigment less abundant.

Microscopic Characteristics. **Conidial heads** predominantly radiate; **stipes** (250) 400-800 (3000) x 7-12 (16) µm, with rough, thick walls which are uncolored to gold; **vesicles** (12) 20-40 (45) µm wide, nearly spherical to somewhat elongate; **biseriate**; metulae covering almost the entire surface of the vesicle, variable in size, 7-15 (25) x 3-8 µm; phialides 8-10 (11) x 2.5-3 µm. **Conidia** variable in shape, most subglobose, some ovoid, ellipsoidal or pyriform; globose conidia usually with smooth to finely roughened walls, (3.5) 4-5 (7) µm; elongate conidia usually finely roughened, 4-6 x 3-3.5 µm.

Distinguishing Features. This species is distinguished by pale yellow to yellow buff colored colonies with long-stiped conidiophores producing conidia which are usually 4-5 µm in diameter. Sclerotia are frequently produced and are cream to clay in color.

Taxonomic References. Raper & Fennell, 1965; Christensen, 1982; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990.

Habitats. This species has been reported from animal feed, chicory seed (Christensen, 1982) and gram (*Cicer*) seed in storage (Deo & Gupta, 1980).

Major Mycotoxins. Ochratoxin A, penicillic acid.

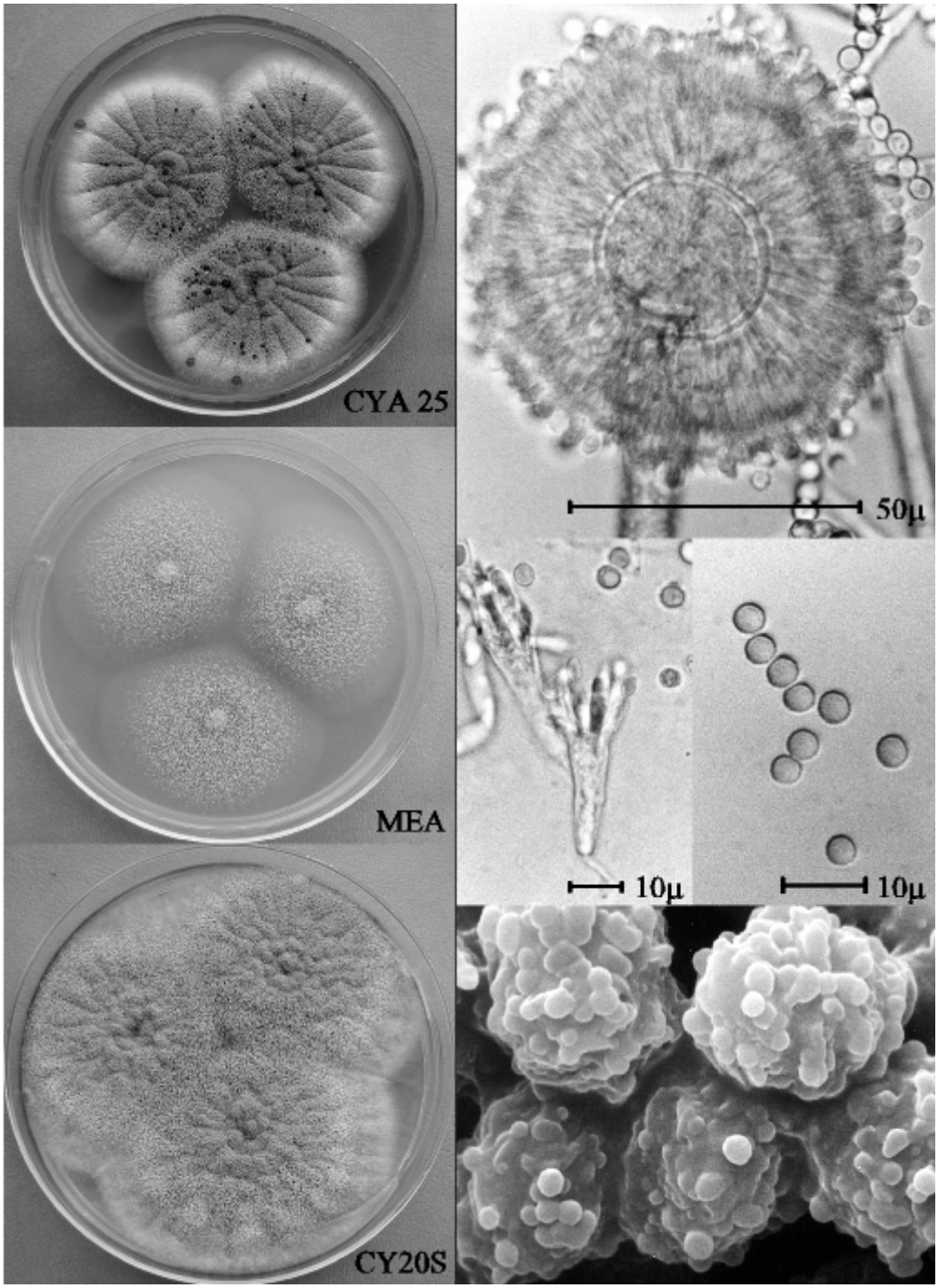

Fig. 33. *Aspergillus ostianus*: left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial head, metulae and phialides, conidia, and SEM of conidia (x 8000).

Aspergillus paradoxus Fennell & Raper — Figs. 34 and 3c.

Mycologia 47: 69. 1955. Neotype IMI 117502
Teleomorph: *Hemicarpenteles paradoxus* Sarbhoy & Elphick in Trans. Br. mycol. Soc. 51: 156. 1968. Neotype IMI 61446.

Subgenus: *Ornati* Section: *Ornati*

Colony Diameters at 7 days, in mm: **CYA25** 25-55; **MEA** (25) 35-55 (60); **CY20S** (15) 25-55 (60); **CYA37** no growth; **CZ** 15-30.

Colony Colors and Textures. Conidia on **CYA25** sparse, dull grey green to blue green (24D2-3, 28D2-3) or absent; mycelium white or pale yellow; sclerotia/cleistothecia cream to yellow when present; exudate occasionally formed, uncolored to yellow; reverse usually bright yellow (3-4A-B8); soluble pigment bright yellow; colony texture variable. On **MEA**, conidia sparse or absent; mycelium white; sclerotia/cleistothecia cream colored when present; reverse and soluble pigment uncolored to yellow (3A6-7); colony velutinous to floccose, plane. On **CY20S**, conidia often more abundant than on CYA25 in greyish green colors (27B-C2-3); reverse and soluble pigment sometimes uncolored, otherwise bright yellow. On **CZ,** conidia absent, reverse uncolored to yellow (3A3), soluble pigment yellow when present, colony dense, lanose, plane.

Microscopic Characteristics. **Conidial heads** loosely columnar to radiate; **stipes** (100) 500-1000 (1500) x (6) 10-20 µm, walls usually uncolored and finely roughened; **vesicles** clavate to spathulate (10) 15-35 (45) µm; **uniseriate**; phialides covering the upper two-thirds of the vesicle (extending 10-30 µm from apex), (8) 9-12 x 4-6 µm. **Conidia** ellipsoidal, ovoid or apiculate, occasionally spherical, (4) 5-7 x (3) 4-5 µm, walls smooth to finely roughened. Mature **cleistothecia** not observed: *fide* Sarbhoy & Elphick (1968); maturing in 20-30 days; walls composed of 2-3 layers of sclerenchymatous cells surrounded by a thin network of hyaline hyphae; asci globose to ovoid, 8-10 µm, 8-spored; ascospores lenticular, 4.5-5.5 x 3-3.5 µm, smooth-walled with two longitudinal crests which are less than 1 µm wide.

Distinguishing Features. *A. paradoxus* is characterized by its sparse conidial formation on most media, bright yellow reverse and soluble pigment, and large ellipsoidal conidia.

Taxonomic References. Raper & Fennell, 1965; Sarbhoy & Elphick, 1968; Klich & Pitt, 1988.

Habitats. This uncommon species has been isolated from opossum dung, and soil (Fennell & Raper, 1955; Rai *et al*., 1964).

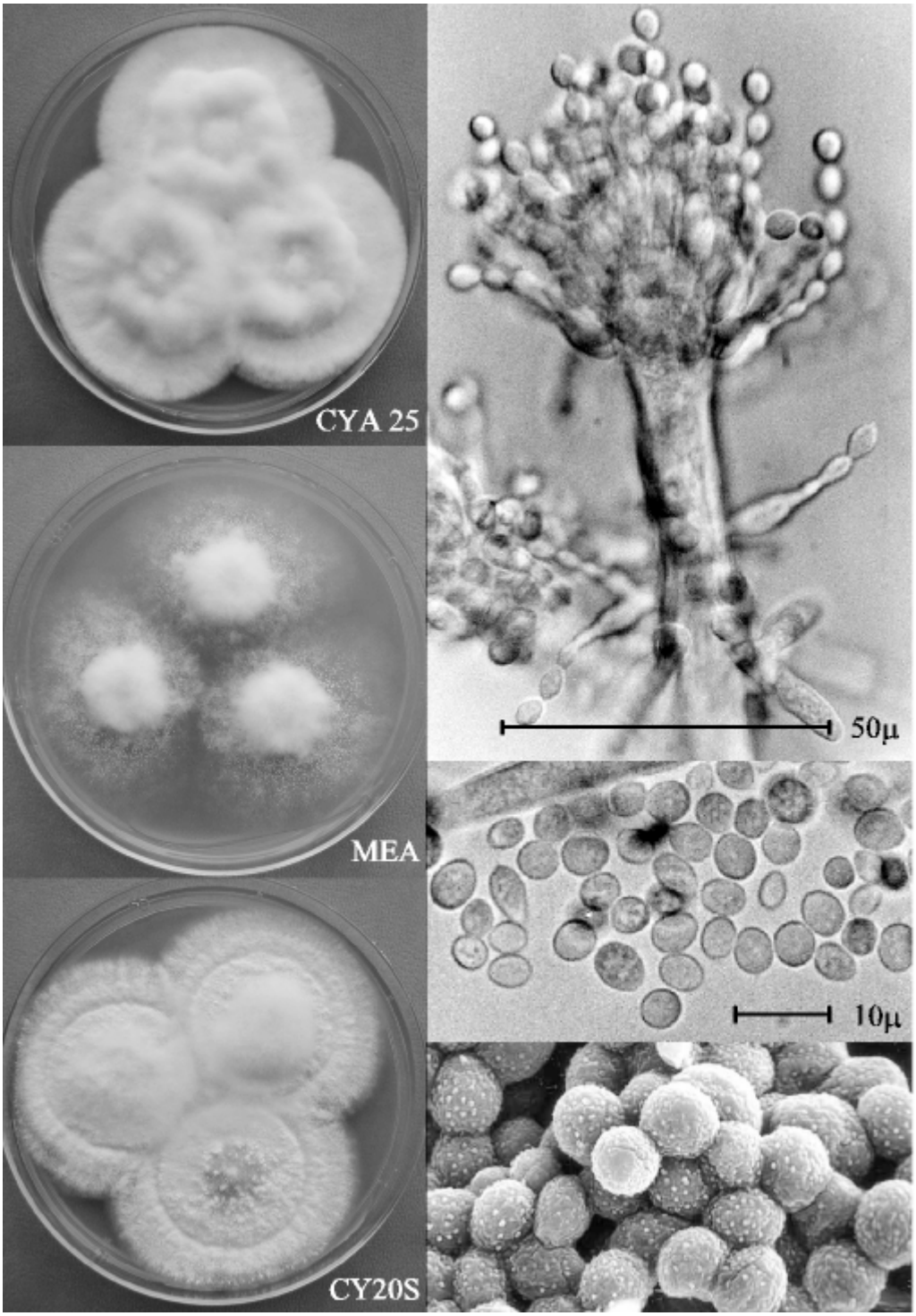

Fig. 34. *Aspergillus paradoxus:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right coloumn (top to bottom), conidial head with lateral phialides, conidia, and SEM of conidia (x 8000).

Aspergillus parasiticus Speare — Figs. 35 and 3k.

Bull. Div. Pathol. Physiol. Hawaiian Sugar Planters' Assoc. Exp. Stn.12: 38. 1912. Neotype IMI 15957ix.

Subgenus: *Circumdati* Section: *Flavi*

Colony Diameters at 7 days, in mm: **CYA25** (50) 60-70; **MEA** (45) 60-70; **CY20S** 60-70; **CYA37** (40) 50-70; **CZ** 45-65.

Colony Colors and Textures. Conidia on **CYA25** dark olive (1-3E-F5-8) or deep dark green (29-30D-F6-8); mycelium white, usually inconspicuous; sclerotia occasionally formed, brown to black; exudate hyaline when present; reverse uncolored, dull pinkish-red or dull yellow, sometimes brown; colonies usually quite low, velutinous, some isolates becoming floccose. On **MEA**, conidial areas olive or dark green (29-2E-F7-8); mycelium usually inconspicuous, occasionally with floccose tufts; brown to black sclerotia occasionally formed; reverse uncolored or in dull yellow to dull green shades; colonies floccose, not dense. Colonies on **CY20S** generally slightly more yellow-green than on CYA25; colonies similar in appearance to those on CYA25 except colony reverse in yellow, orange or even drab green shades. On **CYA37**, exudate absent; yellow to brown soluble pigment sometimes formed; other characters as on CYA25. Colonies on **CZ** tend to be more velutinous than on CYA25, other characters similar to those on CYA25.

Microscopic Characteristics. **Conidial heads** usually radiate; **stipes** (100) 250-500 (1100) µm, walls finely roughened to very rough, colorless; **vesicles** (10) 20-35 (40) µm wide, spherical or slightly elongate; predominantly **uniseriate**, up to 20% **biseriate** in some isolates; metulae, if present, 7-10 (14) x 3-7 µm; phialides (7) 8-11 x 3-5 (7) µm, metulae or phialides covering at least half of the vesicle. **Conidia** globose, 3.5-6 (7) µm in diameter, distinctly rough-walled.

Distinguishing Features. Dark yellow green conidial areas, predominantly uniseriate conidial heads with nearly spherical vesicles producing distinctly roughened conidia 3.5-6 µm in diameter, separate this species from others. *A. parasiticus* may be distinguished from *A. sojae* by its smaller conidia, usually velutinous texture, and dark green colony color. Growth rate on antibiotic media also distinguishes it from *A. sojae* (Klich & Mullaney, 1989). *A. parasiticus* may be readily distinguished from *A. flavus* by its rough-walled conidia.

Taxonomic References. Raper & Fennell, 1965; Murakami, 1971; Christensen, 1981; Klich & Pitt, 1985; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Habitats. *A. parasiticus* has been reported occasionally from a variety of soils. Lack of reported isolations may be due in part to failure of investigators to differentiate *A. parasiticus* from *A. flavus*. It has been isolated more frequently from seeds, other plant parts, and insects (Domsch *et al*., 1980; Diener *et al*., 1987; Klich, 2002).

Major Mycotoxins. Aflatoxin B_1 B_2 G_1 G_2.

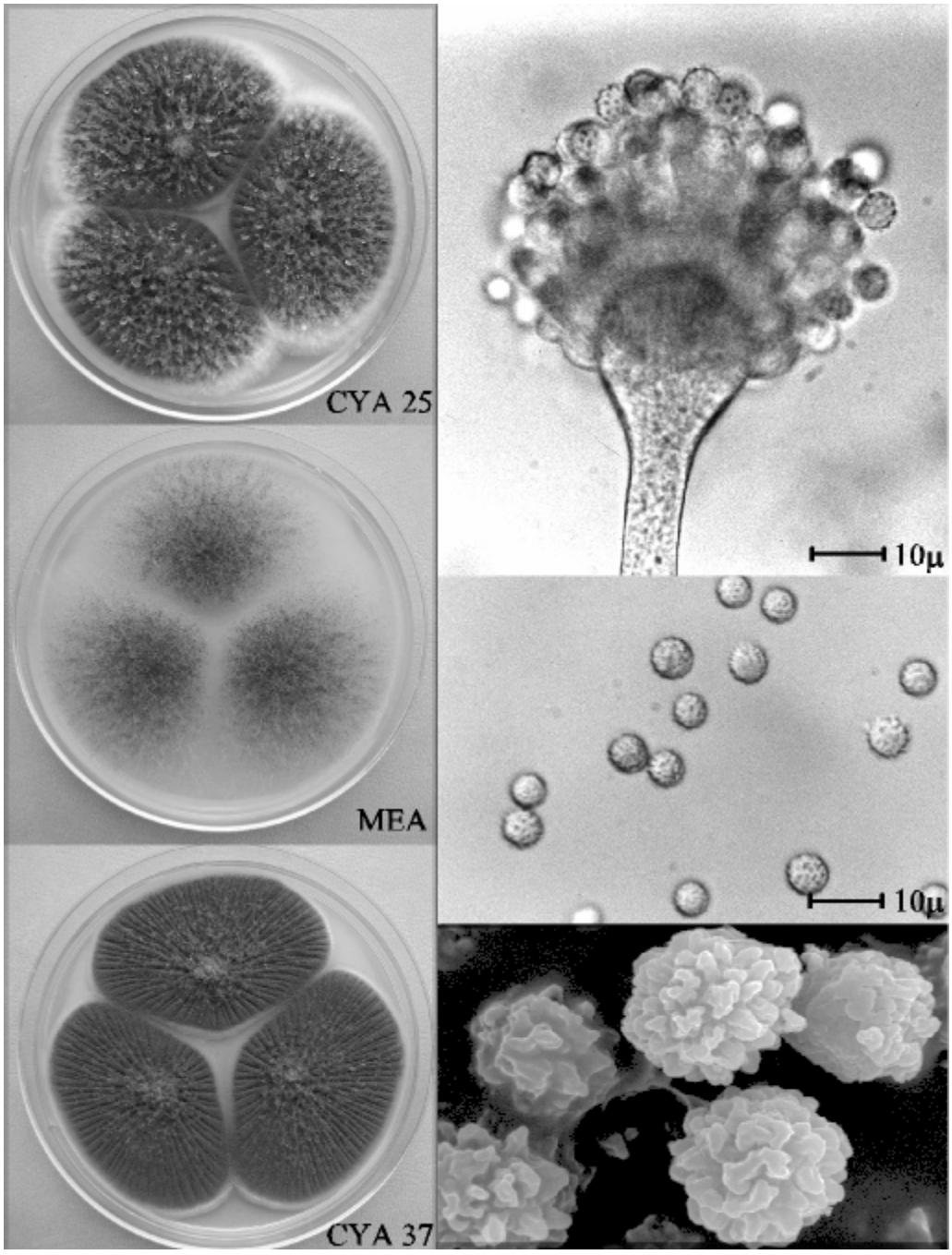

Fig. 35. *Aspergillus parasiticus:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom) conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus penicillioides Speg. — Fig. 36.

Revista Fac. Agron. Univ. Nac. La. Plata 2: 246. 1896. Neotype IMI 211392.

Subgenus: *Aspergillus* Section: *Restricti*

Colony Diameters at 7 days, in mm: **CYA25** 2-8; **MEA** (1) 2-5; **CY20S** 4-12; **CYA37** no growth; **CZ** 3-4.

Colony Colors and Textures. On **CYA25** and **MEA**, sporulation generally poor, dull pale green (25-29A-B3-4); mycelium white; reverse uncolored to pale yellow or brownish; colonies dense, velutinous, plane to sulcate. Conidia on **CY20S** dull green to slightly blue green (24-26C-D3-4); mycelium dense white; reverse pale, grey or dark green. On **CZ**, no conidia observed; mycelium white, dense or thin; reverse uncolored; colonies low, velutinous.

Microscopic Characteristics. **Conidial heads** usually radiate; **stipes** (70) 150-500 (750) µm, uncolored, smooth-walled, with subglobose to spathulate **vesicles** (7) 9-25 µm in diameter; **uniseriate**, phialides (6) 7-10 (11) µm covering more than half of the vesicle. **Conidia** subspherical to ellipsoidal, finely rough to rough-walled; ellipsoidal conidia 3-5.5 (6) x 3-4 µm, spherical conidia 3-5 µm.

Distinguishing Features. The small colony diameters on all media, and generally poor sporulation distinguish this species from most other aspergilli. It differs from *A. restrictus*, a similar species, by producing vesicles with phialides covering more than half the vesicular area, and by producing conidia borne as ellipses rather than cylinders.

Taxonomic References. Raper & Fennell, 1965; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Habitats. *A. penicillioides* is a xerophilic fungus that grows very poorly on the usual laboratory media, and is easily overlooked. Reports in the literature are quite rare. However, if suitable media are used, the species can be recovered in large numbers from a variety of dried foods such as spices and cereals (Hocking, 1981) and from indoor environments (Samson *et al*., 2001). It has been reported as a human pathogen (Raper & Fennell, 1965). It has been reported from soils (Behera & Mukerji, 1984).

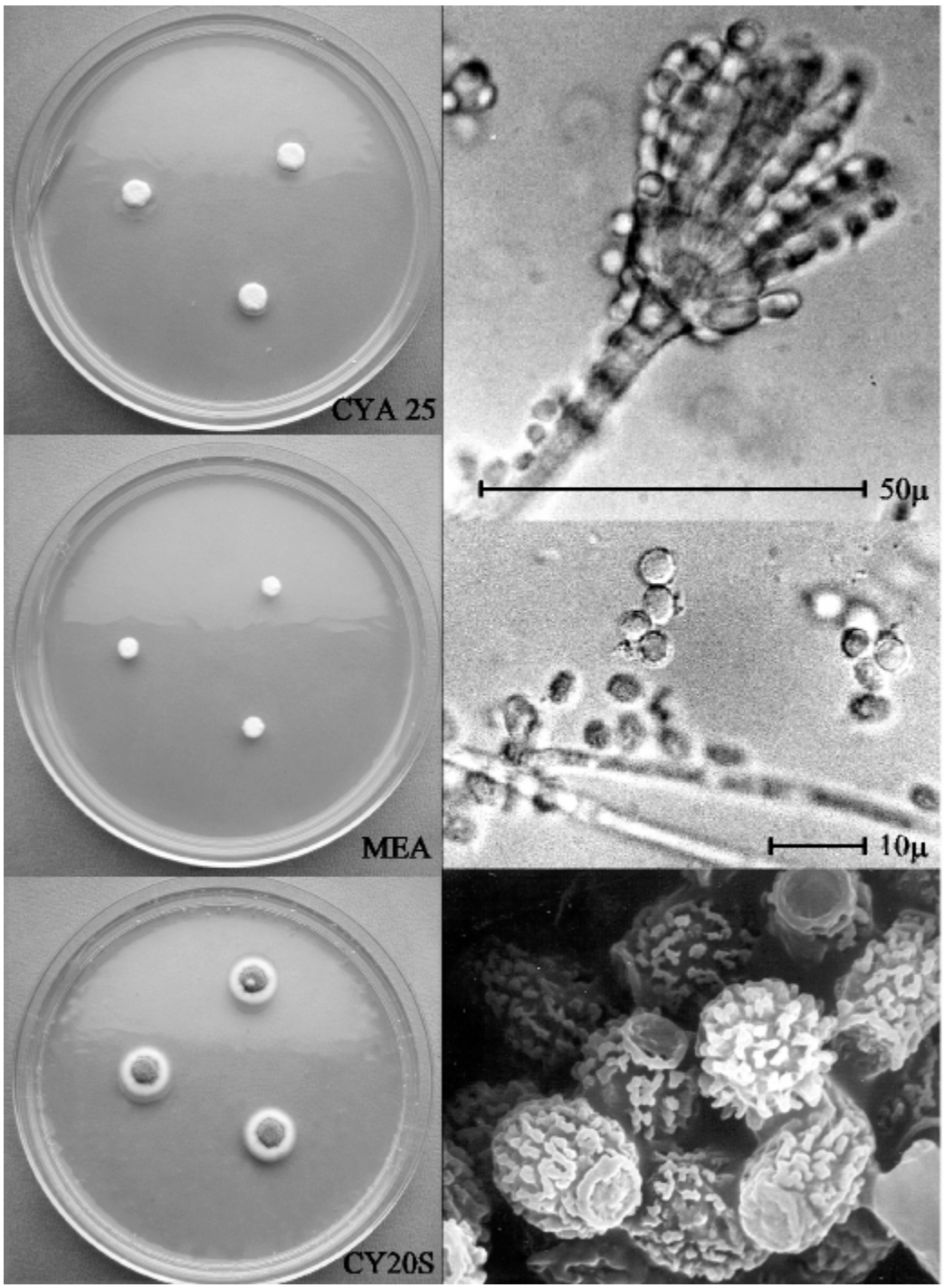

Fig. 36. *Aspergillus penicillioides:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus puniceus Kwon-Chung & Fennell — Fig. 37.

In Raper & Fennell, Genus *Aspergillus*: 547. 1965. Neotype IMI 126692.

Subgenus: *Nidulantes* Section: *Usti*

Colony Diameters at 7 days, in mm: **CYA25** 30-45; **MEA** 24-45; **CY20S** 22-47; **CYA37** 0-8; **CZ** 25-35.

Colony Colors and Textures. Conidia not abundant on **CYA25**, overall color pale orange, "flesh" (6B3) to dull pink (8A-C2-3); mycelium white to grey, tan or pale yellow, in a thick mat; Hülle cells, if present, dull yellowish to gold; exudate, occasionally formed, in uncolored to brown or dark red; reverse golden brown to red brown; yellow to yellow brown soluble pigment occasionally present; colonies dense, wrinkled or radially sulcate. On **MEA**, conidia brownish orange (7C4) to light brown (6D6), becoming dark green (30F5) or olive (3D3) in age; mycelium white, inconspicuous to floccose with scattered knots of white to dull gold Hülle cells; reverse in dull greyish yellow to olive colors; texture variable. Colonies on **CY20S** similar to those on CYA25 in appearance except exudate absent and reverse tending to be orange, red or yellow in some isolates. Colonies on **CYA37** consisting of dense mounds with white to pale orange-yellow colors predominating. Colony characters on **CZ** similar to those on CYA25.

Microscopic Characteristics. **Conidial heads** radiate to loosely columnar; **stipes** in two ranges, 100-250 (400) x 4-7 µm, or 30-80 x 4-6 µm, walls smooth, brown; **vesicles** nearly spherical to pyriform or spathulate, 7-18 (22) µm wide; **biseriate**, metulae covering three-fourths to all of the vesicle, 4-7 x 3-4 (4.5) µm; phialides 4-7 x 2.5-3 (4) µm. **Conidia** spherical, (2.5) 3-4 (4.5) µm in diameter, spinulose, appearing finely roughened to quite rough. **Hülle cells** often present, generally irregular and elongate.

Distinguishing Features. The drab-colored sporulating areas are the most distinctive feature of *A. puniceus*. The vesicles are nearly spherical, and conidia 3-4 µm in length. Elongate Hülle cells are often evident. *A. puniceus* may be distinguished from *A. ustus* by its pinkish color on CYA25.

Taxonomic References. Raper & Fennell, 1965; Klich & Pitt, 1988; Kozakiewicz, 1989.

Habitats. *A. puniceus* is relatively uncommon and has been isolated predominantly from soils in tropical to warm-temperate zones (Raper & Fennell, 1965; Kamal & Kumar, 1979; Klich, 2002).

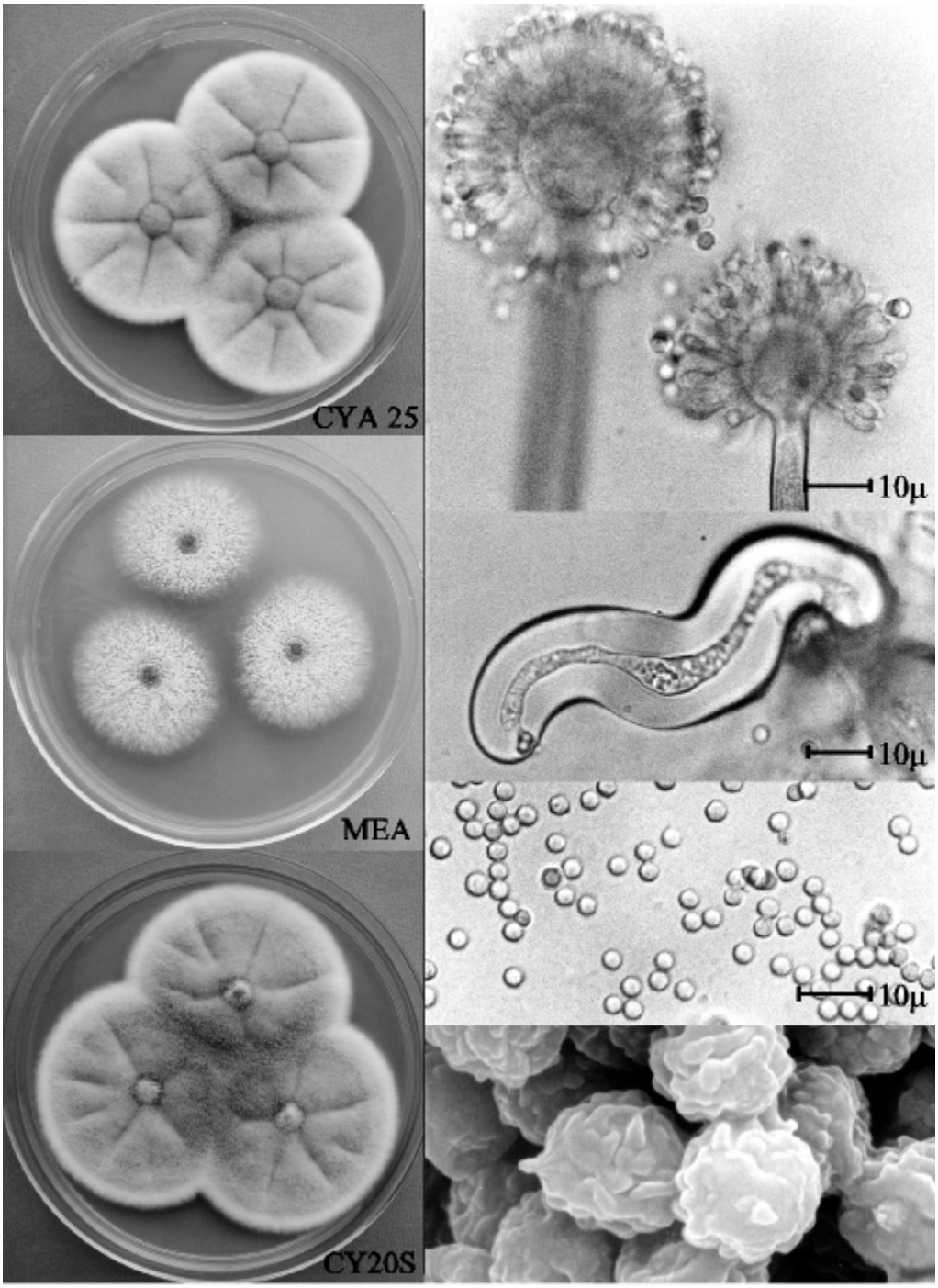

Fig. 37. *Aspergillus puniceus:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial heads, Hülle cell, conidia, and SEM of conidia (x 8000).

Emericella quadrilineata (Thom & Raper) C.R. Benjamin — Fig. 38.

Mycologia 47: 680. 1955. Neotype IMI 89351.
Anamorph: *A. tetrazonus* (Thom & Raper) Samson & W. Gams in Samson & Pitt, Adv. *Penicillium Aspergillus* System.: 48. 1985. Holotype IMI 89351.

Subgenus: *Nidulantes* Section: *Nidulantes*

Colony Diameters at 7 days, in mm: **CYA25** (37) 40-65; **MEA** (29) 35-65 (67); **CY20S** 45-65; **CYA37** (55) 60-70; **CZ** 40-52.

Colony Colors and Textures. Conidia sparse on **CYA25**, usually only in the center of the colony dull green to grey green (27-30C-D2-4); mycelium white to greyish, cleistothecial areas pale buff to dull yellow (4A3); exudate uncolored when present; reverse usually orange brown, red brown or purple brown; soluble pigment, if present, yellow brown, red brown or pink; colony low, velutinous, plane to sulcate. On **MEA**, conidia not abundant, sometimes only at the colony center, dull green to greyish green (26-28D-E3-5); white inconspicuous mycelium, dull yellow cleistothecial areas; reverse uncolored to dull brownish yellow, sometimes with yellow soluble pigment; colonies low, velutinous, plane, often with fimbriate margins. Few conidia formed on **CY20S**; mycelium white to buff, cleistothecial areas dull yellow; reverse in dark brown, red brown to purple brown colors, sometimes spreading as soluble pigment; colonies low, sulcate. On **CYA37,** conidia scattered, exudate absent, otherwise similar to colonies on CYA25. Morphology on **CZ** similar to that on CYA25.

Microscopic Characteristics. **Conidial heads** radiate to columnar; **stipes** (25) 40-120 (200) x 4-6 µm, smooth-walled, brown at maturity, expanding into pyriform **vesicles** (6) 8-12 (15) µm in diameter; **biseriate**; metulae (4) 5-7 (8) x 2.5-4 µm, covering only the upper third to half of the vesicle; phialides 5-8 x 2.0-3.5 (4) µm. **Conidia** 2.5-4 µm, spherical, smooth to finely roughened. **Cleistothecia** globose (90) 100-250 (300) µm in diameter, walls brownish red at maturity, consisting of tightly packed hyphae. **Hülle cells** globose, 10-30 µm in diameter, yellowish en masse. Asci globose 10-12 µm, 8-spored, dehiscent. **Ascospores** maturing within two weeks, red, lenticular, 4.5-6 x 3.5-4 µm, smooth-walled, with 4 short crests (<1 µm), two of these are very obvious, two quite indistinct.

Distinguishing Features. This species is distinguished by brown-stiped biseriate conidial heads, cleistothecia with globose Hülle cells containing red, smooth-walled ascospores each with 4 short longitudinal crests. *E. quadrilineata* may be distinguished from *E. nidulans* by the presence of 4 crests on the ascospores, and from *E. rugulosa* by its faster growth rates.

Taxonomic References. Raper & Fennell, 1965; Klich & Pitt, 1988.

Common Synonyms. *A. quadrilineatus* Raper & Thom. This name is invalid because the species description included the teleomorph.

Habitats. Like other *Emericella* species, *E. quadrilineata* is a soil fungus of widespread distribution (Raper & Fennell, 1965), reported at relatively high frequencies in the 26-35 degree latitude range (Klich, 2002).

Major Mycotoxins. Sterigmatocystin.

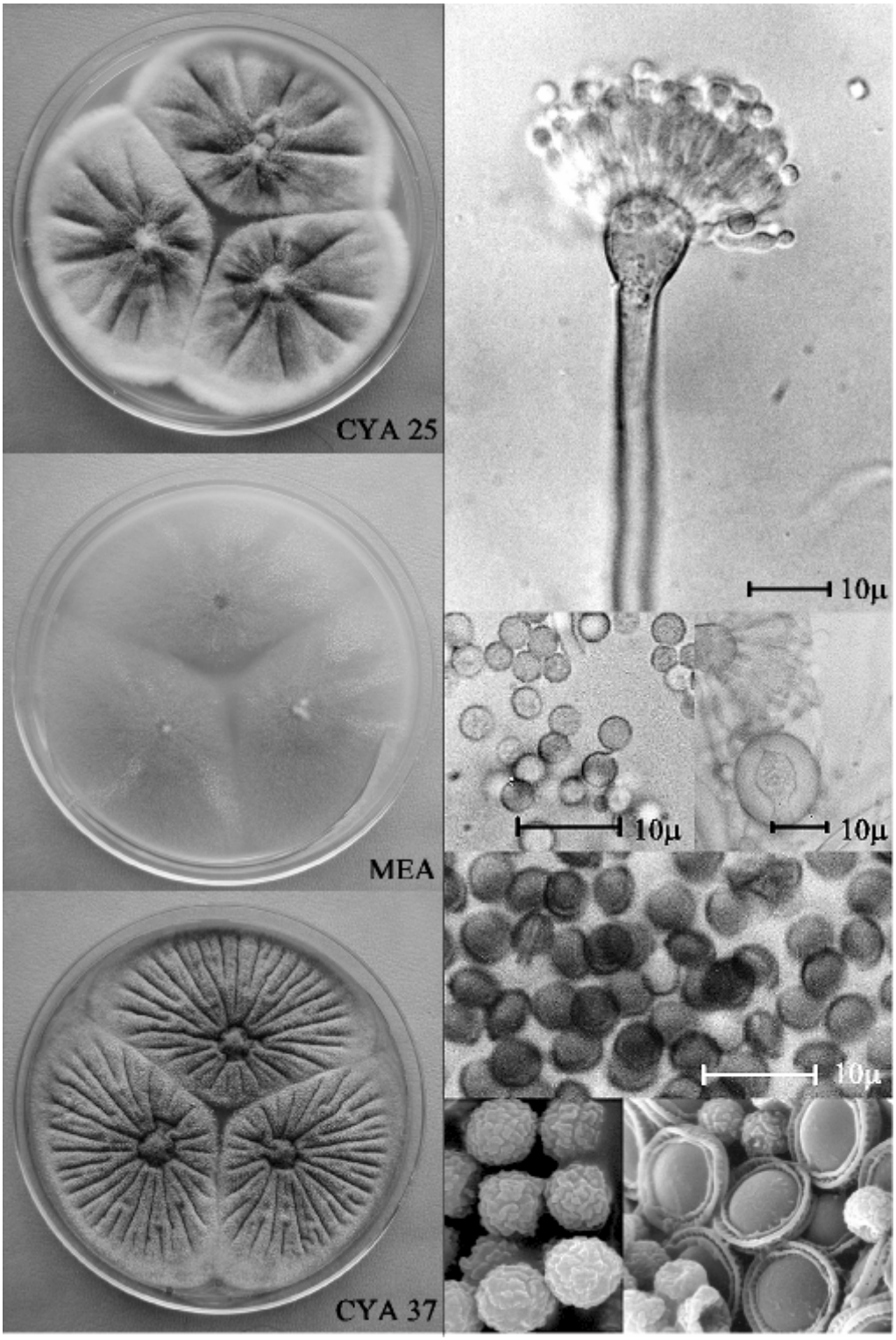

Fig. 38 . *Emericella quadrilineata:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom, left to right), conidial head, conidia, hülle cell, ascospores, SEM of conidia (x 8000), and SEM of ascospores (x 5000).

Aspergillus restrictus G. Smith — Fig. 39.

J. Textile Inst. 22: T115. 1931. Neotype IMI 16267.

Subgenus: *Aspergillus* Section: *Restricti*

Colony Diameters at 7 days, in mm: **CYA25** (4) 8-12; **MEA** (3) 6-12; **CY20S** (11) 16-25; **CYA37** no growth or germination only; **CZ** 5-7.

Colony Colors and Textures. Conidia on **CYA25** dull green (30D-E3), grey green (26-27C-E3), to dark green (26F8); mycelium white or inconspicuous; reverse uncolored to brown or dark grey-green (27D3-4); exudate absent; colonies velutinous, sometimes centrally floccose, dense, often with fimbriate margins. On **MEA**, conidia dull to dark green (26-30C-F8); mycelium white; reverse uncolored to dark green (27F3-4); colony velutinous with an irregular margin. Conidia on **CY20S** dark green (27-30F8), or dark turquoise (24F8), other characters as on CYA25. On **CZ**, conidia dark green (26-28F8), mycelium inconspicuous, reverse uncolored to dark grey-green (27D3), colonies low, dense, plane.

Microscopic Characteristics. Conidial heads columnar; **stipes** (70) 80-200 (320) x 4-8 µm, walls smooth or finely roughened, uncolored, expanding into pyriform or hemispherical **vesicles** (6) 8-21 (25) µm wide; **uniseriate**; phialides (7) 8-10 (12) x 2-3.0 (4) µm, covering only the upper quarter to third of the vesicle. **Conidia** variable in shape, often nearly cylindrical when borne, at maturity ellipsoidal or pyriform, usually rough-walled, 4-7 (10) x 3-4 (5.5) µm.

Distinguishing Features. Together with *A. penicillioides*, *A. restrictus* is distinguished from most other green-spored aspergilli by very slow growth (< 15 mm in diameter) on both CYA25 and MEA, and rarely exceeding 20 mm in diameter on CY20S. *A. penicillioides* are even more restricted on CYA25 and MEA than *A. restrictus*, rarely exceeding 8 mm in diameter at seven days. The phialides of *A. restrictus* are all on the upper portion of the vesicles, yielding columnar heads. *A. penicillioides* has phialides on a greater proportion of the vesicle than *A. restrictus*, and the conidial heads are usually radiate when young. Conidia of *A. restrictus* are usually borne as cylinders, whereas those of *A. penicillioides* are borne as ellipsoids.

Taxonomic References. Raper & Fennell, 1965; Klich & Pitt, 1988; Kozakiewicz, 1989; Pitt & Hocking, 1997.

Habitats. *A. restrictus* is a slow growing fungus, often overlooked in surveys. It has been isolated from a variety of substrates including; indoor environments, soil, seeds, cotton goods, fruit juices and from air (Domsch *et al*., 1980; Samson *et al*., 2001). It has been reported at higher relative frequencies in studies from desert soils and at latitude ranges of 0-15 and 26-35 than in studies from other latitudes or biomes (Klich, 2002).

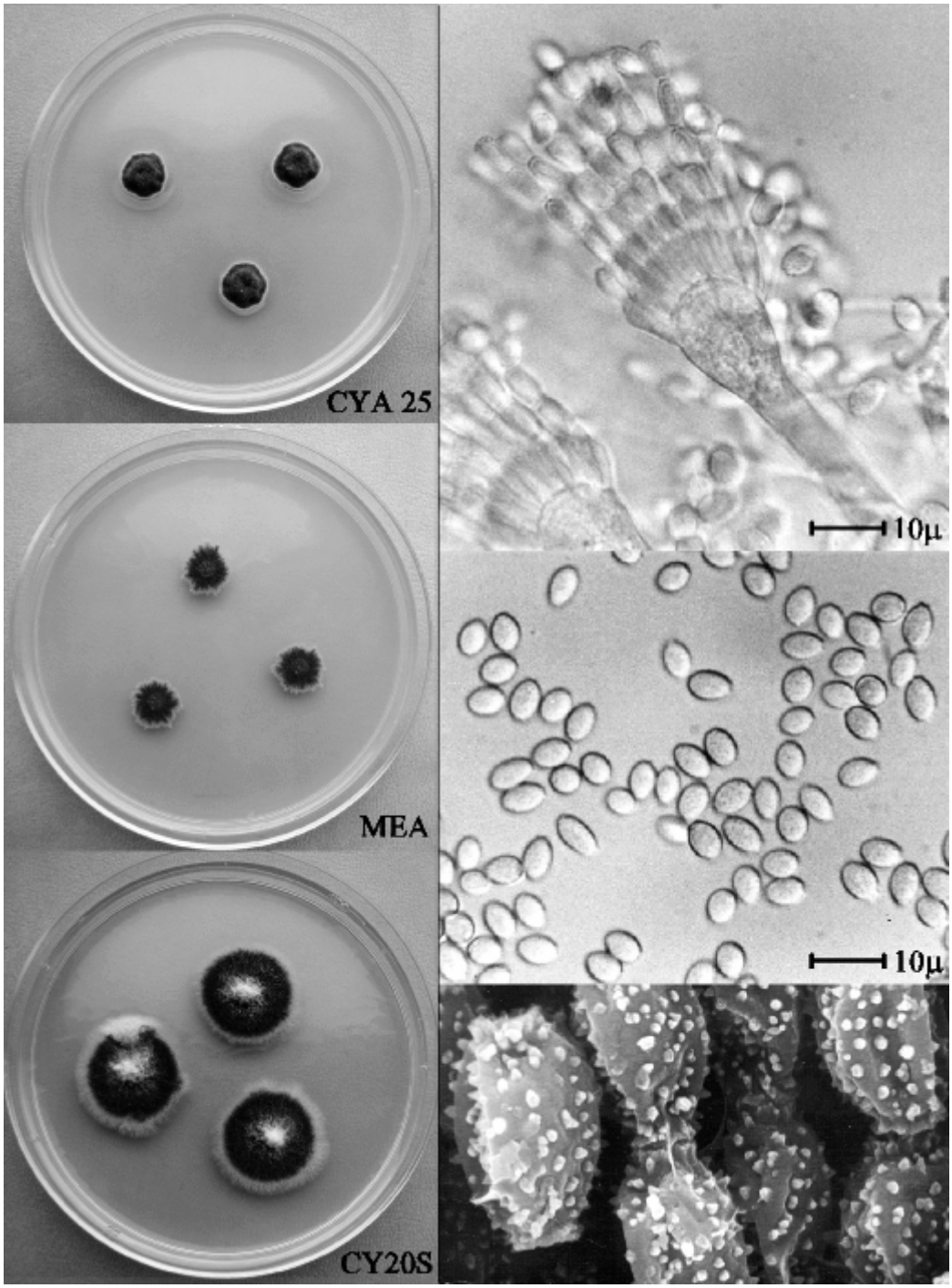

Fig. 39. *Aspergillus restrictus:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial head, conidia, and SEM of conidia (x 8000).

Emericella rugulosa (Thom & Raper) C.R. Benjamin — Fig. 40.

Mycologia 47: 680. 1955. Neotype IMI 136775.
Anamorph: *A. rugulovalvus* (Thom & Raper) Samson & W. Gams in Samson & Pitt, Adv. *Penicillium Aspergillus* System.: 49. 1985. Holotype IMI 136775.

Subgenus: *Nidulantes* Section: *Nidulantes*

Colony Diameters at 7 days, in mm: **CYA25** 10-17 (33); **MEA** 12-20 (42); **CY20S** 12-20 (31); **CYA37** 53-60 (70); **CZ** 14-20 (26).

Colony Colors and Textures. Conidia on **CYA25** dull greyish green (28-30B-E3-7); mycelium white with dull yellow to yellow Hülle cells embedded in the mycelium and surrounding the cleistothecia which are pale at first but become dull red in age; exudate, when present, uncolored to reddish brown or vinaceous; reverse uncolored to yellowish- reddish- or orangish- brown; soluble pigment occasionally present, brown to yellow brown or orange brown; colonies velutinous, plane or radially sulcate, usually umbonate. On **MEA**, conidia usually dark green (27-30F8), occasionally grey green (28C3); mycelium inconspicuous, white; scattered yellowish Hülle cells visible surrounding cleistothecia; cleistothecia usually pale at one week, but reddish at two weeks; greyish yellow to brownish orange reverse (2C3, 4-5C5-6); colony low velutinous, often with an irregular margin. Colony colors on **CY20S** similar to those on CYA25, except exudate absent and reverse generally brown (5-6C-F4-8). Exudate absent on **CYA37**, other characters similar to those on CYA25. On **CZ**, colonies grey green to olive (4D4-5); exudate absent; reverse generally dark brown, other characters similar to those on CYA25.

Microscopic Characteristics. **Conidial heads** often radiate on CYA25, usually columnar on MEA. **Stipes** (40) 60-100 (180) x 4-6 (7) µm, walls smooth, becoming brown in age; **vesicles** (4) 8-12 (14) µm wide, pyriform or spathulate; **biseriate**, metulae covering upper one third to two thirds of the vesicle, 4-7 (8) x 2-3.5 (4) µm; phialides 5-8 (9) x 2-3 µm. Conidia 3-4 µm, globose, walls finely roughened to very rough. **Cleistothecia** spherical, (80) 100-200 (300) µm in diameter, wall thick, consisting of a layer of irregular cells surrounded by several layers of tightly packed hyphae, reddish in color, surrounded in turn by Hülle cells 12-22 µm in diameter, globose to subglobose, yellow to tan en masse. Asci 8-spored, 8-14 µm in diameter, dehiscent. **Ascospores** usually maturing within two weeks, broadly lenticular (walnut-shaped), 5-6.5 x 3-4.5 µm, red, walls usually extremely rough, but smooth in some isolates, with two longitudinal crests about 1 µm high.

Distinguishing Features. Red ascospores with 2 longitudinal crests, conidiophores with short brown stipes, and colony diameters at 37^{o} usually greater than that on any media at 25^{o} make this a very distinctive species. Colony diameters on CYA25 and MEA are usually smaller than those on the other common *Emericella* species *E. nidulans* and *E. quadrilineata.*

Taxonomic References. Raper & Fennell, 1965; Christensen & States, 1982; Klich & Pitt, 1988; Klich *et al*., 2001.

Common Synonyms. *A. rugulosus* Thom & Raper. This name is invalid because the species description included the teleomorph.

Habitats. *E. rugulosa* is known primarily from soils in latitudes from 16-35 degrees (Domsch *et al*., 1980; Klich, 2002).

Major Mycotoxins. Sterigmatocystin.

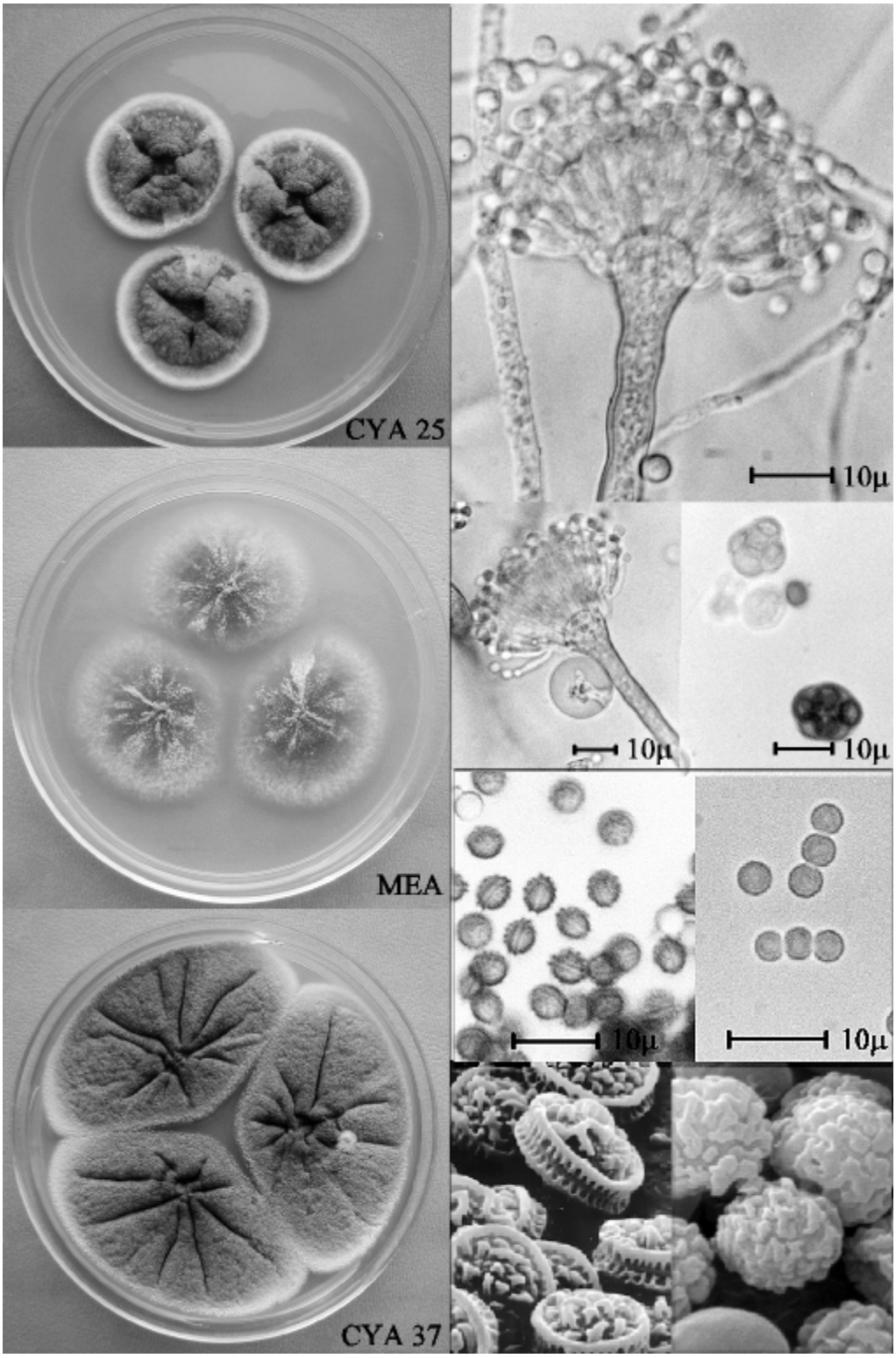

Fig. 40. *Emericella rugulosa:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom, left to right), conidial head, conidial head with Hülle cell, asci, ascospores, conidia, SEM of ascospores (x 8000), and SEM of conidia (x 8000).

Aspergillus sclerotiorum Huber — Fig. 41.

Phytopathology 23: 306. 1933. Neotype IMI 56673.

Subgenus: *Circumdati* Section: *Circumdati*

Colony Diameters at 7 days, in mm: **CYA25** (40) 45-60; **MEA** 45-56; **CY20S** 60-70; **CYA37** (16) 20-30 (35); **CZ** 32-37.

Colony Colors and Textures. Conidia on **CYA25** pastel yellow to light yellow (3A3-4, 4A3-4); mycelium white; exudate clear to amber; sclerotia usually formed, white to buff; reverse cream, pale yellow or greyish yellow; soluble pigment absent or pale orange; colony texture variable. Conidia on **MEA** pale to light yellow (3-4A2-4); mycelium white, not dense; sclerotia white to buff; reverse in light yellow shades to dark brown shades; granular. Conidia and mycelium on **CY20S** colored as on CYA25; reverse bright yellow (3A3-7), lake red (9C8), or orange red (7-8B8); no exudate observed; soluble pigment sometimes formed, orange; colony texture variable. Conidia absent on **CYA37**, exudate and reverse pale yellow, peach or brown, other characters as on CYA25. Colonies low, dense, velutinous to lanose on **CZ**, other characters as on CYA25.

Microscopic Characteristics. **Conidial heads** radiate, sometimes splitting into columns; **stipes** rough-walled, yellow to pale brown, measuring (200) 400-1200 (2000) x (5) 7-10 µm; **vesicles** 17-35 (40) µm wide, pyriform, spherical to elongate; **biseriate**, metulae usually covering the entire vesicle surface, measuring (6) 7-12 x 3-5 µm; phialides 6-8 x 2-3 µm. Diminutive conidial heads often present, also usually biseriate. **Conidia** spherical, (2) 2.5-3 (3.5) µm in diameter, smooth to finely roughened.

Distinguishing Features. This species is distinguished by pale yellow conidia, yellow reverse coloration on MEA, small (2.5-3 µm) smooth-walled conidia, and white to buff-colored sclerotia.

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980; Christensen, 1982; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990.

Habitats. *A. sclerotiorum* is predominantly a soil fungus isolated most frequently from tropical and subtropical zones (Domsch *et al*., 1980). It has been reported at greater than expected frequencies in desert soils and in the 36-45 degree latitude range (Klich, 2002).

Major Mycotoxins. Ochratoxin A, penicillic acid.

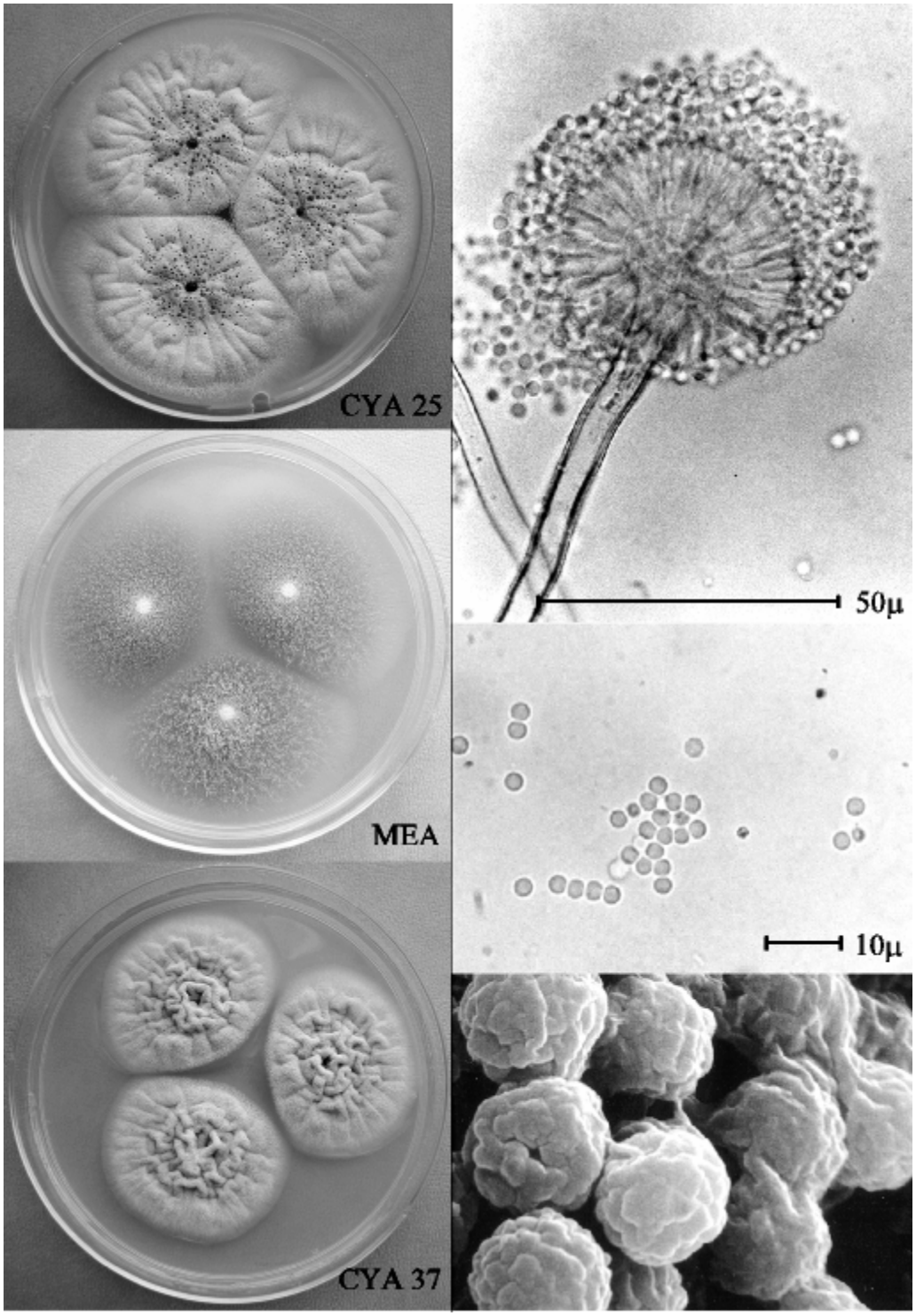

Fig. 41. *Aspergillus sclerotiorum:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus sojae Sakaguchi & Yamada ex Murak — Figs. 42 and 4a.

Rep. Res. Inst. Brewing 143: 8. 1971. Neotype IMI 1791300

Subgenus: *Circumdati* Section: *Fla*vi

Colony Diameters at 7 days, in mm: **CYA25** 60-70; **MEA** 60-70; **CY20S** 60-70; **CYA37** 45-70; **CZ** 50-60.

Colony Colors and Textures. Conidia on **CYA25** dark olive brown to yellowish brown or raw umber (3-5E-F7-8); mycelium white, inconspicuous to dense and floccose; exudate uncolored when present; reverse uncolored to pale greyish brown; colony texture variable, granular to deeply floccose. On **MEA**, conidia dark green (28-29E-F7-8) to olive (1-2E-F8); mycelium white, inconspicuous; reverse uncolored to slightly grey green; colony not dense, with inconspicuous hyphae giving rise to conidiophores of varying lengths, colonies occasionally lightly floccose. Conidia on **CY20S** usually olive yellow to olive (3D-E6,7) or olive brown (4D-E7); other characters similar to those on CYA25 except reverse in dull yellow shades rather than browns. Colony colors on **CYA37** often slightly more citrine than on CYA25; no exudate; brown to yellow-brown soluble pigment; colony textures as on CYA25. Conidia olive green (1-2D-E8) on **CZ**, other characters similar to those on CYA25.

Microscopic Characteristics. **Conidial heads** radiate to loosely columnar; **stipes** (100) 300-900 (1400) µm, walls smooth to rough, uncolored; **vesicles** (10) 17-35 (50) µm, pyriform to globose, rarely clavate; predominantly **uniseriate**, some of the larger ones **biseriate**; metulae, when present, (8) 10-15 x 5-9 µm; phialides 9-12 (14) x 4-6 µm. **Conidia** (4.5) 5.5-7 (13) µm in diameter, spherical, rough-walled.

Distinguishing Features. This species is distinguished by its olive brown colors on CYA25, predominantly uniseriate conidial heads, and large rough-walled conidia. *A. sojae* may usually be distinguished from *A. parasiticus* by its olive brown conidial colors in age, larger conidia, and more floccose colonies. Growth on antibiotic-containing media has also proved useful in distinguishing *A. sojae* from A. *parasiticus* (Klich & Mullaney, 1989).

Taxonomic References. Murakami, 1971; Christensen, 1982; Klich & Pitt, 1985; Klich & Pitt, 1988; Klich & Mullaney, 1989.

Habitats. With one exception, *A. sojae* is known only from koji fermentations.

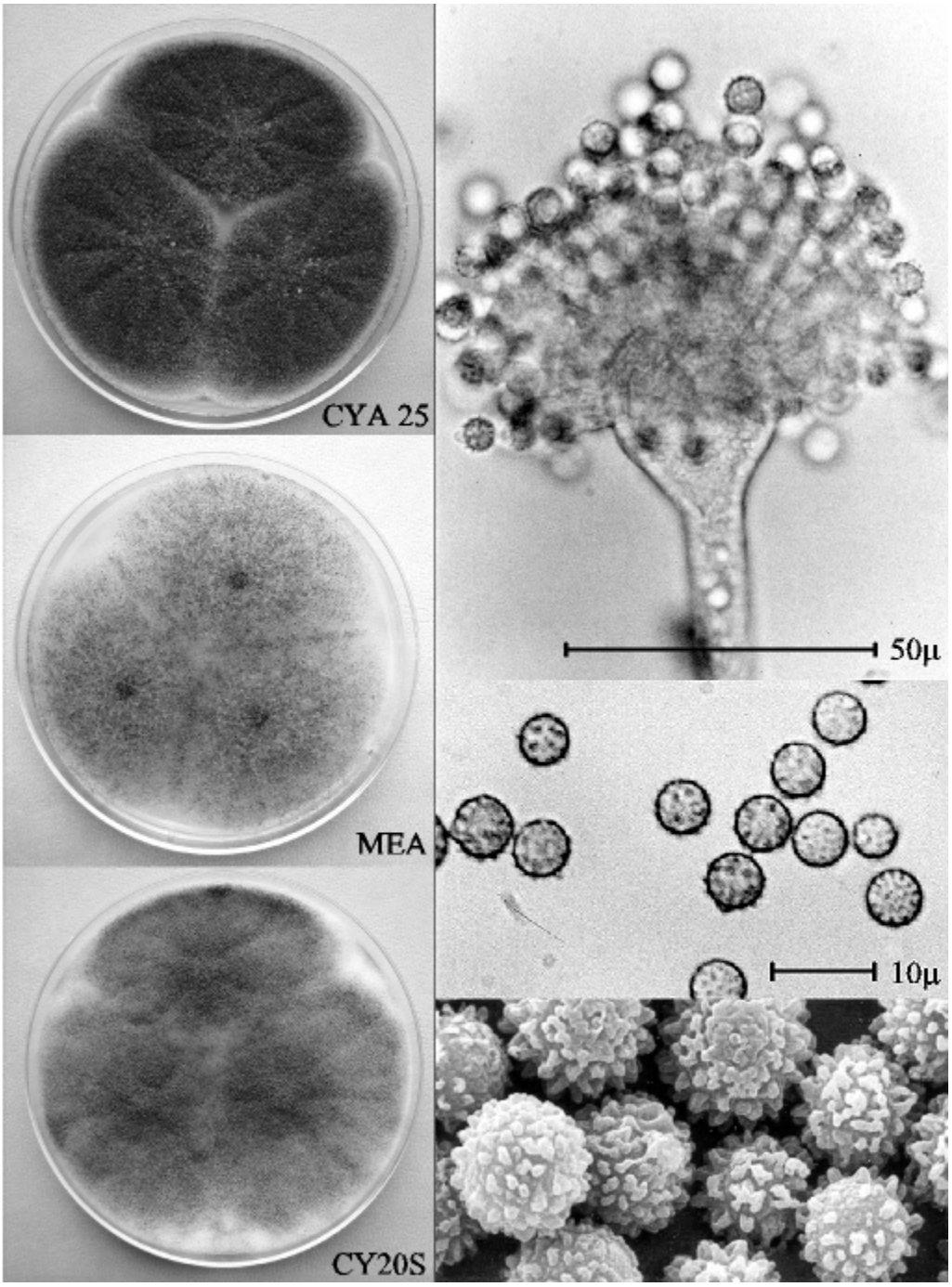

Fig. 42. *Aspergillus sojae:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial head, conidia, and SEM of conidia (x 3000).

Aspergillus sparsus Raper & Thom — Fig. 43.

Mycologia 36: 572. 1944. Neotype IMI 19394.

Subgenus: *Circumdati* **Section: *Sparsi***

Colony Diameters at 7 days, in mm: **CYA25** 20-30; **MEA** 15-25; **CY20S** 20-30; **CYA37** 0-28; **CZ** 20-30.

Colony Colors and Textures. Conidia on **CYA25** very sparse, dull greenish tan; mycelium dense white to grey brown; reverse dull brown to orange brown; soluble pigment brownish yellow when present; colonies lanose or with tufts or sectors of floccose hyphae. On **MEA**, conidia absent or cream-buff when present; mycelium white to cream; reverse in bright yellow to burnt orange colors; soluble pigment absent or yellow to orange-brown; colony plane, velutinous to floccose. Colonies on **CY20S** producing few cream to pale greenish-tan conidia, other characters similar to those on CYA25. Conidia absent or buff in color on **CYA37**, mycelium white to dull grey brown; reverse uncolored to dull brown. Colonies on **CZ** inconspicuous, thin, almost invisible or with cream to white mycelium and gold reverse.

Microscopic Characteristics. **Conidial heads** radiate; **stipes** 250-500 (1500) µm, almost uncolored to red brown with rough walls; **vesicles** globose to slightly elongate, (13) 20-40 (50) µm wide; **biseriate**; metulae 7-10 x 3-6 µm, covering the entire surface of the vesicle; phialides (5) 6-8 x 2.5-4 µm. **Conidia** 3-4 (5.5) µm, globose to very broadly ellipsoidal, smooth to very finely roughened. The bases of the stipes of this species are enmeshed in a network of distinctive `feeder' hyphae.

Distinguishing Features. As the name *A. sparsus* implies, conidia are produced sparsely on all media. Colony diameters are generally less than 30 mm, and stipes become red-brown in age.

Taxonomic References. Raper & Fennell, 1965; Klich & Pitt, 1988.

Habitats. *A. sparsus* is not a common species, and has been reported predominantly from soil (Raper & Fennell, 1965; Kamal & Kumar, 1979).

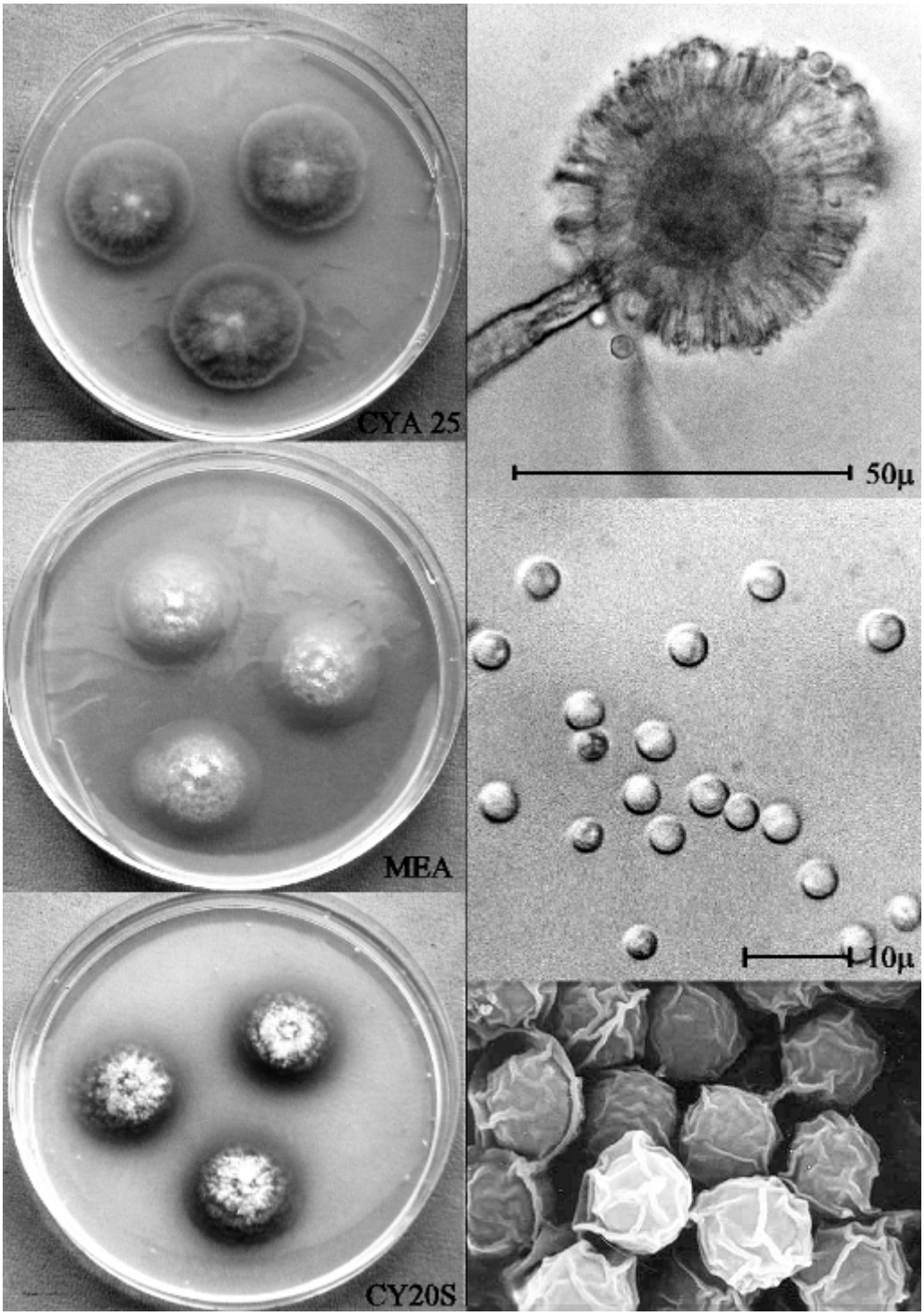

Fig. 43. *Aspergillus sparsus:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus sydowii (Bain. & Sart.) Thom & Church — Figs. 44 and 5i.

The Aspergilli, 147. 1926. Neotype IMI 211384.

Subgenus: *Nidulantes* Section: *Versicolores*

Colony Diameters at 7 days, in mm: **CYA25** 20-30; **MEA** (16) 22-30; **CY20S** 24-35 (37); **CYA37** (0) 2-10; **CZ** 20-27.

Colony Colors and Textures. Colonies **CYA25** heavily sporulating in greyish turquoise or dark turquoise to dark green colors (24-25C-F4-8); mycelium white; exudate reddish brown to dark brown when present; reverse brown to orange brown or maroon; soluble pigment, when present, colored as reverse; colonies dense, velutinous to lanose, radially sulcate. Conidia on **MEA** greyish turquoise to dark turquoise or dark green (24-25D-F7-8); mycelium white, inconspicuous; reverse often uncolored sometimes dull green or deep red brown; colony texture velutinous to granular, plane. Colonies on **CY20S** similar in appearance to colonies on CYA25 except exudate usually not formed and texture somewhat more floccose. Colonies on **CYA37** differing from those on CYA25 in that the conidial colors are less intense (24-25B-C 3-4) and the colonies are sometimes slightly more floccose. Colonies on **CZ** similar in appearance to those on CYA25 except that the conidial colors are less intense (24C-D3-4).

Microscopic Characteristics. **Conidial heads** radiate; **stipes** (15) 200-35 (50) x 3-8 µm smooth, thick-walled, colorless to pale brown, expanding into pyriform, spathulate, or almost clavate **vesicles**, 7-17 (20) µm in width; usually **biseriate**, metulae (3) 4-6 (8) x 2-3.5 µm, phialides (4) 5-7 (10) x 2-3 (3.5) µm. Diminutive conidial structures produced by many isolates, down to simple penicillate heads. **Conidia** spherical, very rough to spinose, (2.5) 3-4 (4.5) µm in diameter. Raper & Fennell (1965) reported that Hülle cells are sometimes produced.

Distinguishing Features. The turquoise colony color on CYA25 is the most striking feature of *A. sydowii* and is the character which distinguishes it most readily from *A. versicolor*. The relatively small colony diameters, extremely rough-walled spherical conidia borne from small biseriate conidial heads with uncolored to slightly brown stipes are also distinctive.

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Klich, 1993; Pitt & Hocking, 1997; Samson *et al*., 2000.

Common Synonyms. *A. sydowii* (Bain. & Sart.) Thom & Church. This was a misspelling (Domsch *et al*., 1980).

Habitats. *A. sydowii* is worldwide in distribution. Its primary habitat is soil, but it has been reported from many other substrates in indoor and outdoor environments (Domsch *et al*., 1980; Samson *et al*., 2001). It appears to be much less common in foods than *A. versicolor* (Pitt & Hocking, 1997). Soil studies conducted in the 26-35 degree latitude ranges report this species with greater relative frequency than studies conducted in other latitude ranges (Klich, 2002).

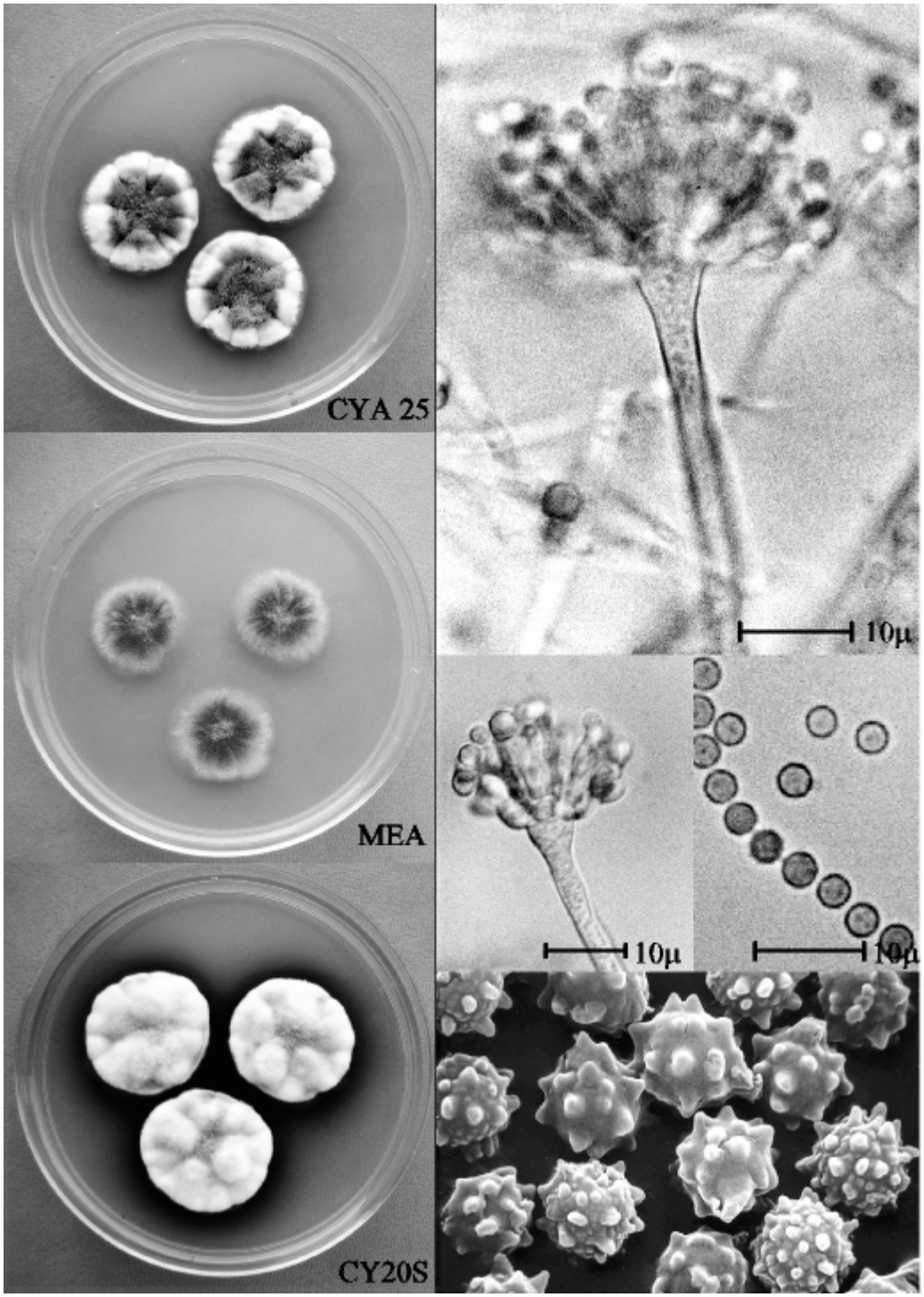

Fig. 44. *Aspergillus sydowii:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom, left to right), conidial head, small conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus tamarii Kita — Fig. 45.

Centralbl. Bakteriol. Abth., 2, 37; 433. 1913. Neotype CBS 104.13.

Subgenus: *Circumdati* Section: *Flavi*

Colony Diameters at 7 days, in mm: **CYA25** (45) 55-70; **MEA** (55) 65-70; **CY20S** 60-70; **CYA37** 40-70; **CZ** 54-70.

Colony Colors and Textures. Conidia on **CYA25** olive brown (4D-E8) to yellowish brown (5E8); mycelium white; reverse uncolored to greyish yellow; colonies low and radially sulcate to floccose and plane. On **MEA**, conidia olive brown to yellowish brown or linoleum brown (4-5E7-8); mycelium white, inconspicuous; reverse uncolored to slightly yellow; conidial heads uncrowded, stipes uneven in length, giving the colony a coarse texture. Colonies on **CY20S** and **CYA37** similar to those on CYA25 in all characters. Colonies on **CZ** also similar to those on CYA25 except the reverse is uncolored to very pale brown.

Microscopic Characteristics. **Conidial heads** radiate or splitting into columns; **stipes** (300) 600-150 (2600) x 12-20 µm, rough-walled, uncolored; **vesicles** globose to pyriform, (15) 20-45 (75) µm wide; **uniseriate** and **biseriate** conidial heads present in most isolates; metulae/phialides usually covering the entire surface of the vesicle, metulae 8-13 (20) x 4-8 (9) µm; phialides (7) 9-15 x 4-6 µm. **Conidia** globose, coarsely roughened with very thick walls, (3) 5.5-8 (13) µm in diameter.

Distinguishing Features. The deep brown/green color of the colonies, and large thick-walled rough conidia are the major distinctive features of this species.

Taxonomic References. Raper & Fennell, 1965; Christensen, 1981; Klich & Pitt, 1985; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Common Synonyms. *A. erythrocephalus* Berk. & Curt. Although this name predates *A. tamarii*, there is an argument for conservation of the name *A. tamarii* because of the industrial importance of this fungus.

Related Species. The recently described species *A. caelatus* (Horn, 1997) has more intense yellow colors in the reverse than *A. tamarii.* In my observations, stipes of *A. caelatus* grown on MEA are usually under 1000 µm in length, while those of *A. tamarii* are usually over 1000 µm in length. *A. pseudotamarii* (Ito *et al*., 2001), produces aflatoxin, and has colony diameters of less than 33 mm on CZ incubated at 37°C.

Habitats. *A. tamarii* was originally isolated from tamari sauce. It is also a fairly common soil fungus, especially in tropical soils and has been isolated from the seeds of various crops and other substrates (Domsch *et al*., 1980; Klich, 2002).

Major Mycotoxins. Cyclopiazonic acid.

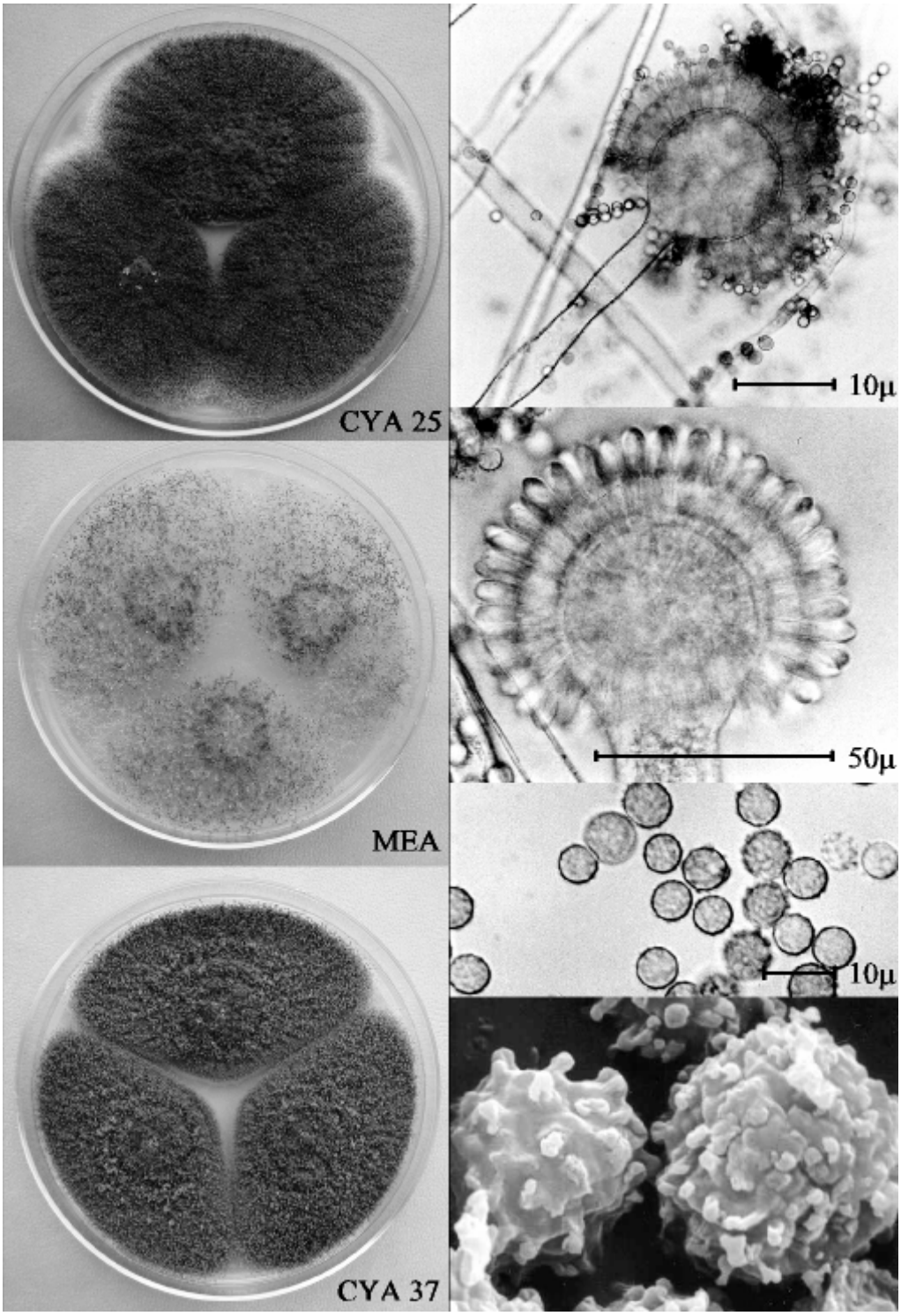

Fig. 45. *Aspergillus tamarii:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, young conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus terreus Thom — Figs. 46 and 3g.

Thom & Church, Am. J. Bot. 5: 85. 1918. Neotype IMI 17294.

Subgenus: *Nidulantes* Section: *Terrei*

Colony Diameters at 7 days, in mm: **CYA25** (30) 40-60; **MEA** (30) 40-70; **CY20S** (55) 65-70; **CYA37** (55) 65-70; **CZ** 30-48.

Colony Colors and Textures. Conidia pale greyish/brownish orange (5B-C3-4) to camel (6D4) on **CYA25**; mycelium white, sometimes yellow centrally; exudate yellow to gold when present; reverse yellow, gold or brown; yellowish to brown soluble pigment sometimes present; colony velutinous to lanose, sometimes floccose centrally, plane or radially sulcate. Conidia on **MEA** sparse, pale orange to greyish orange or flesh (5A-B3, 6B-C3-4); mycelium white, usually inconspicuous; reverse in greyish yellow shades (4-5AB3-6); colony texture granular to somewhat floccose. Colony colors on **CY20S** similar to those on CYA25; velutinous to lanose, usually radially sulcate. Colonies on **CZ** and **CYA37** similar in morphology to colonies on CYA25, however, CZ colonies have a tendency to develop yellow mycelia centrally and usually have fimbriate margins.

Microscopic Characteristics. **Conidial heads** in compact columns; **stipes** smooth-walled, uncolored, (70) 100-25 (300) x 4-7 µm; **vesicles** (7) 12-20 µm wide, somewhat variable in shape, spherical or pyriform; **biseriate**, metulae over the upper half to three quarters of the vesicle, tightly packed, 5-7 x 2-3 µm; phialides 5-7 (9) x 1.5-2.5 µm. **Conidia** 2-2.5 µm in diameter, smooth-walled, globose to broadly ellipsoidal. Globose to ovoid hyaline cells (aleurioconidia) are usually produced laterally on submerged hyphae.

Distinguishing Features. Compactly columnar pale orangish to tan conidial heads with tightly packed metulae, very small (2-2.5 µm) smooth-walled conidia and the presence of hyaline lateral cells on the submerged hyphae are the distinguishing characteristics of this species.

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Related Taxa. Two varieties of this species, *A. terreus* var. *africanus* Fennell & Raper and *A. terreus* var. *aureus* Thom & Raper, have been described. The former is distinguished by the presence of yellow to buff colored sclerotium-like masses on MEA, and the latter by golden yellow mycelium and stipes over 50 µm long. Both varieties are quite rare.

Habitats. *A. terreus* is distributed worldwide in soils but is more abundant in tropical and subtropical regions than temperate regions, and more common in cultivated soils and forests than grasslands. This is one of the few *Aspergillus* species that occurs in greater than expected numbers of reports from cultivated soils (Klich, 2002). It is common in stored crops and has been isolated from other foodstuffs and from indoor environments (Domsch *et al*., 1980; Samson *et al*., 2001).

Major Mycotoxins. Patulin, citrinin, citreoviridin, gliotoxin.

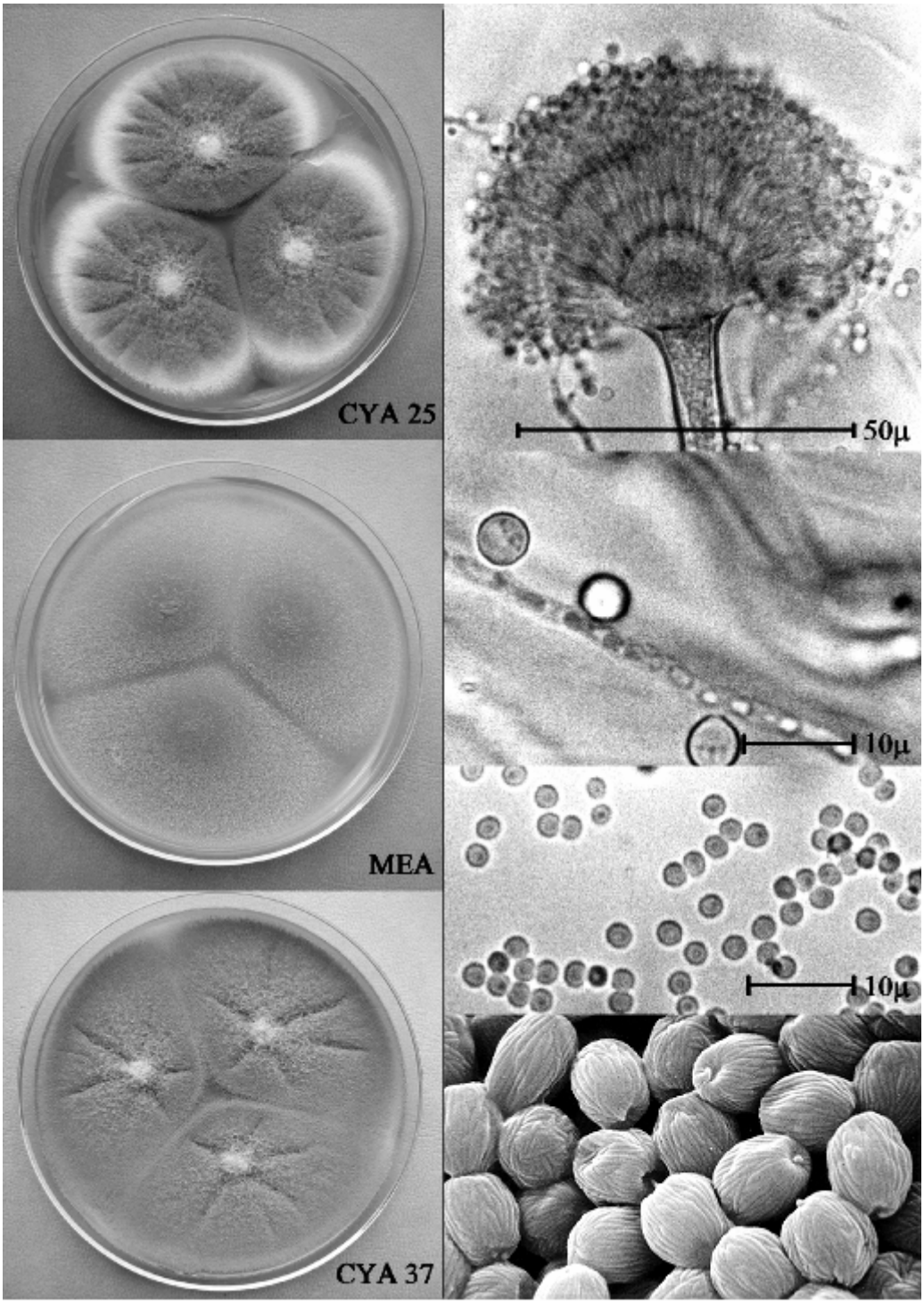

Fig. 46. *Aspergillus terreus:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, aleuriospores, conidia, and SEM of conidia (x 8000).

Aspergillus unguis (Emile-Wiel & L. Gaudin) Thom & Raper — Figs. 47 and 4d.

Mycologia 31: 667. 1939. Neotype IMI 136526.
Teleomorph: *Emericella unguis* Malloch & Cain Can. J. Bot. 5: 62. 1972. Holotype NRRL 2393

Subgenus: *Nidulantes* **Section: *Nidulantes***

Colony Diameters at 7 days, in mm: **CYA25** 16-28; **MEA** 30-42; **CY20S** 24-42; **CYA37** 8-20; **CZ** 18-21.

Colony Colors and Textures. On **CYA25,** conidia abundant, with younger conidial areas greyish green to dark green (26E-F5-7), older conidia near the colony center olive (2-3D-E4-7); mycelium white, usually visible only as a dense narrow margin; reverse uncolored to dull brown or red brown; soluble pigment brown, when present; colony velutinous, plane or sulcate sometimes with a floccose central overlay of white mycelium. On **MEA,** conidial areas fimbriate, greyish green to dark green (26E-F5-7); mycelium white, inconspicuous; reverse uncolored to slightly yellowish or brown; colonies low, sometimes with a floccose center. Colony morphology on **CY20S** similar to that on CYA25. On **CYA37**, conidia olive (3-4D3-4) to brown (5D4-5); mycelium white, exudate absent; reverse brown to black; brown soluble pigment; colonies velutinous, radially sulcate, often with a raised floccose center. Colonies on **CZ** similar to those on CYA25, except soluble pigment not observed and colony margins uneven.

Microscopic Characteristics. **Conidial heads** radiate to loosely columnar on CYA25, definitely columnar on MEA, with sterile thick-walled **white spicular hyphae** rising above the conidial heads are readily visible under the stereo microscope. **Stipes** (40) 100-25 (300) x 3.5-7 µm, walls smooth, thick, uncolored to brown, expanding into spathulate to pyriform **vesicles** 5-14 µm in width; **biseriate**, metulae (4) 5-8 (11) x 3-4 µm, covering the upper half to two-thirds of the vesicle; phialides 5-7 (10) x 2-3.5 µm. **Conidia** smooth to slightly rough, spherical, (2.5) 3-3.5 (4) µm in diameter. Mature **cleistothecia** not observed: *fide* Raper & Fennell (1965); cleistothecia 200-25 µm surrounded by globose Hülle cells, with 8-spored asci, and lenticular purple-red ascospores measuring 4.5-5.5 x 3.2-3.5 µm with low longitudinal crests and smooth walls.

Distinguishing Features. The hallmark of this species is the spicular hyphae extending above the conidia which are readily visible under the stereo microscope. *A. unguis* may also be distinguished from related *Emericella* species by its slow growth on all media.

Taxonomic References. Raper & Fennell, 1965; Klich & Pitt, 1988.

Habitats. This species has not been reported frequently, but has been isolated from man, shoe leather, soil (at latitudes below 36 degrees) and sesame seeds (Raper & Fennell, 1965; Kamal & Kumar, 1979; Vaidehi & Lalitha, 1985; Klich, 2002).

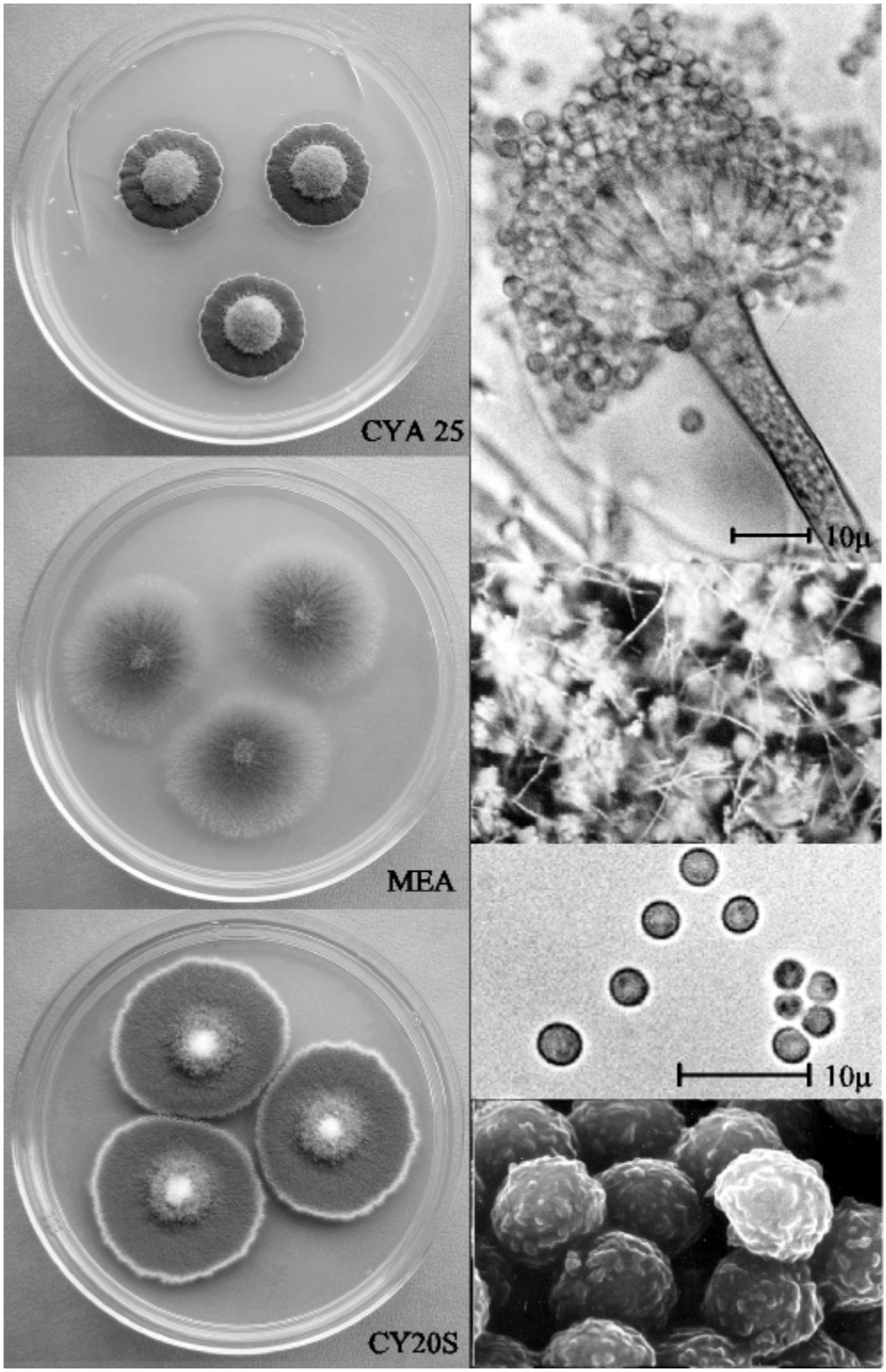

Fig. 47. *Aspergillus unguis*: left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial head, white spicular hyphae (x 5), conidia, and SEM of conidia (x 8000).

Aspergillus ustus (Bainier) Thom & Church Figs. 48, 3b and 5h.

The Aspergilli: 152. 1926. Neotype IMI 211805.

Subgenus: ***Nidulantes*** **Section:** ***Usti***

Colony Diameters at 7 days, in mm: **CYA25** 25-40; **MEA** 30-5; **CY20S** 30-45; **CYA37** 0-45; **CZ** 25-40.

Colony Colors and Textures. On **CYA25**, conidia variable in abundance, light brown (6D4-5) or greyish brown (7-10D3); white to greyish mycelium; exudate, when present uncolored or yellow to dark purple brown; reverse usually yellowish brown centrally and yellow (2A4) to yellow orange or brown at margin; soluble pigment yellow to brownish, when present; colony velutinous or lanose with a raised floccose center, plane or radially sulcate. Conidia sometimes sparse on **MEA**, greenish grey (26-29D-F1-2) or olive brown (4E4); mycelium white, inconspicuous; soluble pigment brown, when present; reverse uncolored dull greyish-yellow or brown; colony low, plane, dense, sometimes floccose. Colony morphology on **CY20S** similar to that on CYA25, but with sporulating areas and reverse sometimes in greenish shades. Colonies on **CYA37** similar in colors and textures to those on CYA25. On **CZ,** conidia brownish grey (7B-C2) to reddish grey (9B2), other characters similar to those on CYA25.

Microscopic Characteristics. **Conidial heads** radiate to loosely columnar; **stipes** (30) 75-200 (35) x 4-7 (10) µm, walls smooth, brown at maturity, expanding into pyriform **vesicles** 7-16 µm wide; **biseriate**; metulae 4-6 (7) x 3-4 µm, covering upper half to three-fourths of the vesicle; phialides 5-7 (8) x 2.5-4 µm. **Conidia** 3-4.5 µm in diameter, spherical, with very rough walls. Irregular to elongate Hülle cells sometimes present.

Distinguishing Features. Very small vesicles on quite long, brown-walled stipes are the principal distinctive features of *A. ustus*. Moderately fast growth on all media, dull grey to drab green conidia with yellow to brown reverse on CYA25, and rough-walled spherical conidia add to the unique appearance of this fungus. *A. ustus* is distinguished from *A. puniceus* by its grey to brown colony color on CYA25.

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980: Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Habitats. *A. ustus* is present at low frequencies in many soils, predominantly from tropical to warm temperate areas, (26-35 degrees latitude). It is relatively uncommon in habitats other than soil, but has been isolated from indoor environments and food (Domsch *et al*., 1980; Pitt & Hocking, 1997; Samson *et al*., 2000; Klich, 2002).

Major Mycotoxins. Austamide, austidiol, austins, austocystins.

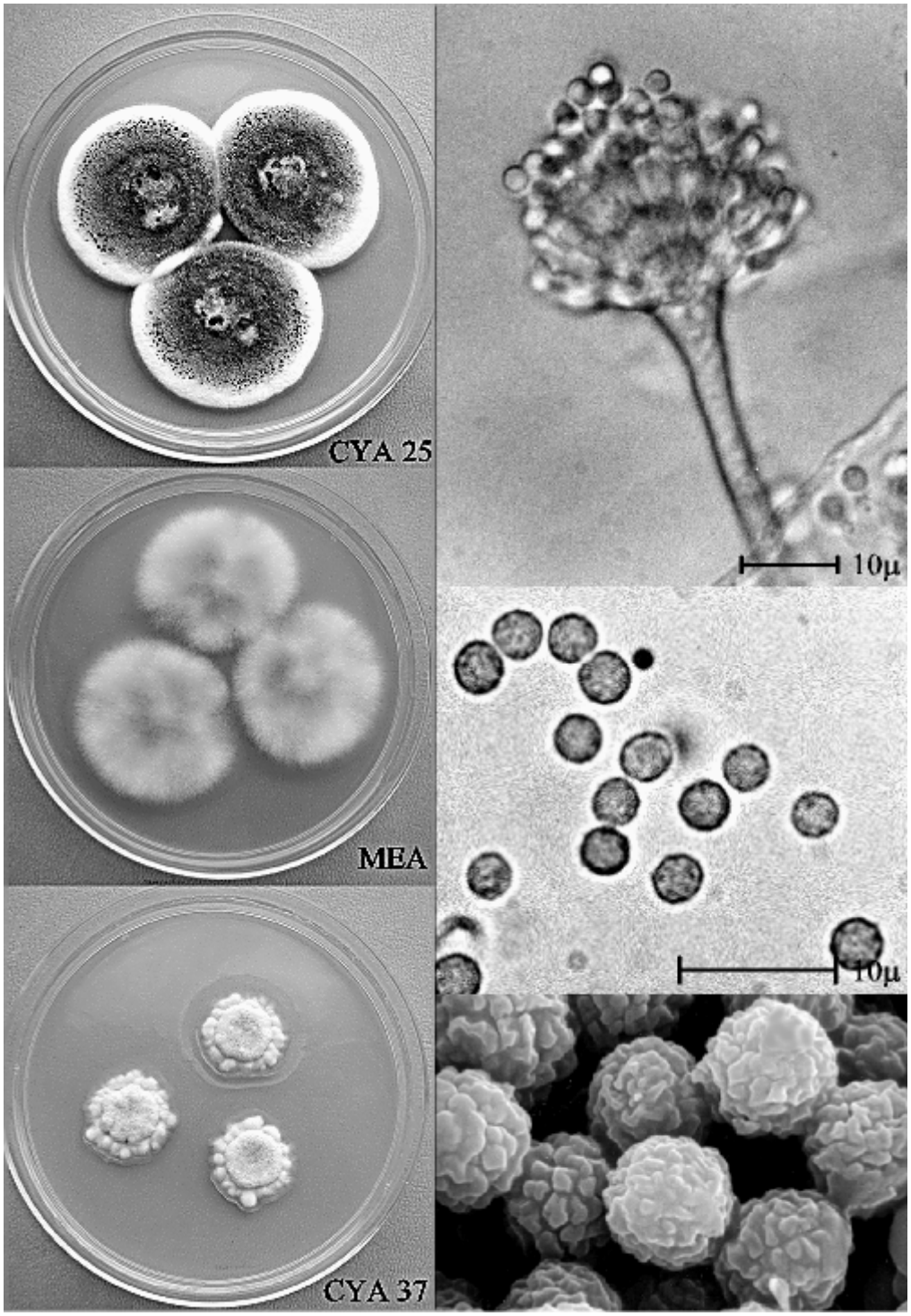

Fig. 48. *Aspergillus ustus:* left column (top to bottom), colonies on CYA25, MEA, and CYA37, 7 days; right column (top to bottom), conidial head, conidia and SEM of conidia (x 8000).

Aspergillus versicolor (Vuill.) Tiraboschi — Figs. 49, 4c and 5*l*.

Ann. Bot. (Roma) 7: 9. 1908. Neotype. CBS 583.65.

Subgenus: ***Nidulantes*** **Section:** ***Versicolores***

Colony Diameters at 7 days, in mm: **CYA25** 15-25 (26); **MEA** 12-26; **CY20S** 14-30; **CYA37** 0-10; **CZ** (10) 15-19 (22).

Colony Colors and Textures. Conidia on **CYA25** variable in abundance, dull green to grey green (27-28C-D3-4); mycelium white, dull pink, buff or orange; exudate, when present, uncolored to red brown; reverse uncolored to shades of brown or reddish purple; soluble pigment, when present, pink to brownish orange or brown; colony texture generally velutinous, often radially sulcate. On **MEA**, conidia greyish turquoise (24C4) to greyish green (25-28C-E3-5); mycelium white to buff, often inconspicuous; reverse uncolored, yellow brown, orange brown or greenish drab; texture velutinous to granular. Colonies on **CY20S** differing from those on CYA25 by a lack of exudate, and reverse and soluble pigment colors tending to be red-brown. Colonies (when present) small, lightly sporulating, dense and wrinkled on **CYA37**, colors as on CYA25. Colors and textures on **CZ** similar to those on CYA25.

Microscopic Characteristics. **Conidial heads** radiate; **stipes** (120) 200-400 (700) x 4-7 µm, uncolored to yellow or slightly brownish, smooth-walled, brittle, expanding into pyriform to spathulate **vesicles**, (8) 9-16 µm in diameter; **biseriate**; metulae (3) 4-8 x 2.5-3.5 (4) µm covering half to all of the vesicle; phialides (4) 5-9 (11) x 2-3 µm. Diminutive conidial heads sometimes present, resembling penicilli. **Conidia** 2.0-3.5 (4.5) µm in diameter, most globose to subglobose, with finely to distinctly roughened walls. According to Raper & Fennell (1965), globose Hülle cells are sometimes produced.

Distinguishing Features. Relatively small colony diameters with grey green to dull green conidia on CYA25, variably colored reverse and mycelia, and small biseriate conidial heads with small roughened globose conidia distinguish this species from all others. The green rather than turquoise conidial color on CYA25 distinguish *A. versicolor* from *A. sydowii*.

Taxonomic References. Raper & Fennell, 1965; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Klich, 1993; Pitt & Hocking, 1997; Samson *et al*., 2000.

Related Species. Section *Versicolores* contains over 20 species, many of which resemble *A. versicolor*. For example, *A. protuberus* differs from *A. versicolor* in that the former species produces roughened stipes and *A. janus* produces both white and grey green conidial heads (see Klich, 1993).

Habitats. *A. versicolor* is a very widely distributed fungus. It is extremely widespread in soils (Domsch *et al*., 1980; Klich, 2002). It occurs in many kinds of foods, especially spices, dried cereals and nuts, and is common in indoor environments (Pitt & Hocking, 1997; Samson *et al*., 2001).

Major Mycotoxins. Sterigmatocystin.

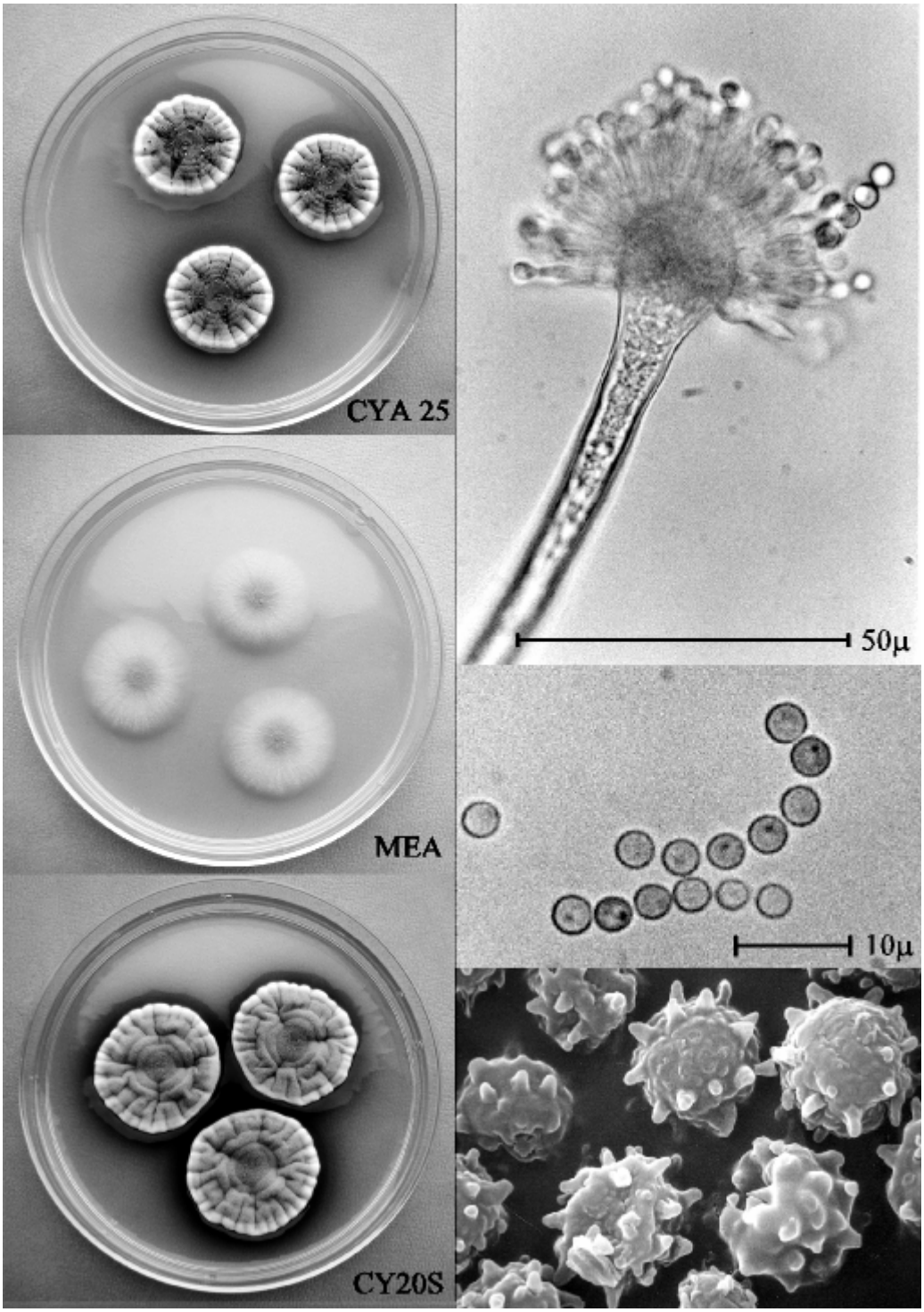

Fig. 49. *Aspergillus versicolor:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial head, conidia, and SEM of conidia (x 8000).

Aspergillus wentii Wehmer — Figs. 50, 3i and 5a.

Centralbl. Bakteriol. 2 Abth., 2: 15. 1896. Neotype IMI 17295.

Subgenus: *Circumdati* Section: *Wentii*

Colony Diameters at 7 days, in mm: **CYA25** 25-35; **MEA** (20) 25-35 (40); **CY20S** 5-70; **CYA37** no growth; **CZ** 24-27.

Colony Colors and Textures. Conidia variable in abundance on **CYA25**, greyish yellow (4B-C4-8) to olive brown (4D-E6-8); mycelium dense, white to pale yellow; dense white to pinkish hyphal masses sometimes formed; exudate, when present, uncolored to yellow-brown; reverse uncolored to yellow or pale brown; texture variable velutinous to floccose, plane or radially sulcate. On **MEA**, conidia abundant, olive yellow (3D8), orangish yellow (4-5B-C5-8) to olive brown (4D-E5-8); mycelium white; white to dull pink hyphal masses sometimes formed; reverse uncolored to dull yellow or pale brown; texture generally deep and floccose, occasionally velutinous. Conidia often sparse on **CY20S**, colored as on CYA25 or olive (3E8); mycelium dense, white to pale yellow; reverse uncolored to pale yellow or dull brown. On **CZ**, colors and textures similar to those on CYA25.

Microscopic Characteristics. **Conidial heads** radiate, often splitting into columns in age; **stipes** 200-1200 (3000) x 10-12 (16) µm, often sinuous, usually uncolored, smooth-walled or slightly warted beneath vesicles; **vesicles** elongate to globose, (7) 30-80 µm wide; **biseriate**; metulae densely packed, 10-18 (23) x (3) 5-8 (10) µm, covering most of the vesicular surface; phialides 7-10 (15) x 3-5 (6) µm. **Conidia** globose to broadly ellipsoidal, (3.5) 4-5 (6) µm, surface smooth to very rough.

Distinguishing Features. This species is distinguished by olive brown conidia on a dense white to yellowish mycelial mat and no growth at 37°.

Taxonomic References. Raper & Fennell, 1965; Domsch *et al*., 1980; Klich & Pitt, 1988; Kozakiewicz, 1989; Tzean *et al*., 1990; Pitt & Hocking, 1997; Samson *et al*., 2000.

Habitats. This is a common species with its main distribution in tropical and subtropical soils, reported in a relatively high number of studies from the 26-35 degree latitude range. It has also been isolated from plant litter and seeds and is used in Asian food fermentations (Domsch *et al*., 1980; Samson *et al*., 2000; Klich, 2002).

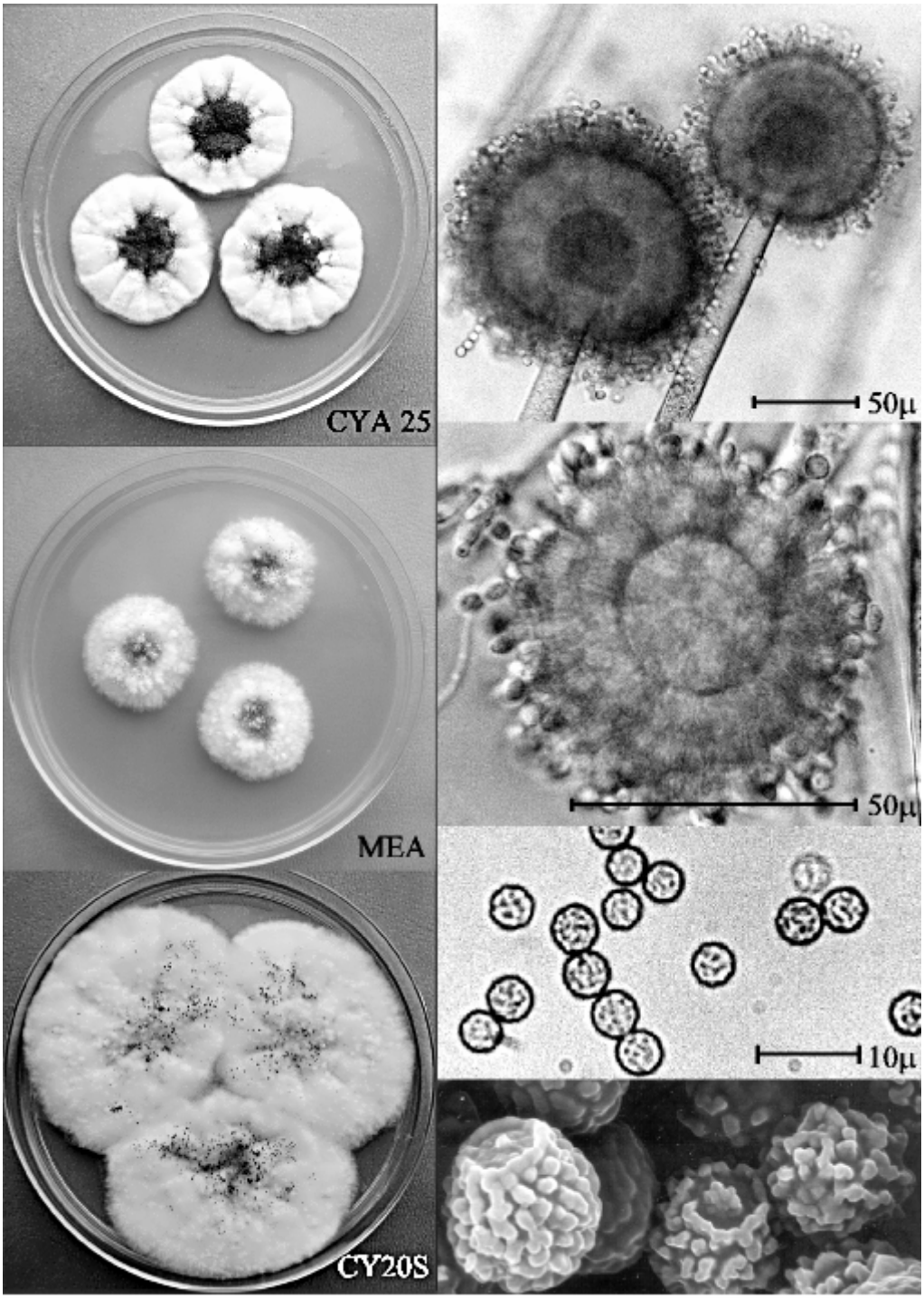

Fig. 50. *Aspergillus wentii:* left column (top to bottom), colonies on CYA25, MEA, and CY20S, 7 days; right column (top to bottom), conidial heads, conidial head, conidia, and SEM of conidia (x 8000).

Literature Cited

Al-Musallam, A. 1980. Revision of the black *Aspergillus* species. Ph.D. Thesis. Utrecht, Netherlands: University of Utrecht.

Behera, N. & Mukerji K. G. 1984. Seasonal fluctuation of aspergilli in Delhi soils. *Indian J. Mycol. Pl. Pathol.* 14: 283-285.

Bennett, J. W. & Klich, M. A. (eds). 1992. Aspergillus: *Biology and Industrial Applications.* Boston: Butterworth-Heinemann.

Berka, R. M., Dunn-Coleman, N. & Ward, M. 1992. Industrial enzymes from *Aspergillus* species. In: Aspergillus: *Biology and Industrial Applications* (Eds. J. W. Bennett & M. A. Klich), pp 155-202. Boston: Butterworth-Heinemann.

Blakeslee, A. F. 1915. Lindner's roll tube method of separating cultures. *Phytopathology* 5: 68-69.

Bossche, H. V., Mackenzie, D. W. R. & Cauwenbergh, G. (eds). 1988. Aspergillus *and Aspergillosis*. New York: Plenum Press.

Burge, H. A. 2001. Fungi: Toxic killers or unavoidable nuisances? Ann. Allergy, Asthma and Immunology 87: 52-56

Christensen, M. 1981. A synoptic key and evaluation of species in the *Aspergillus flavus group. Mycologia* 73: 1056-1084.

Christensen, M. 1982. *The Aspergillus ochraceus* group: two new species from western soils and a synoptic key. *Mycologia* 74: 210-225.

Christensen, M. & Fennell, D. I. 1964. The rediscovery of *Aspergillus cervinus. Mycologia* 56: 350-353.

Christensen, M. & States, J. S. 1982. *Aspergillus nidulans* group: *Aspergillus navahoensis* and a revised synoptic key. *Mycologia* 74: 226-235.

Christensen, M., Fennell, D. I. & Backus, M. P. 1964. *Aspergillus kanagawaensis* and related species in Wisconsin forest soils. *Mycologia* 56: 354-362.

Deo, P. P. & Gupta, J. S. 1980. A note on the mycoflora associated with seeds of gram *(Cicer arietinum)* during storage. *Seed Res.* 8: 83-84.

Diener, U. L., Cole, R. J., Sanders, T. H. Payne, G. A., Lee, L. S. & Klich, M. A. 1987. Epidemiology of aflatoxin formation by *Aspergillus flavus. Ann. Rev. Phytopathol.* 25: 249-270.

Dixon, D. M. & Walsh, T. J. 1992. Human pathogenesis. In: Aspergillus: *Biology and Industrial Applications* (Eds. J. W. Bennett & M. A. Klich), pp 249-267. Boston: Butterworth-Heinemann.

Domsch, K. H., Gams, W. & Anderson, T. H. 1980. *Compendium of Soil Fungi*. London: Academic Press.

Dox, A. W. 1910. The intracellular enzymes of *Penicillium* and *Aspergillus* with special reference to those of *P. camemberti*. U. S. Dept. Agr. Bur. Animal Ind. Bull. No. 120.

El-Dohlob, S. M. & Ali, B. Z. 1981. Fungal populations inhabiting polluted water of the River Shatt Al-Arab and its creeks at Basrah. Iraq. *J. Univ. Kuwait (Sci.)* 8: 235-242.

Ellis, D. H. 1980. Thermophilous fungi isolated from some antarctic and subantarctic soils. *Mycologia* 72:1033-1036.

Etzel, R. A. 2002. Mycotoxins. J.A.M.A. 287: 425-427.

Fennell, D. I. & Raper, K. B. 1955. New species and varieties of *Aspergillus*. *Mycologia* 47: 68-89.

Flannigan, B. 1986. *Aspergillus clavatus* - an allergenic, toxigenic deteriogen of cereals and cereal products. *Int. Biodeter.* 22: 79-89.

Frisvad, J. C. & Samson, R. A. 1991. Mycotoxins produced by species of *Penicillium* and *Aspergillus* occurring in cereals. In: *Cereal Grain Mycotoxins, Fungi and Quality in Drying and Storage*. (Ed. J. Chelkowski), pp 441-476. Amsterdam: Elsevier Science Publishers.

Gams, W., Christensen, M., Onions, A. H., Pitt, J. I. & Samson, R. A 1985. I Infrageneric taxa of *Aspergillus*. In: *Advances in* Penicillium *and* Aspergillus *Systematics* (Eds. R. A. Samson & J. I. Pitt), pp 55-62. New York: Plenum Press.

Golinski, P. 1991. Secondary metabolites (mycotoxins) produced by fungi colonizing cereal grain in storage – structure and properties. In: *Cereal Grain, Mycotoxins, Fungi and Quality in Drying and Storage* (Ed. J. Chelkowski), pp 355-403. Amsterdam: Elsevier Science Publishers.

Greuter, W. et al (eds). 1994. International Code of Botanical Nomenclature (Tokyo Code) *Reg Veget.* 131. Konigstein. Reg.

Hara, S., Kitamoto, K. & Gomi, K. 1992. New developments in fermented beverages and foods with *Aspergillus*. In: Aspergillus: *Biology and Industrial Applications* (Eds. J. W. Bennett & M. A. Klich), pp 133-153. Boston: Butterworth-Heinemann.

Hocking, A. D. 1981. Improved media for enumeration of fungi from foods. *CSIRO Food Res. Q.* 41:7-11.

Horn, B. W. 1997. *Aspergillus caelatus* a new species in section *Flavi*. *Mycotaxon* 61:185-191.

Huang, A.F., Edwards, F., Bernard, E. M., Armstrong, D. & Schmitt, J. H. 1990. *In vitro* activity of the new semisynthetic polypeptide Cilofungin (LY121019) against *Aspergillus* and *Candida* species. *Eur. J. Clin. Microbiol. Infect. Dis*. 9: 697-699.

Ito, Y., Peterson, S. W., Wicklow, D. T. & Goto, T. 2001. *Aspergillus pseudotamarii*, a new aflatoxin producing species in *Aspergillus* section *Flavi*. *Mycol. Res*. 105: 233- 239.

Jaitly, A. K. & Rai, J. N. 1982. Thermophilic and thermotolerant fungi isolated from mangrove swamps. *Mycologia* 74:1021-1022.

Jong S-C. & Burmingham, J. M. 1992. Patent protection for *Aspergillus*-related inventions. In: Aspergillus: *Biology and Industrial Applications* (Eds. J. W. Bennett & M. A. Klich), pp 297-311. Boston: Butterworth-Heinemann.

Kamal, M. L. G., & Kumar, P. 1979. *Aspergillus* species from soils of Gorakhpur. VIII. Distribution in four soil types as against plant cover. *Indian J. Mycol. Pl. Pathol*. 9: 66-74.

Klich, M. A. 1993. Morphological studies of *Aspergillus* section *Versicolores* and related species. *Mycologia* 85: 100-107.

Klich, M. A. 1998. Soil fungi from some low-altitude desert cotton fields and ability of their extracts to inhibit *Aspergillus flavus*. *Mycopathologia* 142: 97-100.

Klich, M. A. 2002. Biogeography of *Aspergillus* species in soil and litter. *Mycologia* 94: (in press)

Klich, M. A., Mendoza C., E. J. Mullaney, N. P. Keller & J. W. Bennett. 2001. A new sterigmatocystin-producing *Emericella* variant from agricultural desert soils. *System. Appl. Microbiol*. 24: 131-138.

Klich, M. A. & Mullaney, E. J. 1987. DNA restriction enzyme fragment polymorphism as a tool for rapid differentiation of *Aspergillus flavus* from *Aspergillus oryzae*. *Exp. Mycol*. 11:170-175.

Klich, M. A. & Mullaney, E. J. 1989. Use of a bleomycin-containing medium to distinguish *Aspergillus parasiticus* from *A. sojae*. *Mycologia* 81: 159-160.

Klich, M. A. & Pitt, J. 1. 1985. The theory and practice of distinguishing species of the *Aspergillus flavus* group. In: *Advances in* Penicillium *and* Aspergillus *Systematics* (Eds. R. A. Samson & J. I. Pitt), pp. 211-220. New York: Plenum Press.

Klich, M. A. & Pitt, J. I. 1988. *A Laboratory Guide to* Aspergillus *species and their Teleomorphs.* CSIRO, Division of Food Processing, North Ryde, NSW, Australia

Kornerup, A. & Wanscher, J. H. 1978. *Methuen Handbook of Colour*, 3rd edn. London: Eyre Methuen.

Kozakiewicz, Z. 1989. *Aspergillus* species on stored products. *Mycological Papers* 161.

Kurtzman, C. P., Smiley, M. J., Robnett, C. J. & Wicklow, D. T. 1986. DNA relatedness among wild and domesticated species in the *Aspergillus flavus* group. *Mycologia* 78:955-959.

Lam, T.Y. 1983. US Patent 4,376,863.

Latge, J-P. 1999. *Aspergillus fumigatus* and Aspergillosis. *Clinical Microbiology Reviews* 12: 310-350.

Malloch, D. & Cain, R. F. 1972. The Trichocomataceae: Ascomycetes with *Aspergillus, Paecilomyces,* and *Penicillium* imperfect states. *Can. J. Bot*. 50: 2613-2628.

Micheli, P. A. 1729. *Nova plantarum genera juxta Tournefortii methodum disposita*. Florence.

Murakami, H. 1971. Classification of the koji mold. *J. Gen. Appl. Microbiol*. 17: 281-309.

Okuda, T., Klich, M. A., Seifert, K. A. & Ando, K. 2000. Media and incubation effects on morphological characteristics of *Penicillium* and *Aspergillus.* In: *Integration of Modern Taxonomic Methods for* Penicillium *and* Aspergillus *Classification* (Eds. R.A. Samson & J. I. Pitt), pp 83-99. Reading, U. K.: Harwood Academic Publishers.

Parenicova, L. 2000. Pectinases of *Aspergillus niger*: A molecular and biochemical characterisation. PhD Thesis. Wageningen, The Netherlands, Wageningen University.

Peterson S. W. 1995. Phylogenetic analysis of *Aspergillus* sections *Cremei* and *Wentii*, based on ribosomal DNA sequences. *Mycological Research* 99: 1349-1355.

Peterson, S. W. 2000. Phylogenetic relationships in *Aspergillus* based on rDNA sequence analysis. In: *Integration of Modern Taxonomic Methods for* Penicillium *and* Aspergillus *Classification* (Eds. R. A. Samson & J. I. Pitt), pp 323-355. Reading, U. K.: Harwood Academic Publishers.

Peterson, S. W., Ito, Y., Horn, B. W. & Goto, T. 2001. *Aspergillus bombycis* a new aflatoxigenic species and genetic variation in its sibling species *A. nomius*. *Mycologia* 93: 689-703.

Pier, A. C. & Richard, J. L. 1992. Mycoses and mycotoxicoses of animals caused by aspergilli. In: Aspergillus*: Biology and Industrial Applications* (Eds. J. W. Bennett & M A. Klich), pp 233-248. Boston: Butterworth-Heinemann.

Pitt, J. I. 1973. An appraisal of identification methods for *Penicillium* species: novel taxonomic criteria based on temperature and water relations. *Mycologia* 65: 1135-1157.

Pitt, J. I. 1985. Nomenclatorial and taxonomic problems in the genus *Eurotium*. In: *Advances in* Penicillium *and* Aspergillus *Systematics* (Eds. R. A. Samson & J.I. Pitt), pp 383-396. New York: Plenum Press.

Pitt, J. I. & Hocking, A. D. 1997. *Fungi and Food Spoilage 2nd ed.* London, U.K.: Blackie Academic & Professional.

Pitt, J. I., Samson, R. A. & Frisvad, J. C. 2000. List of accepted species and their synonyms in the family Trichocomaceae. In: *Integration of Modern Taxonomic Methods for* Penicillium *and* Aspergillus *Classification* (Eds. R. A. Samson & J. I. Pitt), pp 9-49. Reading, U. K.: Harwood Academic Publishers.

Pohl, R. W. 1954. A rapid softening agent for dried plant structures. *Proc. Iowa Acad. & Sci*. 61:149-150.

Powell, K. A., Renwick, A. & Peberdy, J. F. (eds). 1994. *The Genus* Aspergillus*: from Taxonomy and Genetics to Industrial Applications*. New York: Plenum Press

Rabie, C. J. & Lübben, A. 1984. The mycoflora of sorghum. *S. Afr. J. Bot*. 3: 251-255.

Rai, J. N., Tewari, J. P. & Mukerji, K. G. 1964. Cultural and taxonomic studies on two rare species of *Aspergillus – A. paradoxus* and *A. aeneus*, and an interesting strain of *A. variecolor* from Indian soils. *Mycopath. Mycol. Appl.* 24: 369-376.

Raper, K. B. & Fennell, D. I. 1965. *The Genus* Aspergillus*.* Baltimore, U.S.A.: Williams & Wilkins.

Richard, J. L & Thurston, J. R. (eds). 1986. *Diagnosis of Mycotoxicoses*. Dordrecht, The Netherlands: Martinus Nijhoff Publishers.

Roehr, M., Kubicek, C. P. & Kominek, J. 1992. Industrial acids and other small molecules. In: Aspergillus: *Biology and Industrial Applications* (Eds. J. W. Bennett & M. A. Klich), pp 91-131. Boston: Butterworth-Heinemann.

Samson, R. A. 1979. A compilation of the Aspergilli described since 1965. *Studies in Mycology*, Baarn: 18: 1-38.

Samson, R. A. 1994. Taxonomy-Current concepts of *Aspergillus* systematics. In: Aspergillus. *Biotechnology Handbooks Vol. 7* (Ed. J. E. Smith), pp 1-22. New York.: Plenum Press,

Samson, R. A. & Frisvad, J. C. 1991. Current taxonomic concepts in *Penicillium* and *Aspergillus*. In: *Cereal Grain Mycotoxins, Fungi and Quality in Drying and Storage* (Ed, J. Chelkowski), pp 405-439. Amsterdam: Elsevier Science Publishers.

Samson, R. A. & Gams, W. 1985. Typification of the species of *Aspergillus* and related teleomorphs. In: *Advances in* Penicillium *and* Aspergillus *Systematics* (Eds. R. A. Samson & J. I. Pitt), pp. 31-54. New York: Plenum Press.

Samson, R. A., Hoekstra, E. S., Frisvad, J. C. & Filtenborg, O. 2000. *Introduction to Food- and Air-borne Fungi 6th ed*. Baarn, The Netherlands: Centraalbureau voor Schimmelcultures.

Samson, R. A., Houbraken, J., Summerbell, R. C., Flannigan, B. & Miller, J. D. 2001. Common and important species of fungi and actinomycetes in indoor environments. In: *Microorganisms in Home and Indoor Work Environments* (Eds. B. Flannigan, R.A. Samson & J. D. Miller), pp 287-292. New York: Taylor and Francis.

Sandhu, D. K., Singh, S. & Waraich, M. K. 1980. Thermophilous fungi of decomposing sugarcane bagasse. *Can. J. Bot*. 58: 2015-2016.

Sarbhoy, A. K. & Elphick, J. J. 1968. *Hemicarpenteles paradoxus* gen. & sp. nov.: the perfect state of *Aspergillus paradoxus*. *Trans. Brit. Mycol. Soc*. 51:155-157.

Smith, G. 1949. The effect of adding trace elements to Czapek-Dox medium. *Trans. Brit. Mycol. Soc*. 32: 280-283.

Smith, J. E. (ed). 1994. Aspergillus. *Biotechnology Handbooks Vol. 7*. New York: Plenum Press.

Smith, J. E. & Henderson, R.S. (eds). 1991. *Mycotoxins and Animal Foods*. Boca Raton, Florida: CRC Press, Inc.

Subramanian, C. V. 1972. The perfect states of *Aspergillus. Curr. Sci*. 41: 755-761.

Tan, T. K. & Lim, G. 1983. Effects of water pollution on fungi of submerged organic debris. *Mycopathologia* 82: 121-124.

Thom, C. & Church, M. B. 1926. *The Aspergilli*. Baltimore, U.S.A.: Williams & Wilkins.

Thom, C. & Raper, K. B. 1945. *A Manual of the Aspergilli*. Baltimore, U.S.A.: Williams & Wilkins.

Tzean, S. S., Chen, J. L., Liou, G. Y., Chen, C. C. & Hsu, W. H. 1990. Aspergillus *and Related Teleomorphs from Taiwan.* Hsinchu, Taiwan R.O.C.: Food Industry Research and Development Institute.

Vaidehi, B. K. & P. Lalitha. 1985. Fungal succession in *Sesamum* seeds. *Indian J. Bot*. 8: 39-48.

Wiley, B. J. & Fennell, D. I. 1973. Ascocarps of *Aspergillus stromatoides*, *A. niveus*, and *A. flavipes*. *Mycologia* 65: 752-760.

Wiley, B. J. & Simmons, E. G. 1973. New species and a new genus of Plectomycetes with *Aspergillus* states. *Mycologia* 65: 934-938.

Yip, H. Y. & Weste, G. 1985. Rhizoplane mycoflora of two understorey species in the dry sclerophyll forest of the Brisbane Ranges. *Sydowia Ann. Mycol*. 38: 383- 399.

Young, L. S. 1990. Aspergillosis. In: *Tropical and Geographic Medicine, 2nd ed*. (Eds. K. S. Warren & A. A. F. Mahmoud), pp 933-940. New York: McGraw Hill.

Appendix 1. Some Major Characteristics of Aspergillus Species

	Normal Colony Diameter (mm)[1]					Stipe		Vesicle		Seriation[5]	Conidia		
	CYA 25	MEA	CY20S	CYA 37	CZ	length[2]	surface texture[3]	diam[2]	shape[4]		shape[4]	length[2]	surface texture[3]
Subgenus *Aspergillus*													
Section Aspergillus													
Eu. amstelodami	14-20	18-22	34-59	2-13	7-19	110-350	sm	17-30	gl/sp	u	gl/el	4-5	fr
Eu. chevalieri	18-23	16-25	45-68	0-10	16-20	300-500	sm	25-35	py/gl/cl	u	gl/py	4-5	fr/rf
Eu. herbariorum	3-20	0-17	30-45	0	0-13	300-700	sm/rf	18-36	gl/py	u	gl/el	5-8	sm/rf
Section *Restricti*													
A. penicillioides	2-8	2-5	4-12	0	3-4	150-500	sm	9-25	sp/gl	u	gl/el	3-5.5	fr/rf
A. restrictus	8-12	6-12	16-25	0	5-7	80-200	sm/fr	8-21	py	u	el/py	4-7	rf
Subgenus *Fumigati*													
Section *Fumigati*													
Neo. fischeri	60-70	65-70	60-70	60-70	53-60	150-350	sm	10-20	py	u	gl/el	2.5-3	sm/fr
A. fumigatus	40-70	45-70	40-70	60-70	45-60	200-400	sm	15-30	py/sp	u	gl/el	2-3	sm/fr
Section *Cervini*													
A. cervinus	12-20	57-61	10-19	0-12	11-22	100-300	sm	10-20	gl	u	gl	3-3.5	sm
A. kanagawaensis	7-13	45-58	5-11	0-10	4-14	150-700	sm	11-22	gl	u	gl	2.5-3.5	sm
Subgenus *Ornati*													
Section *Ornati*													
Scl. ornata	8-27	40-70	9-35	0	8-9	200-500	sm	12-30	sp/cl/py	u	el/py	8-11	rf
A. paradoxus	25-55	35-55	25-55	0	15-30	500-1000	fr	15-35	cl/sp	u	el/gl	5-7	sm/fr
Subgenus *Clavati*													
Section *Clavati*													
A. clavatus	37-48	35-45	35-54	8-30	25-35	500-2000	sm	10-75	cl/py	u	el/py	3-6	sm
Subgenus *Nidulantes*													
Section *Nidulantes*													
Em. nidulans	40-60	53-60	40-60	50-70	38-43	70-150	sm	8-12	sp/py	b	gl	3-4	sm
Em. quadrilineata	40-65	35-65	45-65	60-70	40-52	40-120	sm	8-12	py	b	gl	2.5-4	sm/fr
Em rugulosa	10-17	12-20	12-20	53-60	14-20	60-100	sm	8-12	py/sp	b	gl	3-4	fr
A. unguis	16-28	30-42	24-42	8-20	18-21	100-250	sm	5-14	sp/py	b	gl	3-3.5	sm
Section *Versicolores*													
A. caespitosus	35-50	47-60	40-58	10-35	30-40	100-300	sm	9-15	py/sp	b	gl	3.5-4.5	rf
A. sydowii	20-30	22-30	24-35	2-10	20-27	200-350	sm	7-17	py/sp/cl	b	gl	3-4	rf
A. versicolor	15-25	12-26	14-30	0-10	15-19	200-400	sm	9-16	py/sp	b	gl	2.0-3.5	fr/rf
Section *Usti*													
A. puniceus	30-45	24-45	22-47	0-8	25-35	30-250	sm	7-18	gl/py/sp	b	gl	3-4	fr/rf
A. ustus	25-40	30-50	30-45	0-45	25-40	75-200	sm	7-16	py	b	gl	3-4.5	rf

Section *Terrei*													
A. terreus	40-60	40-70	65-70	65-70	30-48	100-250	sm	12-20	gl/py	b	gl/el	2-2.5	sm
Section *Flavipedes*													
A. carneus	16-30	20-42	30-45	0-53	17-23	80-500	sm	9-15	cl/gl/py	b	gl/el	2.5-3	sm
A. flavipes	24-33	28-31	23-39	8-20	20-17	200-800	sm/rf	10-18	sp/gl	b	gl	2-3	sm
A. niveus	20-38	23-38	30-53	0-45	16-30	100-500	sm	8-15	sp/py	b	gl	2.5-3.5	sm/fr
Subgenus *Circumdati*													
Section *Circumdati*													
A. auricomus	30-50	40-60	45-60	0-25	18-27	300-1000	rf	12-35	gl/sp	b	gl/el	2.5-3	sm/fr
A. melleus	30-50	33-60	58-70	25-35	15-35	350-700	rf	20-35	gl/sp or py	b	gl/el	3-3.5	sm/fr
A. ochraceus	39-59	44-55	44-70	0-35	22-42	300-1700	rf	25-55	gl/el	b	gl/el	2.5-3.5	sm/fr
A. ostianus	38-50	40-50	50-60	0-15	20-30	400-800	rf	20-40	gl/el	b	gl/el/py	4-5	sm/fr
A. sclerotiorum	45-60	45-56	60-70	20-30	32-37	400-1200	rf	17-35	py/gl/el	b	gl	2.5-3	sm/fr
Section *Flavi*													
A. alliaceus	68-70	65-70	65-70	40-55	65-70	40-2000	sm	20-50	gl/py	u/b	gl	3-3.5	sm
A. flavus	65-70	65-70	65-70	55-65	55-65	400-800	rf/fr	20-45	gl/el	u/b	gl/el	3-6	sm/fr
A. oryzae	55-70	60-70	60-70	50-65	39-65	500-2500	fr/rf	22-50	py/cl/gl	u/b	gl/el	4-8.5	sm/fr
A. parasiticus	60-70	60-70	60-70	50-70	45-65	250-500	fr/rf	20-35	gl/el	u/b	gl	3.5-6	rf
A. sojae	60-70	60-70	60-70	45-70	50-60	300-900	sm/rf	17-35	py/gl/cl	u/b	gl	5.5-7	rf
A. tamarii	55-70	65-70	60-70	40-70	54-70	600-1500	rf	20-45	gl/py	u/b	gl	5.5-8	rf
Section *Wentii*													
A. wentii	25-35	25-35	50-70	0	24-27	200-1200	sm/rf	30-80	el/gl	b	gl/el	4-5	sm/rf
Section *Nigri*													
A. awamori	60-70	60-70	60-70	65-70	30-60	300-1500	sm	20-40	gl	b	gl	4-5	sm/rf
A. carbonarius	65-70	55-70	68-70	10-30	35-45	1000-3500	sm/fr	65-90	gl	b	gl	7-10	rf
A. foetidus	45-60	55-65	55-70	48-65	30-40	400-800	sm	30-50	gl/el	b	gl	4-5	sm
A. japonicus	60-70	60-70	-70	20-50	30-70	300-600	sm	14-30	gl/el	u	gl/el	4-5	sm
A. niger	55-70	50-70	68-70	50-70	40-62	400-3000	sm	30-75	gl	b	gl	3.5-4.5	rf/fr
Section *Candidi*													
A. candidus	15-28	14-23	19-33	0-25	14-27	200-500	sm/fr	17-35	gl/el	u/b	gl	3-4	sm
Section *Cremei*													
A. cremea	10-25	18-25	35-55	0	17-18	4000-8000	sm	60-75	gl	b	gl/el	5-8	rf
Section *Sparsi*													
A. sparsus	20-30	15-25	20-30	0-28	20-30	250-500	rf	20-40	gl/el	b	gl/el	3-4	sm/fr

[1] Note: Ranges given are those usually found, outliers have been excluded. See text for complete descriptions.
[2] Microscopic characteristics in μm
[3] surface texture - sm, smooth; fr, finely roughened; rf, rough.
[4] shape - gl, globose; el, ellipsoidal; py, pyriform; sp, spathulate; cl, clavate.
[5] seriation - u, uniseriate; b, biseriate; u/b, both/either.

Appendix 2. Data Sheet

See Introduction for instructions on how to use this page

Macroscopic Characteristics

	CYA25	MEA	CYA37	CY20S	CZ
Diameter Colors					
Conidia					
Mycelium					
Exudate					
Reverse					
Soluble pigment					
Cleistotheia./Sclerotia					

Microscopic Characteristics

Stipe: Length ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Width ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Surface Texture ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Vesicle: Diameter ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Shape _____

Seriation: Uniseriate/Biseriate

Conidia: Length ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Shape _____
Surface Texture _____

Cleistothecia/Sclerotia: Diameter ___ ___ ___ ___ ___ ___ ___
Shape _____
Color _____
Surface cells - hyphae/parenchyma

Ascospores: Days to Maturation _____
Length ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Width ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
SurfaceTexture _____
Furrows/Flanges _____

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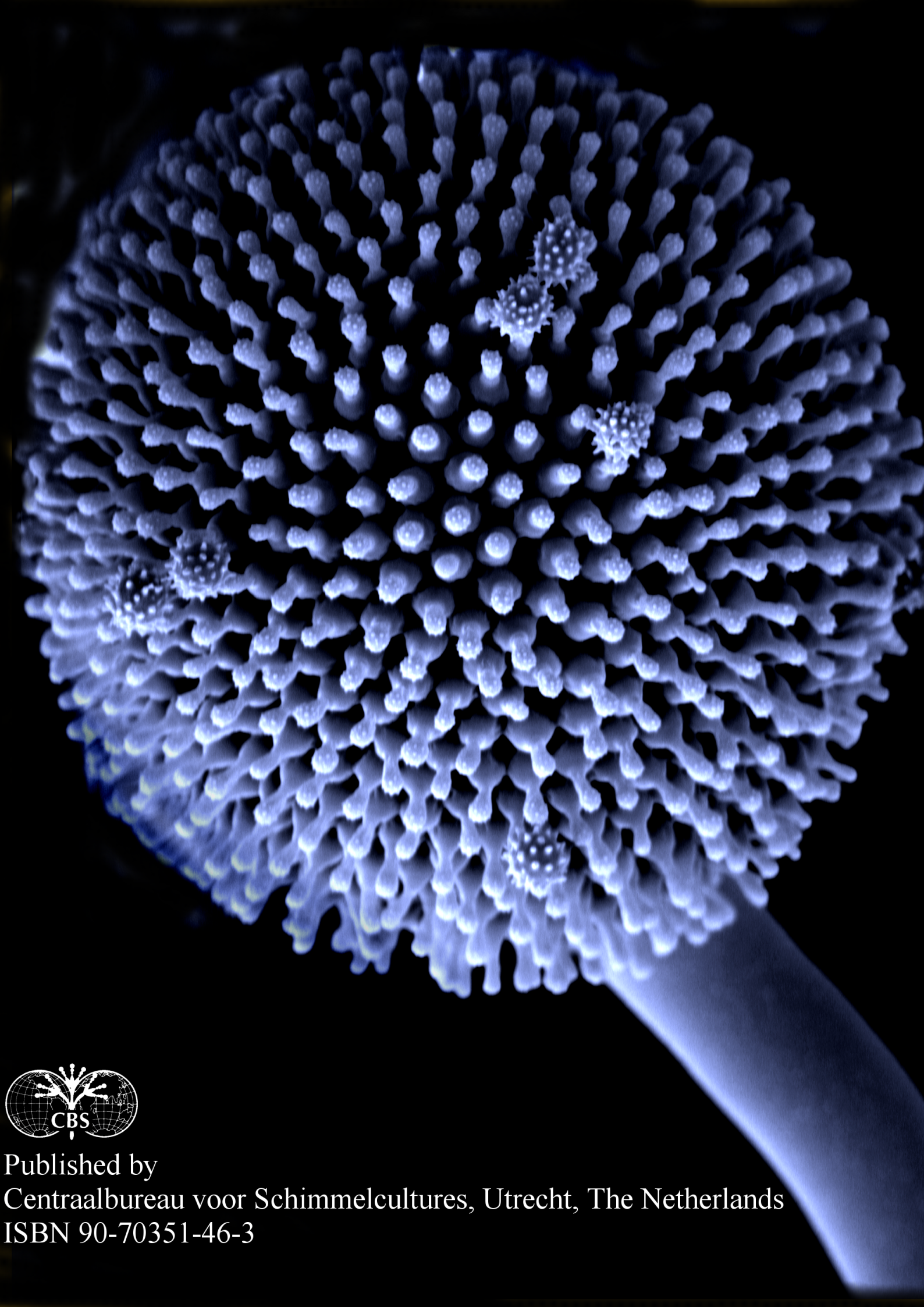

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