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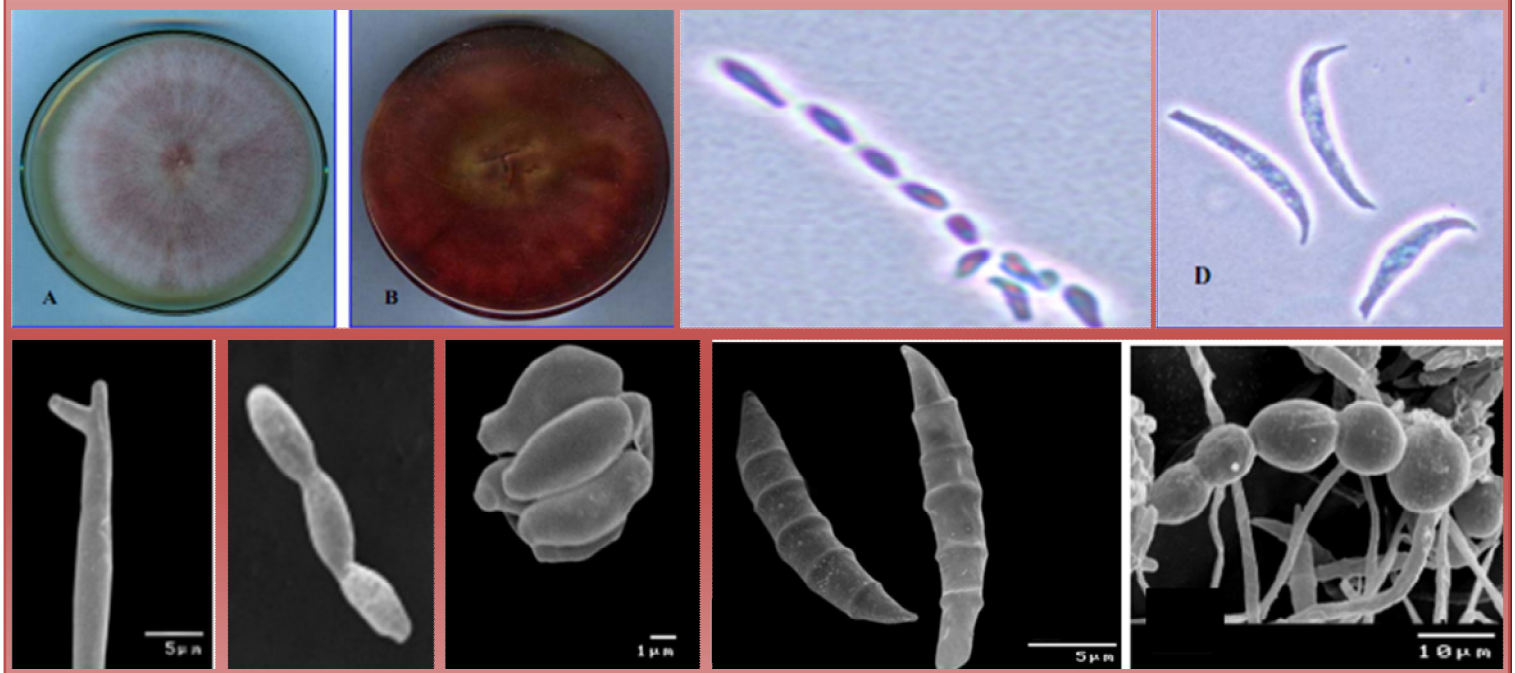
WITH DICHOTOMOUS KEYS FOR IDENTIFICATION OF SPECIES



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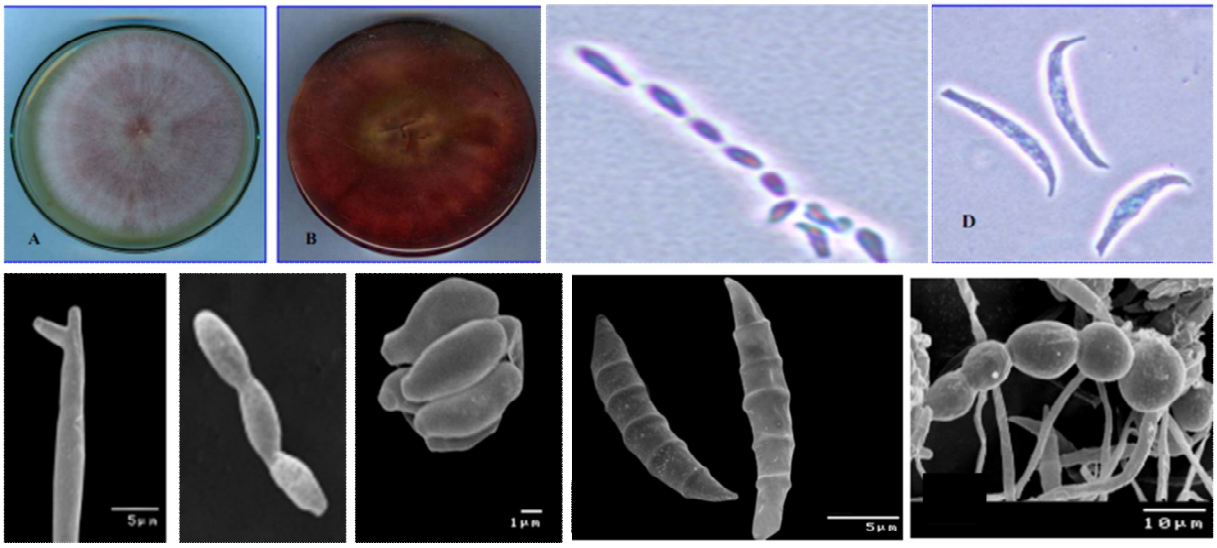

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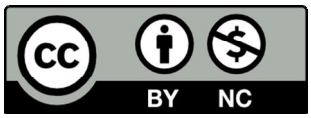

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Introduction

Fusarium is a genus of Hyphomycetes, formerly classified in the Deuteromycetes, and now widely considered an anamorphic affiliated within the Hypocreales (Ascomycetes). Its type species is *Fusarium sambucinum* Fukel 1870 (= *Fusarium roseum* Link, nomen *ambiguum*). Telemorphs of this genus includes species within three genera; *Gibberella* Sacchardo 1877, *Haematonectria* Samuels & Nirenberg 1999 and *Albonectria* Rossman & Samuels 1999. However, some species of *Fusarium* form only anamorph states.

The genus *Fusarium* was introduced by Link in 1809 for species with fusiform, non-septate spores borne on a stroma and was based on *Fusarium roseum*. With the recognition of new species and with the development of pure culture methods, the presence of a stroma or sporodochium was no longer considered as a basic character of the genus. The most diagnostic character of the genus is the presence of slimy, hyaline, canoe-shaped 1-several-septate macroconidia with a well-marked basal cell bearing some kind of heel at the attachment end of the conidium. This foot-shaped cell separates *Fusarium* from its closely related genus, *Cylindrocarpon*, whose macroconidia have a round basal cell. In addition to this, some species also produce distinctly different conidia in the aerial mycelium (often referred to as microconidia). Acccording to the species and/or the ecological situation, either macroconidia or microconidia may dominate on the natural substrate. Chlamydospores are also produced by some species.

Fusarium taxonomy has been plagued by changing species concepts, with as few as nine or well over a thousand species being recognized by various taxonomists during the past 100 years depending on the species concept employed. The literature stabilized significantly in the early 1980s with the publications of Gerlach & Nirenberg (1982) and Nelson *et al*. (1983), who defined morphological species concepts that were widely accepted and successfully used by numerous practitioners. Gerlach & Nirenberg (1982) accepted 90 species based on the Berlin school (Wollenweber & Reinking 1935), while Nelson *et al*. (1983) accepted 43 species based on the American school (Snyder & Hansen 1940, 1941, 1945). These publications are best thought of as definitive signposts rather than as the end of the journey. Since the 1980s the number of recognized species has increased gradually, with the number of recognized species now > 80, of which 70 were described and illustrated by Leslie & Summerell (2006). The application of biological (Leslie 2001) and phylogenetic (Nirenberg

& O'Donnell 1998) species concepts to the new and existing strain collections has indicated that many of the previously described species were in need of further splitting if the species designations are to be biologically meaningful. In many cases, formal descriptions of such species have been made (Klittich *et al*. 1997, Geiser *et al*. 2001, Marasas *et al*. 2001) or old names have been resurrected and associated with groups of strains now split from previous species (Samuels *et al*. 2001).

The relatively large amount of work done on the morphological taxonomy of these fungi means that, as a genus *Fusarium* often has served as testing ground for new speciation concepts in fungi. The genus *Fusarium* consists of populations that are quite variable. For this reason, identification of its different species requires special culture media and methods, as well as standard incubation conditions. High variability in species, especially under different environmental conditions, has caused taxonomists to consider some special criteria to be important in the classification of species. For this reason, different methods and/or keys have been presented for the identification of the species (Booth 1975, Gerlach & Nirenberg 1982, Nelson *et al*. 1983, Leslie & Summerell 2006). A culture of *Fusarium* must be subcultured and purified before the identification process proceeds further. A common mistake is to try to identify the culture directly from the isolation medium. There are many isolation media for recovering *Fusarium* species such as Czapek Dox agar medium (CZDA) (Raper & Thom 1949), Peptone-PCNB medium (PPA) (Nash & Snyder 1962), Dichloran chloramphenicol peptone agar medium (DCPA) (Andrews & Pitt 1986) and Czapek iprodione dichloran agar medium (CZID) (Abildgren *et al*. 1987). Accurate identification of a culture requires growing it on at least two media: carnation leaf-piece agar (CLA) and potato dextrose agar (PDA) or potato sucrose agar (PSA). Carnation leaf-piece agar is a natural medium that is useful for many species of *Fusarium* which readily form sporodochia and uniform macroconidia that are particularly useful for identification purposes. PDA cultures are used primarily to assess pigmentation and gross colony morphology (Summerell *et al*. 2003). Also, other media used are Spezieller Nahrstoffarmer agar (SNA) (Nirenberg 1976) for producing abundant microconidia and chlamydospores (Gerlach & Nirenberg 1982), and KCL medium for the formation of microconidia in chains in section Liseola (Fisher *et al*. 1983).

The morphological criteria useful for identification of *Fusarium* species include two categories: primary characters which include macroconidia, microconidia, conidiogenous cells, chlamydospores and secondary characters such as rate of growth and pigmentation. Relevant microscopic features for *Fusarium* identification include colony characteristics on either Potato Dextrose agar (PDA) or Potato sucrose agar (PSA) (including growth rates,

aerial mycelium and colony reverse), macroconidia from sporodochia (including shape, dimensions, septation, basal cell and apical cell), microconidia from aerial mycelium (including abundance, shape, in chains or as false heads), conidiogenous cells (mono- or polyphialidic conidiogenous cells and short or long) and chlamydospores (shape, thin or thickwalled, colour and arrangement) (Booth 1971, Gerlach & Nirenberg 1982, Nelson *et al*. 1983, Seifert 1996, Summerell *et al*. 2003, Leslie & Summerell 2006). Until the 1990s, the species concept was based on morphological characters. Then, new tools like metabolite profiling and different molecular techniques came up as valuable supplements and correctives to the traditional species description (Logrieco *et al*. 1995a,b, Hering & Nirenberg 1995, Thrane & Hansen 1995, Gams *et al*. 1998, 1999, O'Donnell *et al*. 1998, 2000, Aoki & O'Donnell 1999, Aoki *et al*. 2001, Thrane 2001, Britiz *et al*. 2002, Dhoro 2010, Abedi-Tizaki & Sabbagh 2012).

As molecular studies progress and the definition of common and important species solidify, the development of molecular diagnostics for many species also should be possible. These diagnostics should be much faster than the present morphological diagnosis. However, the molecular diagnostics will need to be carefully evaluated on a broad range of species as well as strains within the species to accurately define their diagnostic ability and limitations (Leslie & Summerell 2006). For laboratories that currently lack and are unable to acquire molecular expertise, morphological species definitions will remain the rule, and these laboratories should consult researchers with access to molecular technologies to confirm their identification especially for those very closely-related species (Leslie & Summerell 2006).

Fusarium species are widely distributed in soil, air or carried in plant residue, and can be recovered from any part of a plant from the deepest root to the highest flower. They abound in cultivated soil both in temperate and tropical regions and also have been isolated from permafrost in the arctic and from the sand of the Sahara. Fusaria are also involved in diseases of animals and man, and as major storage rots often produce toxins which contaminate human and animal food. They can survive on a wide range of substrates and have been isolated from many preserved foods, from stored chemicals and from aircraft fuel tanks (Booth 1971, de Hoog *et al*. 2000, Leslie & Summerrell 2006). So, identification of the different species of *Fusarium*, including saprobic, pathogenic and toxin producing species, is of vital importance (Nelson *et al*. 1983).

Booth (1971) stated that the predominant interest in the genus has been and still is in their role as plant pathogens. The serious wilts, such as Panama disease of bananas caused by *F. oxysporum*, are amongst the most devastating plant diseases in the world. *F. verticillioides*,

F. graminearum, *F. avenaceum* and *F. culmorum* are serious pathogens of Gramineae causing pokkahboeng of sugarcane, bakanae disease of rice, pre- and postemergence blight of cereals and many others. Strains of *F. solani* are also of world-wide occurrence as root rots, but may also cause cankers of hardwood trees. A recent perusal of the plant disease list maintained by the American Phytopathological Society revealed that over 81 of the 101 economically important plants on the list had at least one associated *Fusarium* species. The types of diseases induced are quite varied as is their severity, and may include root or stem rots, cankers, wilts, fruit or seed rots, and leaf diseases. Thus identifying the *Fusarium* strain in a diseased plant sample remains an important task in many plant diagnostic laboratories (Leslie & Summerell 2006).

As *Fusarium* species are very common plant pathogens or saprobes on plant debris, in soil, some occur on seeds or grains, they rather frequently occur as agents of various kinds of hyalohyphomycosis after traumatic inoculation (Anaissie at al. 1988, Goldschmied-Reouven *et al*. 1993, Vartivarian *et al*. 1993, Rabodonirina *et al*. 1994), particulary keratitis (Rosa *et al*. 1994, Hennequin *et al*. 1997, Naiker & Odhav 2004, Al-Hussaini *et al*. 2010). In leukemic patients sinusitis *Fusarium* is often observed (Lopes *et al*. 1995). Moreover, several reviews of *Fusarium* infections in humans have been published (Anaissie *et al*. 1992, Guarro & Gene' 1992, 1995, Nelson *et al*. 1994, Boutati & Anaissie 1997). Also, de Hoog *et al*. (2000) in their atlas of clinical mycology described eleven medically important *Fusarium* species. These were involved either in endophthalamitis (Pflugfelder *et al*. 1988), keratitis (Zapater 1986), endocarditis (Camin *et al*. 1999), disseminated and systemic infections in leukemic and immunocopromised patients (Melcher *et al*. 1993, Summerbell *et al*. 1988, Helm *et al*. 1990, Krulder *et al*. 1996), onychomycosis (Gianni *et al*. 1997), mycetoma (Luque *et al*. 1991) and sinusitis (Kurien *et al*. 1992).

Some *Fusarium* species produce mycotoxins. Ingestion of grains contaminated with these toxins may give rise to allergic symptoms or be carcinogenic in long-term consumption. Fumonisins are the mycotoxins produced by *F. verticillioides* and *F. proliferatum* in maize. They may cause oesophageal cancer (Pitt 2000). Another group of mycotoxins, zearalenones, may also be produced by some *Fusarium* spp. growing in grains (Schaafsma *et al*. 1998). Studies on reduction or elimination of *Fusarium* mycotoxins from contaminated agricultural and food commodities are in progress (Visconti *et al*. 2000). Also, *Fusarium* species have the ability to produce trichothecenes, which constitute the largest group of mycotoxins (Ueno 1983, 1987).

Aim of the work

The present work aimed to:

1. Identify *Fusarium* isolates to species level based on different micro- and macro-morphological features.
2. Try to make use of some physiological behaviors in differentiation of these species.
3. Design keys for sections, species within sections and for all species isolated in Egypt.
4. Describe and differentiate of all species treated.

Fusarium species in Egypt

In Egypt, *Fusarium* has received, considerable attention from the pathological viewpoint (Abd-El-Aziz 1970, Atalla 1970, Abdel-Fattah 1973, Ashour *et al*. 1973, Abd-Elrazik *et al*. 1976, Abd-Elkader *et al*. 1978, Ahmed 1978, Aly 1978, Rushdi *et al*. 1980a,b, Mohamed *et al*. 1981, Arafa *et al*. 1986, Shihata & Gad El-Hak 1989, Abdel-Kader & Ashour 1999, El-Mohamedy 2004, El-Mohamedy *et al*. 2006, El-Bramawy 2006, El-Bramawy & Shaban 2007, Osama 2007, Sallam & Abdel-Monaim 2012, Ziedan *et al*. 2012), but its ecology has not received much consideration. Only a Ph. D. thesis presented by Abdel-Hafez (1981), on the genus *Fusarium* from Egyptian cultivated, desert and salt marsh soils as well as seasonally fluctuated in cultivated soil and air was conducted (Mazen *et al*. 1982, 1991, Moubasher *et al*. 1984). Moubasher (1993) in his text book on soil fungi in Qatar and other Arab countries made an excellent contribution of the genus *Fusarium* and its telemorphs with 14 species being well illustrated, described and given their ecological distribution.

Fusarium species in soil of Egypt

Moubasher & Moustafa (1970) found that *Fusarium* was the third commonest fungus in Egyptian soils after *Aspergillus* and *Penicillium*. It was represented by four species namely, *F. moniliforme*, *F. oxysporum*, *F. semitectum* and *F. solani*. Moubasher & Abdel-Hafez (1978a) found also that *Fusarium* ranked third according to the number of cases of isolation from Egyptian agricultural soils. Five species were collected and these were *F. oxysporum*, *F. moniliforme*, *F. solani*, *F. concolor* and *F. equiseti* which comprised 0.48%, 0.6%, 0.54%, 0.05% and 0.01% of total fungi, respectively.

Abdel-Fattah *et al*. (1977a) isolated three species of *Fusarium* from Egyptian salt marsh soils and these were *F. oxysporum*, *F. moniliforme* and *F. solani*. They occurred in 44.6%, 12.2% and 7% of the samples, contributing 1.1%, 0.5% and 0.7% of total fungi, respectively. Bagy (1979) isolated six species of *Fusarium* from Egyptian soils, and these were *F. acuminatum*, *F. culmorum*, *F. equiseti*, *F. moniliforme*, *F. oxysporum* and *F. solani*. Maghazy (1979) isolated three species of *Fusarium* (*F. moniliforme*, *F. oxysporum* and *F. solani*) from soil treated with keratinaceous material.

Moubasher *et al*. (1990) found that *Fusarium* was recovered very frequently from cultivated, desert and saline soils on 5% NaCl-Czapek agar, but it was isolated with low or rare frequency on 10% NaCl-Czapek agar. It was encountered in 68%, 64% and 56% of the samples constituting 7.9%, 4.3% and 29.1% of total fungi in the three soil types on medium supplemented with 5% NaCl, respectively. From the genus 8 species were collected and the most common were *F. solani* and *F. oxysporum* in cultivated and desert soils. *F. equiseti* was isolated in moderate frequency from saline soils, but it was of rare frequency in the other two types of soils. *F. graminearum*, *F. lateritium*, *F. moniliforme*, *F. poae* and *F. roseum* were less frequently recovered (Moubasher *et al*. 1990).

Mazen *et al*. (1991) identified 7 species in addition to 2 varieties of the genus *Fusarium*. Of these species, *F. solani* was the most frequent followed by *F. oxysporum*, *F. equiseti*, *F. acuminatum* and *F. semitectum*, *F. moniliforme* and *F. sulphureum* were recovered in low frequency, while *F. sambucinum* var. coeuleum and *F. moniliforme* var. subglutinans were rarely isolated.

Based on his comprehensive reviewing of soil fungi in Egypt, Moubasher (1993) stated that *Fusarium* was more frequently isolated in agricultural than in salt marsh and reclaimed soils. Abdel-Hafez (2004) isolated 3 species of *Fusarium* from newly reclaimed soil (Petroleum's farm) at Assiut Governorate of which *F. oxysporum* and *F. solani* were the most common. On the other hand Seddek (2007) identified 5 species of the genus *Fusarium* of which *F. verticillioides* was the most common followed by *F. culmorum*, *F. oxysporum*, *F. dimerum* and *F. acuminatum*.

Monthly fluctuations of *Fusarium* in soil of Egypt

The term monthly fluctuation means studying composition, numbers and incidences of soil fungi during the different months of year which is expected to change according to the wide change in the climatic factors. Monthly fluctuation of soil fungi have been studied by several workers (Warcup 1957, Witkamp 1960, Reddy 1962, Fincher 1963, Suprum 1963, Gams & Domsch 1969, Fathi *et al*. 1975, El-Abyad & Ismail 1976, Ali *et al*. 1977, Moubasher *et al*. 1988, Abdel-Hafez *et al* 1989).

In Egypt, Moubasher & El-Dohlob (1970) and Moubasher & Abdel-Hafez (1978b) found that the monthly counts of *Fusarium* in cultivated soils from Assiut Governorate seasonally fluctuated giving peaks during autumn or winter and minimum in summer. Mazen & Shaban (1983) found that the highest periods in soil fungi in wheat field at El-Minya

Governorate were recorded during May 1977 and 1978. Also, the periods of February 1978, December and April 1977 showed fairly high fungal population. *Fusarium* was the most frequently encountered species after *Aspergillus*.

Abdel-Hafez *et al*. (1989) found that *F. solani* was irregularly fluctuated in soils of Wadi Qena at eastern desert during the periods from January-December 1985. *F. oxysporum*, *F. acuminatum*, *F. verticillioides*, *F. equiseti* and *F. graminearum* were isolated, but with different counts and incidences, from non-rhizoshere soil of sugarcane filed in Qena Governorate on glucose, cellulose and Czapek's agar media, and their maxima were recovered during various months as reported by Abdel-Hafez *et al*. (1995).

Gherbawy *et al*. (2006) reported that *Fusarium* species rarely appeared at the beginning of the season and increased sharply between January to March and decreased slightly or sharply at the end of the season according to the type of media and isolation source. They isolated 14 *Fusarium* species from wheat field of which *F. merismoides*, *F. oxysporum* and *F. sambucinum* were the most common followed by *F. anthophilum*, *F. aquaeductuum*, *F. chlamydosporum*, *F. dimerum*, *F. moniliforme*, *F. poae*, *F. proliferatum*, *F. scirpi*, *F. solani*, *F. sporotrichioides* and *F. subglutinans*.

Airborne *Fusarium* in Egypt

Air is seldom free from fungal spores and the cosmopolitan distribution of fungi has been attributed to the fact that fungi occupy micro-environments which occur in various ecosystems and geographical areas (Richards 1956, Gregory 1973, Lacey 1975, Moubasher 1993). Air is one of the main sources of contamination and several microorganisms are present in the air due to numerous causes such as animals and humans activities, dust, aerosols produced by solid waste and waste treatment facilities, and by talking coughing or sneezing (Lighthart & Frisch 1976 and Graham 1980), and several of these organisms are well known to be pathogenic to plants, animals and humans (Frey *et al*. 1979, Sehgal *et al*. 1981, Rippon 1982, Treger *et al*. 1985, Velez & Diaz 1985, Arianayagam *et al*. 1986, Chabasse *et al*. 1989, de Hoog *et al*. 2000).

In Egypt, knowledge on the seasonal variations of airborne fungi was focused on the air of some cities or fields at Delta area and Upper Egypt (Saad 1958, Ali *et al*. 1973, Abu El-Souod 1974, Moubasher & Moustafa 1974, Moubasher *et al*. 1981, 1982, Mazen & Shaban 1983, Youssef & Karam El-Din 1988, Abdel-Hafez *et al*. 1990b, 1993, Ismail *et al*. 2002).

Abu El-Souod (1974) in her survey of air-borne fungi at Assiut reported that *Fusarium* was emerged in 77 and 74 daily exposures out of 366 at low and high levels, respectively. The genus *Fusarium* ranked eighth and ninth in the order of total counts (0.7% at every level) at low and high levels, respectively. The highest monthly record at low level made during December when it was isolated in 16 days, but at high level, it was made during November (20 days). Moubasher & Moustafa (1974) reported that *Fusarium* ranked ninth in total count (1.1% of total fungi) and in frequency of occurrence (33 exposures out of 54). They identified three species of *Fusarium* namely, *F. moniliforme*, *F. oxysporum* and *F. semitectum* which comprised 0.93%, 0.09% and 0.06% of total fungi, respectively.

Mazen *et al*. (1982) in their study on the seasonal fluctuation of air-borne fungi at Assiut, Egypt isolated 41 species belonging to 20 fungal genera of which *Aspergillus*, *Alternaria* and *Cladosporium* were the most common followed by *Curvularia*, *Penicillium* and *Epicoccum*. On the other hand, *Fusarium* occupied the seventh place according to their number of cases of isolation. Only 5 *Fusarium* species were identified of which *F. moniliforme* and *F. oxysporum* were the most common followed by *F. solani*, *F. equiseti* and *F. sulphureum*.

Moubasher *et al*. (1988) studied the seasonal fluctuations of airborne fungi of Wadi Bir-El-Ain at eastern desert during the period from March 1978-Feberuary 1980. They found that the monthly counts of air-borne fungi seasonally fluctuated giving peak during autumn. Twelve fungal species were frequently isolated of which *Fusarium* was isolated in high frequency of occurrence. Abdel-Hafez *et al*. (1989) isolated *F. equiseti* and *F. solani* from one exposure each (out of 36 exposures) in the atmosphere of Wadi Qena during the period January-December 1985.

On the other hand, Abdel-Hafez *et al*. (1993) found that the genus *Fusarium* was irregularly fluctuated in the outdoor air at Assiut over a period of two years during January-December 1985 and 1986. Of the genus four species were identified and these were *F. equiseti*, *F. moniliforme*, *F. solani* and *F. xylarioides*. Their maxima were recorded at various months.

El-Said & Abdel-Hafez (1995) studied the seasonal variation of airborne fungi above banana fields in Qena, Upper Egypt and found that *Fusarium* was recovered in moderate frequency of occurrence on plates of glucose- and cellulose-Czapek's agar at 28 °C and the maximum was recorded during November 1992. From the genus 10 species were collected and the most common were *F. oxysporum* and *F. verticillioides*. The remaining species were

recovered in low (*F. acuminatum*, *F. equiseti* and *F. graminearum*) or in rare (*F. nivale*, *F. poae*, *F. semitectum*, *F. tricinctum* and *F. avenaceum*) frequency of occurrence.

Omar *et al*. (1996) found that *Fusarium* occupied the third place after *Aspergillus* and *Penicillium* in the outdoor and indoor atmosphere of Ismailia city during the period from March 1992 to May 1993. The maximum counts of *Fusarium* were estimated in March and either September and October. Also, the prevalence of airborne mycobiota at six different regions of western desert and eastern desert of Egypt was determined using the exposed-plate method by Ismail *et al*. (2002) and six species were encountered namely *F. dimerum*, *F. oxysporum*, *F. acuminatum*, *F. verticillioides*, *F. solani* and *F. equiseti*.

Rhizosphere and rhizoplane *Fusarium*

The terms rhizosphere and rhizoplane are now widely used by microbial ecologists and pathologists. Because of the widespread interest in the parasitic fungi attacking roots, numerous investigations have been made to characterize the fungus flora of root surface (Katznelson *et al*. 1948, Davey & Papavizas, 1960, Srivastava & Mishra 1971, Foster 1986, Campbell & Neher 1996). Successful manipulation of rhizosphere and rhizoplane micro-organisms to enhance biological disease control depends on knowledge of their ecological associations (Schroth & Hancock 1981, Mandeel & Baker 1991).

The previous investigations achieved in this laboratory presented a good evidence that *Fusarium* is one of the basic constituents of fungi in the rhizosphere and rhizoplane of many Egyptian plants (Abdel-Fattah *et al*. 1977b, Moubasher & Abdel-Hafez 1978a,b; El-Hissy *et al*. 1980, Moubasher *et al*. 1984; Mazen *et al*. 1982, 1991, Moubasher 1993, Abdel-Hafez *et al*. 1990a, 1995, Hasan 2002, Abd-Elhafez 2004, Gherbawy *et al*. 2006, Seddek 2007, Abdel-Hafez *et al*. 2009, Ismail *et al*. 2009).

Abdel-Hafez (1974) recovered five species of *Fusarium* from the rhizosphere of cotton seedlings (*F. oxysporum*, *F. moniliforme*, *F. solani* and *F. semitectum* and *F. equiseti*) and 3 species from rhizoplane (*F. oxysporum*, *F. moniliforme* and *F. solani*). Also, *F. oxysporum*, *F. moniliforme* and *F. solani* were recovered, but with different incidences, from rhizoplane of broad-bean (Abdel-Fattah *et al*. 1977b), rhizoplane and rhizosphere of cotton seedlings (Abdel-Kader *et al*. 1978a,b).

El-Hissy *et al*. (1980) reported that *Fusarium* was frequently recovered from the rhizosphere of five plants namely, *Helianthus annuus*, *Chrysanthemum coronarium*, *Nigella*

sativa, *Datura innoxia* and *Hyoscymaus muticus* in Egypt. Three species were identified and these were *F. moniliforme*, *F. oxysporum* and *F. solani*.

Moubasher *et al*. (1984) isolated five *Fusarium* species in the rhizoplane of healthy and damped-off cotton, pea, tomato, maize and wheat seedlings raised in the field during 12-months experiment, of these *F. solani* and *F. oxysporum* were the most common species followed by *F. moniliforme*, *F. acuminatum* and *F. equiseti*. However, maize roots were surpassed by *F. moniliforme*, which was very scarce in the roots of the other test plants.

Abdel-Hafez *et al*. (1990b) found that *Fusarium* was one of the commonest fungi in the rhizosphere and rhizoplane of wheat plants cultivated in El-Minya Governorate and the most species were *F. oxysporum* and *F. semitectum* or *F. solani* based on the examined source. Abdel-Hafez *et al*. (1995) studied seasonal fluctuation of rhizosphere soils and rhizoplane fungi of sugarcane during the periods from January to December 1992 using glucose-, cellulose and 50% sucrose-Czapek's agar media at 28 °C. *F. oxysporum*, *F. poae*, *F. sambucinum*, *F. acuminatum*, *F. verticillioides* and *F. equiseti* were isolated from rhizosphere, while *F. dimerum*, *F. oxysporum*, *F. poae*, *F. verticillioides*, *F. equiseti*, and *F. sambucinum* were isolated from rhizoplane of sugarcane plants. On the other hand Abdel-Hafez *et al*. (2000) isolated *F. oxysporum*, *F. verticillioides* and *F. solani* from the rhizosphere of wheat fields in El-Kharga Oasis. Hasan (2002) isolated 14 species belonging to seven genera from rhizosphere and rhizoplane of fababean, melochia, sesame and soyabean. *Fusarium* was represented only by *F. oxysporum*.

Abd-Elhafez (2004) studied the monthly fluctuations of rhizosphere and rhizoplane fungi of some cultivated plants in newly reclaimed areas of Wadi El-Assiuty, Assiut Governorate during the periods from October 2001 to September 2002. The counts of *Fusarium* in the above two habitats were irregularly fluctuated giving maxima on November and April, respectively. Six species of *Fusarium* were identified and these were *F. culmorum*, *F. equiseti*, *F. moniliforme* var. subglutinans, *F. oxysporum*, *F. semitectum*, and *F. solani*.

In a study of Fusaria and other fungal taxa associated with rhizosphere and rhizoplane of lentil and sesame at different growth stages, Abdel-Hafez *et al*. (2012) isolated 16 species of *Fusarium* from rhizosphere (13 species) and rhizoplane (11) of both plants studied. In lentil, 11 species were recorded from its rhizosphere (9 species) and rhizoplane (8). *Fusarium* species associated with lentil rhizoplane gave highest number of propagules at the first stage of plant growth while the ones of *Fusarium* associated with the rhizosphere produced the highest number at the second stage of growth. *F. solani* was the most common in the three growth stages. In addition, of two growth stages, *F. culmorum* and *F. tricinctum* were isolated

from the rhizosphere while *F. nygamai* and *F. verticillioides* from the rhizoplane. The other species were recorded from only one growth stage of lentil plant. In sesame plants, rhizosphere yielded nine *Fusarium* species while rhizoplane gave only six from the three stages investigated. Stage I of sesame rhizosphere possessed the highest colony forming units of *Fusarium*. As the case for lentil, *F. solani* was the most common species in sesame rhizospere and rhizoplane. *F. verticillioides* and *F. nygamai* (in three different growth stages) followed by *F. oxysporum* and *F. tricinctum* (in two growth stages) were recorded using the dilution-plate and/or soil-plate methods from sesame rhizosphere soils. Rhizoplane *Fusarium* species of sesame plants were isolated at the three different growth stages with almost equal number of colony forming units. *F. poae* came after *F. solani* in its frequency since it was recovered from two growth stages. Several of the isolated species are well-known as pathogens to many cultivated plants (Abdel-Hafez *et al*. 2012).

It was found that several of the isolated *Fusarium* species are well-known as pathogenic to numerous cultivated plants in Egypt (Abdel-Razik *et al*. 1976; Hussein *et al*. 1977; Abdel-Kader *et al*. 1978; Higgy *et al*. 1978; Rushdi *et al*. 1980a,b, 1981, Mohamed *et al*. 1981, 1982, Ziedan 1993, 1998, Ziedan *et al*. 2012, Khalifa 1997, Sahab *et al*. 2001, El-Mohamedy 2004, El-Mohamedy *et al*. 2006, Morsy 2005, El-Bramawy 2006, El-Bramawy & Shaban 2007, El-Bramawy & Abdel-Wahid 2007, 2009, Sallam & Abdel-Monaim 2012).

Grain/Seed-borne *Fusarium* species

Fungi carried on or within grain or seed can reduce grain or seed germination or seedling emergence (Neergaard 1977). Some plant pathogenic fungi kill seedlings shortly after they emerge, whereas others cause serious disease epidemics after being transmitted from grain/seed to seedlings. Determining what proportion (incidence) of seeds in a given seed lot are contaminated by a fungus (either externally or internally) is therefore of interest to plant disease epidemiologists (Maude 1996, Agarwal & Sinclair 1997). Gilbert *et al*. (1997) reported that use of the infected seed / grain without treatment results in lower plant densities. The natural contamination of seeds with seed-borne fungi plays a vital role in determination of seed quality (Abdel-Monem 2000).

Sesame (*Sesamum indicum* L.) seed is an important oilseed widely grown and used in some African and Asiatic countries. It is an important source of protein in the developing countries and the name Benniseed is used throughout West Africa (Felixtina 1988). Sesame oil is mainly utilized as a salad and cooking oil or in the manufacturing of margarine.

Lentil (*Lens esculenta* Medic.) seed is one of the oldest known protein-rich food legumes (Stoilova & Pereira 1999). Lentil wilt, caused by *Fusarium oxysporum* f. sp. *lentis* is one of the main limiting factors to successful cultivation (Stoilova & Chavdarov 2006). It is an important and widely distributed legume crop grown under a broad range of climates (Abdel-Hafez 1988, El-Nagerabi & Elshafie 2000).

Moubasher *et al*. (1979) identified *F. oxysporum*, *F. moniliforme*, *F. solani* and *F. equiseti* in peanut seeds and shells. *F. oxysporum* was the most common. On the other hand, thirty-two species belonging to 17 genera were recovered from lentil seeds, of which *Fusarium* species (*F. moniliforme*, *F. solani*, *F. semitectum*, *F. equiseti*, *F. oxysporum* and *F. roseum*) were isolated in high frequency of occurrence (Abd-Allah & Hashem 2006). Embaby & Abdel-Galil (2006) found that *Fusarium* was the common species isolated from some legume (bean, cowpea and lupine), emerging in 5.6%, 4.4% and 4.4% of total fungi, respectively. *F. oxysporum* was the most common species.

Maize (*Zea mays* L.) grain is one of the most important dietary staple foods in the world (FAO 2002). Maize plays an important role in the diet of millions of African people due to its high yields per hectare, its ease of cultivation and adaptability to different agro-ecological zones, versatile food uses and storage characteristics (Asiedu 1989). In Egypt, maize is one of the most important and essential crops, especially in upper Egypt, not only as food for animal and human but also for Egyptian economics because the crop is used mainly in several food industries (Abdel-Hafez *et al*. 2003). Several fungi are associated with maize during pre- and post-harvest periods, of which the genus *Fusarium* contains important toxigenic species (Fandohan *et al*. 2005). These include *F. verticillioides* which is one of the most economically important species worldwide (Shephard *et al*. 1996, Munkvold & Desjardins 1997, Marasas 2001, Taligoola *et al*. 2004). Many studies have been conducted in several parts of the world to evaluate the natural occurrence of *Fusarium* in maize (Shephard *et al*. 1996, Marasas 2001, Ismail *et al*. 2003). Kossou & Aho (1993) reported that fungi could cause about 50-80% of damage on farmers' maize during the storage period if conditions are favourable for development.

Sorghum (*Sorghum durrum* L.) is the fourth most important cereal in Egypt (after maize, wheat and rice), and is the only one of these cereals that can be easily cultivated in the "new lands' or in very hot and arid Upper Egypt. *Fusarium* species in the *G. fujikuroi* species complex are widely known from maize and sorghum in Egypt. A common perception is that cause stalk; ear and kernel rot and produce mycotoxins such as fumonisins and moniliformin.

Moubasher *et al*. (1972), Abdel-Kader *et al*. (1979), Abdel-Hafez & Abdel-Kader (1980), El-Kady *et al*. (1982), Abdel-Hafez *et al* (1987, 1992), Abdel-Mallek *et al*. (1993), El-Maghraby *et al*. (1995) and Abdel-Sater *et al*. (1995) isolated 13 species of *Fusarium*, but with different counts and incidences from some Egyptian cereals grains and these were *F. oxysporum*, *F. moniliforme* (= *F. verticillioides*), *F. solani*, *F. equiseti*, *F. acuminatum*, *F. semitectum*, *F. poae*, *F. decemcellulare*, *F. tabacinum*, *F. dimerum*, *F. moniliforme* var. *anthophilum*, *F. subglutinans* and *F. sambucinum*.

Aziz *et al*. (2007) found that *Fusarium* infection of wheat, maize and barley grains ranged from 25% to 40%, 30% to 60% and 10% to 25%, respectively. Five species of *Fusarium* were collected and the most common species was *F. moniliforme* (38.6% of total *Fusarium*) followed by *F. proliferatum* (29%), *F. graminearum* (16.5%), *F. subglutinans* (9.1%), and *F. oxysporum* (6.8%).

Methodology

1. Identification of *Fusarium* species

Fusarium strains used in this study were isolated from a wide variety of sources. These strains were either isolated during the current work or were kindly supplied by other mycologists/plant pathologists, and the Culture Collection of Assiut University Mycological Center (Tables 1-3).

The isolates were identified according to the methods described by Booth (1971), Nelson *et al*. (1983), Gerlach & Nirenberg (1982), and Leslie & Summerell (2006).

2. Media used for identification of *Fusarium* species

2. 1. Potato sucrose agar (PSA)

It contains: potato extract, 500 ml; sucrose, 20 g; agar, 20 g and distilled water 500 ml (Booth 1971). Potato extract is prepared from 1800 g of potatoes (not of a red skinned variety) peeled and diced, then suspended in 4500 ml of water and boiled for 10 min. Then autoclaving was done at 121 °C for 15 min. Potato extract can be stored in fridge for use as required.

2. 2. Potato dextrose agar (PDA)

This medium was used by Nelson *et al*. (1983). It contains: potato extract, 250 ml; glucose, 20 g; agar, 15 g and distilled water 500 ml and boiled for 10 min. Autoclaving was done at 121 °C for 15 min. Potato extract is prepared from 250 g white–skinned potatoes, unpeeled, washed and sliced in 500 H_2O.

2. 3. Carnation – leaf agar (CLA)

The medium contained: 20 g agar in a liter of tap water (TWA). Pieces of young carnation leaves, green in colour (cut into about 5 mm2), dried at 45–55 °C for 2h, and sterilized, then put on the surface of TWA medium (Nelson *et al*. 1983, Leslie & Summerell 2006).

Table 1: Number of isolates studied of *Fusarium* recovered from different sources.

Source	Locality	No of isolates studied on		
		CZID	DCPA	CZDA
Soil cultivated (with)				
Triticum astevium Percival	Assiut (1), El-Badary	9	9	3
Zea mays L.	Assiut (2), El-Badary	5	4	4
Brassica rapa L.	Assiut (3), El-Badary	11	6	7
Corchorus olitorius L	Assiut (4), El-Badary	10	7	3
Psidium guajava L.	Assiut (5), El-Badary	9	5	3
Solanum lycopersicum L.	Assiut (6), Sahel-Saleem	2	4	3
Cucumis sativus L.	Assiut (7), Sahel-Saleem	7	5	4
Medicago sativa L.	Assiut (8), Sahel-Saleem	8	5	6
Vicia faba L.	Assiut (9), Sahel-Saleem	12	3	3
Zea mays L.	Assiut (10), Sahel-Saleem	7	5	4
Desert Soil	Cairo-Seuz road (1)	15	12	3
	Cairo-Seuz road (2)	10	10	3
	Cairo-Seuz road (3)	4	8	3
	Cairo-Seuz road (4)	2	6	5
	Cairo-Seuz road (5)	10	5	3
	Wadi El-Natrum; Cairo-Alexandria desert road (6)	12	6	5
	Wadi El-Natrum; Cairo-Alexandria desert road (7)	15	10	6
	Cairo-Alexandria desert road (8)	5	6	1
	Cairo-Alexandria desert road (9)	8	3	4
	Cairo-Alexandria desert road (10)	10	4	4
Salt marsh soil	Al-Almeen (1)	9	12	1
	Al-Almeen (2)	5	5	8
	Al-Almeen (3	3	5	1
	Al-Almeen (4)	8	3	1
	Al-Almeen (5)	7	5	6
Salt marsh soil	Burg El-Arab (6)	13	3	7
	Burg El-Arab (7)	2	4	3
	Burg El-Arab (8)	5	8	11
	Burg El-Arab (9)	2	-	-
	Burg El-Arab	6	4	7
Reclaimed soil (cultivated with)				
Cicer arietinum L.	Al – Nubariya Alexandaria (1)	5	3	4
Medicago sativa L.	Al – Nubariya Alexandaria (2)	12	3	3

Source	Locality	No of isolates studied on		
		CZID	DCPA	CZDA
Trifolium alexandrinum L.	Al – Nubariya Alexandaria (3)	11	3	4
Cicer arietinum L.	Al – Nubariya Alexandaria (4)	9	6	3
Phaseolus vulgaris L.	Al – Nubariya Alexandaria (5)	7	5	4
Medicago sativa L.	Arab El – Awamer, Assiut (6)	7	8	3
Citrus reticulate L.	Arab El – Awamer, Assiut (7)	6	7	3
Solanum lycopersicum L.	Arab El – Awamer, Assiut (8)	6	8	3
Capsicum annuum L.	Arab El – Awamer, Assiut (9)	6	8	3
Brassica rapa L.	Arab El – Awamer, Assiut (10)	4	7	2
Monthly fluctuations in soil	Botanical Garden of Faculty of Agriculture	-	76	-
Rhizosphere soil of *Lens esculenta* Medic.	Botanical Garden of the Department of Botany	-	20	-
Rhizosphere soil of *Sesamum indicum* L.	Botanical Garden of the Department of Botany	-	21	-
Rhizoplanes of Lentil	Botanical Garden of Botany Department	-	15	-
Rhizoplanes of Sesame	Botanical Garden of Botany Department	-	8	-
Maize grains	Markets at Assiut city	-	18	-
Sorghum grains	Markets at Assiut city	-	26	-
Lentil seeds	Markets at Assiut city	-	10	-
Sesame seeds	Markets at Assiut city	-	12	-
Air	Farm of Faculty of Agriculture	-	37	-

3. Single spore isolation

The simplest and most economical way of obtaining a series of single spore cultures is, as described by Booth (1971): A drop of sterile water is placed on a sterile slide under the dissecting microscope. An accumulation of spores is obtained on the wet tip of a needle and the point of the needle introduced into the drop of water on slide. The spores can be observed to flow from the tip of the needle into the water. When the suspension is adequate the needle can be withdrawn. Experience of the correct dilution can easily be acquired and is approximately the point when the spores are clearly distinguishable in the water and are not obscured by overlapping. The spore suspension on the slide is then picked up by a sterile loop and streaked across a clear water agar plate.

Table 2: *Fusarium* species kindly obtained from Assiut University Mycological Center (AUMC).

AUMC No.	Source	Year of isolation	Locality	Identity
1121	Soil	2002	Egypt	*F. chlamydosporum*
1208	*Beta vulgaris* root	2002	Egypt	*F. verticillioides*
1252= CBS 186.35	-	-	U.S.S.R.	*F. longipes*
1253= CBS 134.24	*Morus alba*	-	-	*F. lateritium*
1254= CBS 448.84	pasture soil	-	Australia	*F. scripi*
1255=CBS 143.25	-	-	-	*F. avenaceum*
1256= CBS 680.74	*Puccinia phragitis*	-	Netherlands	*F. acuminatum*
1257= CBS 187.34	*Zostera marina*	-	U.K.	*F. anthophilum*
1258=CBS 245.61	*Beta vulgaris* root	-	Chile	*F. camptoceras*
1259=CBS 145.25	-	-	Germany	*F. chlamydosporum*
1260=CBS 183.34	*Hordeum vulgare*	-	Uruguay	*F. concolor*
1261=CBS 171.28	-	-	-	*F. culmorum*
1262=CBS 104.09	-	-	-	*F. graminearum*
1263=CBS 126.40	-	-	Italy	*F. heterosporum*
1265=CBS 115.97	*Dianthus caryophyllus*	-	-	*F. proliferatum*
1266=CBS 118.13	-	-	-	*F. sambucinum*
1267=CBS 163.57	*Sorghum vuljare*	-	-	*F. incarnatum*
1268=CBS 215.76	Corn grains	-	Germany	*F. subgltinans*
1269=CBS 253.50	*Hordeum sativum* grains	-	Finland	*F. tricinctum*
1270=CBS 258.52	Trunk of coffea sp.	-	Ivory coast	*F. xylarioides*
185	Soil	2003	Egypt	*F. culmorum*
473	Lupin root	2002	Egypt	*F. graminearum*
757	*Bean aphids*	2002	Egypt	*F. equiseti*
870	Watermelon root	2002	Egypt	*F. oxysporum*
893	Cotton root	2002	Egypt	*F. sambucinum*
1113	Soil	2003	Egypt	*F. proliferatum*
1401	Corn grains	2003	Yemen	*F. proliferatum*
1405	Millet grains	2003	Yemen	*F. sambucinum*
2399	*Matricaria camomella*	2004	El-minia	*F. verticillioides*
2403	Soil	2004	Egypt	*F. oxysporum*
2577	Soil	2004	Egypt	*F. poae*
3181	*Hibiscus sabdariffa*	2005	Egypt	*F. fusarioides*
3190	Soil	2004	Egypt	*F. proliferatum*
2580	Used closes	2004	Saudi Arabia	*F. avenaceum*

4. Examination of isolates

4. 1. Growth rate

Growth rate was determined based on linear growth in a tube contain PDA medium (Ryan *et al*. 1943, Nelson *et al*. 1983) and on radial growth in a Petri dish contain PSA medium (Booth 1971).

4. 2. Assessment of colony characters

The unaided eye is essential for the assessment of colony coloures and pigments. However, coloures can only be expressed satisfactory by reference to a colour dictionary. The Methuen Handbook of colour (Kornerup & Wanscher 1989) was used in this work. Photographs of colony surface and under surface were taken using Scanner (HP Scanjet G3010).

4. 3. Light microscopic examination and photography

Wet mounts were prepared as follows: a portion of the colony near the periphery was cut and put onto a slide with a drop of lactophenol cotton blue stain. The stain contained: lactic acid, 20 ml; glycerol, 40 ml; water, 20 ml; and cotton blue, 0.05 g. The wet mount was covered with a cover slip and the excess stain was removed. A high quality compound microscope (Leitz) provided with a standardized ocular was used for the examination of the prepared slides. The microscopically features and the dimensions of conidiophores, phialides, conidia (micro- and macroconidia) and chlamydospores were assessed, measured and photographed.

4. 4. Scanning electron microscopic examination and photography

From the culture two or three samples in size of 0.5-1 cm were cut and fixed in 5% cold buffered glutaraldehyde for two days. The samples were washed by sodium cacodylate buffer for three times (30 minutes each) and post fixed in 1% osmium tetroxide for two hours. Then, the samples were washed in the same buffer for three times (30 minutes each) and dehydration by using ascending grade of ethanol 30, 50, 70, 90% for two hours and 100% for two days and in amylacetate for two days. After that the samples were dried in critical point drainer using liquid carbon dioxide, and each sample stickled on metallic block by using silver paint. In Gold Sputter Apparatus, the samples were evenly gold coated in thickness of 15 nm. By JEOL JSM 5300 Lv scanning electron microscope found at the Electron

Microscopy Unit, Assiut University. The samples were then examined at 15 Kv and photographed.

Table 3: *Fusarium* species kindly obtained from different mycologists and plant pathologists in Egypt.

Source	**Year of isolation**	**Locality**	**Identity**
Stem of canola	2004	Assiut	*F. oxysporum*
Seeds of canola	2004	Assiut	*F. verticillioides*
Seeds of canola	2004	Assiut	*F. udum*
Root of onion	2004	Assiut	*F. solani*
Stem of canola	2004	Assiut	*F. solani*
Stem of canola	2004	Assiut	*F. nygamai*
Seeds of canola	2004	Assiut	*F. nygamai*
Repeat breader cow	2004	Assiut (Abnoub)	*F. nygamai*
Repeat breader cow	2004	Assiut (Abnoub)	*F. lateritium*
Repeat breader buffalo	2004	Assiut (El-Hawtka)	*F. lateritium*
Repeat breader buffalo	2004	Assiut (El-Hawtka)	*F. verticillioides*
Repeat breader buffalo	2004	Assiut (El-Hawtka)	*F. trichotheciodes*
Repeat breader buffalo	2004	Assiut (El-Hawtka)	*F. sporotrichioides*
Human keratitis	2005	Aswan	*F. solani*
Soil	2005	Assiut (Refa)	*F. xylarioides*
Soil	2005	Assiut University Botanical Garden	*F. poae*
Rhizosphere of onion	2005	Assiut (Refa)	*F. subglutinans*
Rhizosphere onion	2005	Assiut (Refa)	*F. oxysporum*
Rhizosphere of onion	2005	Assiut (Refa)	*F. sporotrichioides*
Rhizosphere of onion	2005	Assiut (Refa)	*F. solani*
Soil	2006	Assiut University Botanical Garden	*F. nygamai*
Soil	2006	Assiut University Botanical Garden	*F. proliferatum*
Banana tissue	2004	Assiut	*F. nygamai*
Banana tissue	2004	Assiut	*F. nygamai*
Banana tissue	2004	Assiut	*F. verticillioides*
Banana soil	2004	Assiut	*F. solani*
Banana soil	2004	Assiut	*F. solani*
Banana soil	2004	Assiut	*F. oxysporum*

5. Physiological studies

Fusarium isolates (185 isolates) from different sources whenever possible were selected. These isolates which represent all *Fusarium* species treated in the present investigation were subjected to some physiological tests and growth behaviors on some selected media. The purpose of these tests was to evaluate and assess the obtained results in a trial to find some criteria that might be useful in *Fusarium* taxonomy (For more details refer to Ismail *et al*. 2013).

5. 1. Growth on 25% glycerol nitrate agar medium (G25N)

Colony diameter and morphology (aerial mycelia and reverse) of *Fusarium* isolates were assessed on 25% glycerol nitrate agar medium of Pitt (1973). This medium contains: K_2HPO_4, 0.75 g; Czapek concentrate, 7.5 ml; yeast extract, 3.7 g; glycerol "analytic grade", 250 g; agar, 15 g; and distilled water, 1000 ml, the final pH was 7. The medium was sterilized at 121 °C for 15 min. Plates were incubated at 25 °C and were examined at 7 days. Czapek concentrate contained: $NaNO_3$, 30 g; KCl, 5 g; $MgSO_4 \cdot 7H_2O$, 5 g; $FeSO_4$, 0.1 g and distilled water, 100 ml.

5. 2. Growth on ammonium salts agar medium (Mannitol medium)

This medium has been developed by Brayford & Bridge (1989) for differentiation of *F. oxysporum* from *F. solani*. The medium contains: $(NH_4)H_2PO_4$, 1 g; KCl, 0.2 g; $MgSO_4 \cdot 7H_2O$, 0.2 g; agar, 15 g; mannitol, 10 g; distilled water, 1000 ml. The medium was sterilized at 121 °C for 15 min. Plates were incubated in the dark at 25 °C and were examined at 7 days.

5. 3. Growth on Czapek iprodione dichloran agar (CZID)

This medium has been initially developed by Abildgren *et al*. (1987) for selective isolation of *Fusarium* species. The medium was used but with slight modification made by Pitt & Hocking (1997) which contained: sucrose, 30 g; yeast extract, 5 g; chloramphenicol, 100 mg; dichloran, 2 mg; Czapek concentrate, 10 ml; trace metal solution, 1 ml; agar, 15 g; distilled water, 1 L and iprodione (suspension) 1 ml.

Trace metal solution contained: $CuSO_4 \cdot 5H_2O$, 0.5 g; $ZnSO_4 \cdot 7H_2O$, 1 g and distilled water 100 ml. Czapek concentrate contained: $NaNO_3$, 30 g; KCl, 5 g; $MgSO_4 \cdot 7H_2O$, 5 g; $FeSO_4$, 0.1 g and distilled water, 100 ml. Iprodione suspension: 0.3 g Iprodione in 50 ml sterile water, shaken before addition to medium.

After autoclaving and cooling to 50 °C, the suspension was added immediately before pouring. The plates were inoculated and after 7 days of incubation, the plates were examined, for colony diameter and culture characteristics.

5. 4. Growth on Dichloran chloramphenicol peptone agar (DCPA)

This medium was first developed for selective isolation of *Fusarium* species and dematiaceous hyphomycetes from cereals (Andrews & Pitt 1986). It contains per liter distilled water: peptone, 15 g; KH_2PO_4, 1 g; $MgSO_4 \cdot 7H_2O$, 0.5 g; dichloran (0.2% solution in ethanol), 1 ml; chloramphenicol, 0.2 mg; agar, 20 g. The medium was sterilized at 121 °C for 15 min; the final pH was 6.2. The plates were inoculated and after 7 days of incubation, the plates were examined, for growth rate and morphology.

5. 5. Growth on tannin – sucrose medium

Tannin-sucrose agar was described by Thrane (1986), as a diagnostic medium for the differentiation of *Fusarium* species. Tannin-sucrose agar (TAN agar) consists of a basal mineral-sucrose medium: (g/l: Sucrose, 3; $K_2HPO_4 \cdot 3H_2O$, 1.3; KCl, 0.5; $MgSO_4 \cdot 7H_2O$, 0.5; $NaNO_3$, 0.3; $FeSO_4 \cdot 7H_2O$, 0.01; Agar, 20; distilled water, 850 ml). After autoclaving and cooling to 50 °C a solution of tannin was added to the mineral-sucrose agar.

The tannin solution comprises tannin (Struers, Copenhagen, Denmark), 10g, dissolved in 150 ml of water. The solution is boiled for 10 min at 100 °C before mixing with the mineral-sucrose agar. The medium was mixed carefully before pouring into Petri dishes. The plates were inoculated and incubated at 25 °C. After 7, 10, 14 and 21 days of incubation the dishes were examined for growth. The isolates can be divided into two groups, a group which is able to grow on TAN agar (TAN+) and a group which is unable to grow on TAN agar (TAN-).

5. 6. Acid production on creatine-sucrose agar

Creatine-sucrose agar (CRE) consists of a basal medium: (g/l: bromocresol purple, 0.05; Agar, 15; Mineral solution, 10 ml; Trace metal solution, 1 ml). The mineral solution consisted of (g/100 ml: KCl, 5; $MgSO_4 \cdot 7H_2O$, 5; $FeSO_4 \cdot 7H_2O$, 0.1). The trace metal solution consisted of (g/100 ml: $ZnSO_4 \cdot 7H_2O$, 1; $CuSO_4 \cdot 5H_2O$, 0.5) (Frisvad 1993).

The basal medium was added to (g/l: creatine$\cdot 1H_2O$, 3; $K_2PO_4 \cdot 7H_2O$, 1.6; sucrose, 30). The cultures were three point inoculated (Frisvad 1985), and incubated at 25 °C in the dark, and examined after 7 and 10 days of incubation.

5. 7. Acetylmethylcarbinol production (Voges-Proskauer test)

The ability of *Fusarium* species to produce acetylmethylcarbinol from glucose was detected using glucose phosphate broth (Harrigan & McCance 1966). The medium contained (g/l: D-glucose, 0.5; K_2HPO_4, 0.5; peptone, 0.5; distilled water, 1L; pH 7.5). The medium was sterilized by autoclaving at 121 °C for 15 minutes. Tubes were inoculated and incubated at 25 °C for 5-7 days. After incubation period, 1 ml of culture was transferred to another tube, 0.6 ml of 5% (wt/vol) α-naphthol dissolved in absolute ethanol was added, and were mixed thoroughly. Then 0.2 ml of 40% aqueous KOH was added. The mixtures mixed well, and incubated in a slanted position to increase the surface area of the medium (the reaction is dependent upon oxygen). Positive test (after 15 and 60 min) is indicated by strong red color that begins to develop at the surface of the medium.

5. 8. Urease activity

The ability of *Fusarium* species to produce urease enzyme was detected using urease medium described by Paterson & Bridge (1994). It contains urea and a pH indicator. The basal test medium contained (g/l: $NH_4H_2PO_4$, 1; KCl, 0.2; $MgSO_4 \cdot 7H_2O$, 0.2; bromocresol purple, 50 mg; glucose, 10; agar, 15 and distilled water, 1 liter; pH 6.6). The basal medium was sterilized by autoclaving at 121 °C for 15 minutes. A filter sterilized 50% (w/v) aqueous urea solution was then added to the autoclaved basal medium to give a final concentration of 2%. Agar plates were inoculated centrally with *Fusarium* species and the results were recorded five days after incubation at 25 °C. Isolates capable of producing urease turned the yellow colour of the acidic medium to purple-red or deep pink colour. The diameters of the colony as well as colour zone (in cm) were measured. Enzyme index for urease was expressed according to Ho and Foster (1972) and Ismail (2001) as follows:

Enzyme index = Diameter of the outer limit of colour zone /Diameter of the fungal colony.

5. 9. Peroxidase activity

The ability of *Fusarium* species to produce peroxidase was determined by a modification of the procedure described by Egger (1986). *Fusarium* species were grown on MEA (Malt extract agar, Pitt & Hocking 1997) in Petri dishes for 12 d and were cut with a flamed cork borer within the outermost 10 mm of the colony. One drop each of a freshly prepared 1% (w/v) aqueous solution of pyrogallic acid and 0.4% hydrogen peroxide was added to the well. Development of a golden yellow to brown colour indicates peroxidase activity (Egger 1986).

5. 10. Phosphatase activity

The ability of *Fusarium* species to produce the phosphatase enzyme was detected using the Phosphatase medium described by Gochenaur (1984). Agar plates were inoculated centrally by *Fusarium* isolates and incubated at 25 °C for 5 days. After incubation, one drop of 30% ammonium hydroxide solution was added to the lid of the inverted plate. Hydrolysis of sodium diphosphophenolphthalein was considered positive if a deep fuchsia-coloured zone developed around the colony in the presence of ammonium hydroxide vapours.

5. 11. Pyrocatechol oxidase activity

The ability of *Fusarium* species to produce the extracellular enzyme pyrocatechol oxidase was detected following the method described by Chandrashekar & Kaveriappa (1988). 2% MEA agar plates containing 0.17% tannic acid were inoculated centrally and incubated at 25 °C for 10 days. The presence of a dark brown zone around the colony indicates pyrocatechol oxidase activity.

Taxonomic studies of *Fusarium* species

The identification of *Fusarium* species is mainly based on morphological, cultural and microscopic features (Booth 1971, 1977, Gerlach & Nirenberg 1982, Nelson *et al*. 1983, Leslie & Summerell 2006). These features include the colony diameter on PSA, linear growth on PDA, characters of aerial mycelia and pigmentation.

In parallel with colony morphology, microscopic feature is very important in the process of identification. Since many isolates/species may show big similarities in their colony morphology, however they are microscopically different.

The microscopic features include: dominance of one or both types of conidia and their dimensions (micro- and macroconidia), the presence of one or both types of conidiogenous cells (mono- and polyphialidic conidiogenous cells), true chlamydospores or other related structures (pseudochlamydospores and swollen cells).

Based on these features it was possible to characterized and identify 820 isolates into 34 species of *Fusarium* belonging to 8 sections: section Arthrosporiella (3 species, 45 isolates), section Discolor (5, 38), section Elegans (1, 91), section Gibbosum (5, 43), section Lateritium (4, 93), section Liseola (10, 189), section Martiella (1, 202) and section Sporotrichiella (5, 119) (refer to Table 4). Classification of these species within different sections was based on Booth 1971, Gerlach & Nirenberg 1982, Nelson *et al*. 1983, and Leslie & Summerell 2006) (Tables 4 & 5).

High proportion of the isolates was identified as *Fusarium solani* (202 isolates), the other species such as *F. oxysporum* (91), *F. verticillioides* (80), *F. nygamai* (62), *F. udum* (42), *F. lateritium* (39), *F. chlamydosporum* (35), *F. sporotrichioides* (29), *F. semitectum* (27), *F. poae* (25), *F. equiseti* (24), *F. subglutinans* (21) and *F. tricinctum* (21) came after *F. solani* in their numbers. The other 21 species were represented all by 120 isolates.

Table 4: List of *Fusarium* species identified during the present investigation and their numbers and origin.

Section	Taxa	Isolates identified			
		Total	**Deposited**	**Accesion numbers**	**Not deposited**
Elegans (1 species)	*F. oxysporum* Schltdl.	91	9	Soil (rhizosphere MH 100, MH 101, desert MH 102, cultivated MH 103), stem of *Canola* (MH 104), maize grains (MH 105), lentil seeds (MH 106), watermelon root (AUMC 870), soil (AUMC 1403)	82
Martiella (1 species)	*F. solani* (Mart.) Sacc.	202	8	Soil (rhizosphere MH 107, desert MH 108, MH 109, cultivated MH 110), maize grains (MH 111), sesame seeds (MH 112), air (MH 113), human keratitis (MH 114)	194
Liseola (10 species)	*F. acutatum* Nirenberg & ODonnell	3	1	AUMC 2051 (wheat grains)	2
	F. anthophilum (A. Braun) Wollenw.	4	4	*Sorghum* grains (MH 115), lentil seeds (MH116, MH 117), *Zostera marina* (CBS 187.34)	0
	F. niskadoi T. Aoki & Nirenberg	2	0		0
	F. nygamai L. W. Burgess & Trimboli	62	8	Soil (salt marsh MH 118, desert MH 119, cultivated MH 120), *Sorghum* grains (MH 121, MH 122), lentil seeds (MH 123), air (MH 124), banana tissue (MH 125)	54
	F. proliferatum (Matsush.) Nirenberg	10	7	Soil (desert MH 126, MH 127, salt marsh MH 128), maize grains (MH 129, MH 130), *Dianthus caryophyllus* (CBS 115.97), soil (AUMC 3190)	3
	F. pseudoantho-phillum Nirenberg, ODonnell & Mubatanhema	3	0		0

Section	Taxa	Isolates identified			
		Total	Deposited	Accesion numbers	Not deposited
Liseola (10 species)	*F. pseudonygamai* ODonnell & Nirenberg	2	0		0
	F. subglutinans (Wollenw. & Reinking) P. E. Nelson, Toussoun & Marasas	21	8	Soil (rhizosphere MH 131, salt marsh MH 132, desert MH 133, cultivated MH 134), corn grains (CBS 215.76), sesame (MH 135, MH 136) and lentil (MH 137) seeds	13
	F. thapsinum Klittich, Leslie, Nelson & Marasas	2	2	AUMC 1402 (millet grain), AUMC 5903 (sorghum grain)	0
	F. verticillioides (Sacc.) Nirenberg	80	9	Soil (desert MH 138, salt marsh MH 139, cultivated MH 140), sesame (MH 141), lentil (MH 142) and *Canola* (MH 143) seeds, *Sorghum* grains (MH 144), air (MH 145), *Matricaria chamomilla* (AUMC 2399)	71
Sporotri-chiella (5 species)	*F. chlamydospo-rum* Wollenw. & Reinking	35	6	Soil (rhizosphere MH 146, cultivated MH 147, reclaimed MH 148), *Sorghum* grains (MH 149), sesame seeds (MH 150), CBS 145.25	29
	F. fusarioides (Gonz, Frag. & Cif.) C. Booth	9	6	Soil (desert MH 151, MH 152, MH 153 and cultivated MH 154, MH 155), *Hibiscus sabdariffa* (AUMC 3181)	3
	F. poae (Peck) Wollenw.	25	8	Soil (rhizosphere MH 156, salt marsh MH 157, MH 158, desert MH 159, cultivated MH 160, MH 161), air (MH 162, MH 163)	17
	F. sporotrichio-ides Sherb.	29	8	Soil (rhizosphere MH 164, salt marsh MH 165, desert MH 166, MH 167, cultivated MH 168, MH 169), repeatedly breeded buffalo (MH 170, MH 171)	21

Section	Taxa	Isolates identified			
		Total	Deposited	Accesion numbers	Not deposited
Sporotri-chiella (5 species)	*F. tricinctum* (Corda) Sacc.	21	5	Soil (rhizosphere MH 172, MH 173, cultivated MH 174, salt marsh MH 175), *Hordeum sativum* grains (CBS 253.50)	16
Arthrospo-riella (3 species)	*F. avenaceum* (Fr.) Sacc.	12	6	Soil (salt marsh MH 176, MH 177, desert MH 178, cultivated MH 179, MH 180), CBS 143.25	6
	F. camptoceras Wollenw. & Reinking	6	6	Soil (salt marsh MH 181, desert MH 182, MH 183, cultivated MH 184, MH 185), *Beta vulgaris* roots (CBS 245.61)	0
	F. semitectum Berk. & Ravenel	27	8	Soil (rhizosphere MH 186, salt marsh MH 187, MH 188, desert MH 189, cultivated MH 190), *Sorghum* grains (MH 191), air (MH 192), *Sorghum vulgare* (CBS 165.57)	19
Discolor (5 species)	*F. culmorum* (W. G. Smith) Sacc.	14	7	Soil (rhizosphere MH 193, salt marsh MH 194, desert MH 195, MH 196, cultivated MH 197), CBS 171.28, soil (AUMC 158)	7
	F. graminearum Schwabe	6	6	Desert soil (MH 189, MH 199), sesame seeds (MH 200, MH 201, MH 202), lupine roots (AUMC 473)	0
	F. heterosporum Nees *ex* Fries	1	1	AUMC 1263	0
	F. sambucinum Fuckel	10	8	Soil (rhizosphere MH 203, salt marsh MH 204, desert MH 205, cultivated MH 206, MH 207), cotton root (AUMC 893), millet grain (AUMC 1405), CBS 118.13	2
	F. trichothecio-ides Wollenw.	7	6	Soil (desert MH 208, MH 209, cultivated MH 210), air (MH 211), repeatedly breeded buffalo (MH 212, MH 213)	1

Section	Taxa	Isolates identified			
		Total	Deposited	Accesion numbers	Not deposited
Gibbosum (5 species)	*F. acuminatum* Ellis & Everhart	1	1	AUMC 1256	0
	F. concolor Reinking	15	6	Soil (salt marsh MH 214, MH 215, desert MH 216, cultivated MH 217, MH 218), *Hordeum vulgare* (CBS 183.34)	9
	F. equiseti (Corda) Sacc.	24	6	Soil (salt marsh MH 219, desert MH 220, cultivated MH 221, MH 222), air (MH 223), bean aphid (AUMC 757)	18
	F. longipes Wollenweber & Reinking	2	1	AUMC 1252 (CBS 186.35)	1
	F. scripi Lambotte & Fautrey	1	1	AUMC 1254 (CBS 448.84)	0
Lateritium (4 species)	*F. lateritium* Nees	39	8	Soil (salt marsh MH 224, MH 225, desert MH 226, cultivated MH 227), lentil rhizoplane (MH 228), air (MH 229), repeatedly breeded cow (MH 230), *Morus alba* (CBS 134.24)	31
	F. stilboides Wollenweber	2	0		0
	F. udum E. J. Butler	42	5	Cultivated soil (MH 231), maize (MH 232) and *Sorghum* (MH 233) grains, lentil rhizoplane (MH 234), seeds of *Canola* (MH 235)	37
	F. xylarioides Steyaert	10	8	Soil (desert MH 236, cultivated MH 237, MH 238), lentil (MH 239) and sesame (MH 240, MH 241) seeds, air (MH 242), trunk of *Coffea* species (CBS 258.52)	2

MH: Mycological Herbarium of Department of Botany and Microbiology, Faculty of Science, Assiut University, Egypt

AUMC: Assiut University Mycological Centre, Egypt

CBS: Centraalbureau voor Schimmelcultures, Utrecht, The Netherlands.

Table 5: Different telemorphs (if known) of the *Fusarium* species treated as reported by different authors.

***Fusarium* species**	**Teleomorph**			
	Booth (1971)	**Gerlach & Nirenberg (1982)**	**Nelson *et. al.* (1983)**	**Leslie & Summerell (2006)**
F. acuminatum	*G. acuminata*	*G. acuminata*	*G. acuminata*	*G. acuminata*
F. acutatum	-	-	-	-
F. anthophilum	-	-	-	-
F. avenaceum	*G. avenacea*	*G. avenacea*	*G. avenacea*	*G. avenacea*
F. camptoceras	-	-	-	-
F. chlamydosporum	-	-	-	-
F. concolor	-	-	-	-
F. culmorum	-	-	-	-
F. equiseti	*G. intricans*	*G. intricans*	*G. intricans*	*G. intricans*
F. fusarioides	-	-	-	-
F. graminearum	*G. zeae*	*G. zeae*	*G. zeae*	*G. zeae*
F. heterosporum	*G. gordonia*	-	*G. gordonia*	*G. cyanea*
F. lateritium	*G. baccata*	*G. baccata*	*G. baccata*	*G. baccata*
F. longipes	-	-	-	-
F. nisikadoi	-	-	-	-
F. nygamai	-	-	-	*G. nygamai*
F. oxsporum	-	-	-	-
F. poae	-	-	-	-
F. proliferatum	-	-	-	*G. intermedia*
F. pseudoanthophilum	-	-	-	-
F. pseudonygamai	-	-	-	-
F. sambucinum	*G. pulicaris*	*G. pulicaris*	*G. pulicaris*	*G. pulicaris*
F. scripi	-	-	-	-
F. semitectum	-	-	-	-
F. solani	*N.haematococca*	*N.haematococca*	*N. haematococca*	*H. haematococca*
F. sporotrichioides	-	-	-	-
F. stilboides	*G. stilboides*	*G. stilboides*	-	-
F. subglutinans	*G. fujikuroi* var. *subglutinans*	*G. fujikuroi* var. *subglutinans*	*G. fujikuroi* var. *subglutinans*	*G. subglutinans*
F. thapsinum	-	-	-	*G. thapsina*
F. tricinctum	-	-	*G. tricincta*	*G. tricincta*
F. trichothecioides	-	-	-	-
F. udum	-	-	*G. indica*	*G. indica*
F. verticillioides	*G. fujikuroi*	*G. moniliformis*	*G. fujikuroi*	*G. moniliformis*
F. xylarioides	*G. xylarioides*	*G. xylarioides*	*G. xylarioides*	-

Dichotomous keys for sections, species within each section and for all species treated.

I. Identification keys of sections and species of the genus *Fusarium* treated in the present investigation

I.1. Key for the sections of the genus Fusarium based on macro- and microscopic characteristics:

1. Microconidia abundant……..... .... **2**

1. Microconidia absent or rare……..……..... **9**

2. Microconidia formed from monophialidic conidiogenous cells……...…..... **3**

2. Microconidia formed from mono- and polyphialidic conidiogenous cells ……..... **7**

3. Microconidia formed in chains……..... **Section Liseola**

3. Microconidia not formed in chains……..……..... **4**

4. Macroconidia relatively straight with beaked apical cell……..... **Section Lateritium**

4. Macroconidia curved, apical cell not beaked……..... **5**

5. Culture reverse red……..... **Section Sporotrichiella**

5. Culture reverse not red……..……..... **6**

6. Conidiogenous cells short, macroconidia thin-walled, slender and falcate ..... **Section Elegans**

6. Conidiogenous cells long, macroconidia thick-walled, stout, relatively wider ..... **Section Martiella**

7. Microconidia formed in chains……..... **Section Liseola**

7. Microconidia not formed in chains (formed as false head)…..……..... **8**

8. Culture reverse almost red, often pale……..……..…..... **Section Sporotrichiella**

8. Culture reverse never red but may be purple, orange, yellow or colourless ……..…..... **Section Liseola**

9. Microconidia when present formed from Monophialidic conidiogenous cells…...…..... **10**

9. Microconidia when present formed from mono- and polyphialidic conidiogenous cells.... **12**

10. Macroconidia straight with beaked apical cell, chlamydospores not abundant ……..……..... **Section Lateritium**

10. Macroconidia curved, chlamydospores abundant ……..... **11**

11. Macroconidia thin-walled, with apical cell often elongate or whip-like ……..…..... **Section Gibbosum**

11. Macroconidia thick-walled, with apical cell peaked or fusoid…..... **Section Discolor**

12. Macroconidia thin-walled, with elongate apical cell..... **Section Gibbosum (*F. scirpi*)**

12. Macroconidia with tapering and curved apical cell.……..... **Section Arthrosporiella**

Table 6: Diagnostic and differential physiological criteria within different sections treated of the genus *Fusarium*.

Sections (species, isolates)	**TAN**	**AC**	**AMC**	**Urease**	**Peroxidase**	**Phosphatase**	**Pyrocatechol oxidase**
Arthrosporiella (3, 20)	+	-	±	±	+	±	±
Discolor (5, 28)	-	±	±	±	±	+	±
Elegans (1, 9)	+	-	-	+	±	+	±
Gibbosum (5, 16)	+	-	-	±	±	+	±
Lateritium (4, 23)	+	-	-	±	±	+	±
Liseola (10, 48)	±	±	±	±	±	+	±
Martiella (1, 8)	+	-	-	-	+	+	+
Sporotrichiella (5, 33)	±	-	±	±	+	+	±

TAN: Tannin-sucrose medium; AC: acid from creatine-sucrose medium; AMC: acetylmethylcarbinol compound.

I.2. Keys for the species within each section based on macro- and microscopic and physiological characteristics

Section Arthrosporiella

The significance characters of this section are the polyphialidic conidiogenous cells; conidia are small to medium, obovate, fusiform, lanceolate, clavate and a pedicellate with a wedge-shaped foot cell. Chlamydospores are formed in species of the section (produced singly, in pairs, chains or clusters, smooth walled, usually light brown) except *F. avenaceum* (Booth 1971).

The teleomorph is known only in *F. avenaceum* (*Gibberella avenacea*). Species treated here in this section are *F. avenaceum*, *F. camptoceras* and *F. semitectum*.

I.2.1. Key for species within section Arthrosporiella

1. Chlamydospores absent, macroconidia up to 80 µm long, slender with elongate apical cell, (growth rate on G25N less than 2 cm diameter, urease negative)..... ***F. avenaceum***

1. Chlamydospores present, macroconidia not exceed 40 µm long (growth rate on G25N greater than 2 cm diameter, urease positive)..... **2**

2. Macroconidia fusoid, 3-7 septate, 23-40 x 5-7 µm, with pointed apical and basal cell, (phosphatase and pyrocatechol oxidase negative)..... ***F. camptoceras***

2. Macroconidia slender, 3-5 septate, 15-40 x 2.5-4 µm, with curved and pointed apical cell and foot-shaped basal cell, (phosphatase and pyrocatechol oxidase positive)..... ***F. semitectum***

Table 7: Diagnostic and differential physiological criteria within species of section Arthrosporiella.

Species (isolates)	G25N (D > 2 cm)	Urease	Phosphatase	Pyrocatechol oxidase
F. avenaceum (6)	-	-	+	-
F. camptoceras (6)	+	+	-	-
F. semitectum (8)	+	+	+	+

G25N: Glycerol nitrate agar medium, D: Colony diameter more than 2 cm.

Section Discolor

This section contains some of the most important cereal pathogens such as *F. culmorum*, *F. graminearum* and *F. heterosporum*, which are responsible for seedling blights, pre- and post-emergence blight and crown rot. This section is largely distinguished on the morphology and range of the spore types. Wollenweber used the section for species with comparatively thick-walled and distinctly septate macroconidia which were fusiform to falcate with a beaked or fusoid apex and a pedicellate basal cell. Five species were identified in this section, namely: *F. culmorum*, *F. graminearum*, *F. sambucinum*, *F. heterosporum* and *F. trichothecioides*.

I.2.2. Key for species within section Discolor

1. Macroconidia exceeds 40 µm long (not produce acid on creatine sucrose medium)..... **2**

1. Macroconidia not exceeds 40 µm long (produce acid on creatine sucrose medium) ..... ***F. trichothecioides***

2. Colony reverse red **3**

2. Colony reverse not red **5**

3. Macroconidia 3-5 septate **4**

3. Macroconidia 3-7 septate, up to 62 x 2.5-5 µm ..... ***F. graminearum***

4. Macroconidia slightly curved, up to 50 x 4-7 µm, with rounded and blunt apical cell notched or poorly foot-shaped basal cell (growth rate on G25N greater than 2 cm diameter, urease negative) …..…….……..…..…..... ***F. culmorum***

4. Macroconidia curved, lanceolate, up to 55 x 4-5.5 µm, with pointed apical cell and foot-shaped basal cell (growth rate on G25N less than 2 cm diameter, urease positive) ……..…..…..... ***F. sambucinum***

5. Macroconidia width 4-5.5 µm, with pointed apical cell and foot-shaped basal cell, microconidia very rare, chlamydospores sparse.(Growth rate on G25N medium less than 2 cm diameter, urease positive) ……..…..... ***F. sambucinum***

5. Macroconidia width 3-5µm, with tapered apical cell and foot-shaped or notched basal cell, microconidia absent chlamydospores absent (growth rate on G25N medium greater than 2 cm diameter, urease negative) ……..... ***F. heterosporum***

Table 8: Diagnostic and differential physiological criteria within species of section Discolor.

Species (isolates)	G25N (D > 2 cm)	AC	Urease
F. culmorum (7)	+	-	-
F. graminearum (6)	+	-	-
F. heterosporum (1)	+	-	-
F. sambucinum (8)	-	-	+
F. trichothecioides (6)	+	+	-

G25N: Glycerol nitrate agar medium, D: Colony diameter more than 2 cm, AC: Acid from creatine-sucrose medium.

Section Elegans

The characteristics of this section are those now found in *Fusarium oxysporum*.

Section Gibbosum

Wollenweber first described the section Gibbosum (1913) for species with *equiseti*-like spores. This section was characterized by monophialidic conidiogenous cells. Also, true microconidia are absent but the macroconidia show a pronounced heterogeneity. Chlamydospores are generally abundant, occasionally formed singly but more often formed in irregular chains or clumps. In the current work five species were identified in this section namely: *F. acuminatum*, *F. concolor*, *F. equiseti*, *F. longipes* and *F. scirpi*.

I.2.3. Key for species within section Gibbosum

1. Colony reverse red……...…….....…. **2**

1. Colony reverse brownish…….……..…….....….. **3**

2. Microconidia absent, macroconidia extremely long 5-7 septate, 35-130 x 2-4.5 µm with long and whip-like apical cell (growth rate: on G25N less than 2 cm diameter, on mannitol medium greater than 4 cm diameter) ……..….....…. ***F. longipes***

2. Microconidia sparse, macroconidia strongly curved, 3-7 septate, commonly 5 septate, 30-60 x 3.5-5.5 µm with elongate apical cell (growth rate: on G25N medium greater than 2 cm diameter, on mannitol medium less than 4 cm diameter).....…… ***F. acuminatum***

3. Microconidia absent …….…….....…. **4**

3. Microconidia present, ellipsoidal to clavate, produced from mono- and polyphialidic conidiogenous cells ……..……..…….....…. ***F. scirpi***

4. Sporodochia abundant, macroconidia long, slender, falcate, 3-7 septate, 22-60 x 3.5-5.5 µm with tapered and elongate or even whip-like apical cell (colony colour and pigmentation orange on G25N medium, urease and pyrocatechol oxidase positive)…..…. ***F. equiseti***

4. Sporodochia in older isolates only, macroconidia fusoid to broadly falcate, 3-5 septate, occasionally up to 7 septate, 20-46 x 4.5-5 µm with curved apical cell (colony color and pigmentation yellow on G25N medium, urease and pyrocatechol oxidase negative) …….....…. ***F. concolor***

Table 9: Diagnostic and differential physiological criteria within species of section Gibbosum.

Species (isolates)	G25N (D > 2 cm)	Urease	Pyrocatechol oxidase
F. acuminatum (1)	+	+	-
F. concolor (6)	+	-	-
F. equiseti (6)	+	+	+
F. longipes (2)	-	+	-
F. scirpi (1)	+	+	-

G25N: Glycerol nitrate agar medium, D: Colony diameter more than 2 cm.

Section Lateritium

The section Lateritium was proposed by Wollenweber for species with intercalary chlamydospores and culures pale to rose with blue erumpent sclerotia. The basic character of section Lateritium is the shape of the macroconidium; quite a large percentage of the spores in any one isolate are relatively straight but have a curved, often beaked apical cell and a foot-shaped basal cell. Cultures are white, pinkish, yellow, orange, violet to dark blue.

I.2.4. Key for species within section Lateritium

1. Microconidia absent, macroconidia fusoid and straight to slightly curved, colony reverse red (growth rate on CZID & DCPA greater than 5 cm diameter)……..... ***F. stilboides***

1. Microconidia present (sparse or abundant) (growth rate on CZID & DCPA less than 5 cm diameter) ……..…….....…….. **2**

2. Microconidia sparse (clavate), macroconidia straight to gently curved with hooked or beaked apical cell, colony reverse brownish (pyrocatechol oxidase positive)..… ***F. lateritium***

2. Microconidia abundant, colony reverse purple, (pyrocatechol oxidase negative).....……. **3**

3. Microconidia oval, fusiform to reniform, aerial mycelia felted or almost absent (growth rate on mannitol medium less than 4 cm diameter, urease negative).....…… ***F. udum***

3. Microconidia strongly curved (growth rate on mannitol medium greater than 4 cm diameter, urease positive).....…….…… ***F. xylarioides***

Table 10: Diagnostic and differential physiological criteria within species of section Lateritium.

Species (isolates)	DCPA (D > 5)	CZID (D > 5)	Urease	Pyrocatechol oxidase
F. lateritium (8)	-	-	+	+
F. stilboides (2)	+	+	-	+
F. udum (5)	-	-	-	-
F. xylarioides (8)	-	-	+	-

DCPA: Dichloran chloramphenicol peptone agar, CZID: Czapek iprodione dichloran agar, D: Colony diameter more than 5 cm.

Section Liseola

The section was originally regarded by Wollenweber as a part of the section Elegans, without chlamydospores. Sherbakoff (1922) regarded it as worthy of a distinct section and proposed the name Moniliform on account of the microconidia occurring in chains (Booth 1971). This section is characterized by the production of microconidia (spindle to ovoid, pyriform, clavate) in chains or false heads and thin-walled macroconidia (slender with a slightly constricted top end and a pedicellate base). The presence or absence of microconidial chains is an important characteristic feature of species of this section in all taxonomic systems of *Fusarium* currently in use (Booth 1971, Nelson *et al*. 1982, Gerlach & Nirenberg 1983, Seifert 1996, Leslie & Summerell 2006).

In the current work, ten species were identified in this section namely: *F. acutatum*, *F. anthophilum*, *F. nisikadoi*, *F. nygamai*, *F. proliferatum*, *F. pseudoanthophilum*, *F. pseudo-nygamai*, *F. subglutinans*, *F. thapsinum* and *F. verticillioides*. Of these *F. acutatum*,

F. nisikadoi, *F. pseudoanthophilum* and *F. pseudonygamai* were recorded for the first time in Egypt according to the literatures available.

I.2.5. Key for species within section Liseola:

1. Microconidia formed in chains and in false heads..... **2**

1. Microconidia not formed in chains (formed in false heads)..... **8**

2. Microconidia produced only from monophialidic conidiogenous cells..... **3**

2. Microconidia produced from mono- and polyphialidic conidiogenous cells..... **4**

3. Microconidia clavate, napiform, colony reverse usually yellow, (growth rate on DCPA medium less than 5 cm diameter and not grow on TAN sucrose medium) ..... ***F. thapsinum***

3. Microconidia oval to clavate, colony reverse violet or colourless (growth rate on DCPA medium greater than 5 cm diameter and grow on TAN sucrose medium) ..... ***F. verticillioides***

4. Chlamydospores present **5**

4. Chlamydospores absent **6**

5. Microconidia formed in short chains, long-oval to obovoide, clavate or pyriform, chlamydospores in chains (not in clusters) (not produce acid on creatine sucrose medium) ..... ***F. pseudoanthophilum***

5. Microconidia formed in longer chains (up to 20 conidia), chlamydospores produced singly, in chains and in clusters (produce acid on creatine sucrose medium)..... ***F. nygamai***

6. Colony reverse orange, microconidia clavate, 0-3 septate to pyriform, 0-septate (growth rate on CZID medium less than 5 cm diameter and not grow on TAN sucrose medium) ..... ***F. nisikadoi***

6. Colony reverse violet or colourless, microconidia clavate (0-septate) (growth rate on CZID medium greater than 5 cm diameter and grow on TAN sucrose medium)..... **7**

7. Hyphal swellings (confusing with true chlamydospores) present, colony reverse orange to violet (urease negative)..... ***F. pseudonygamai***

7. Hyphal swellings not present, colony reverse violet or colourless (urease positive) ..... ***F. proliferatum***

8. Colony reverse orange, apical cell of macroconidia bent, chlamydospores formed slowly ..... ***F. acutatum***

8. Colony reverse purple or colourless, apical cell of macroconidia curved, chlamydospores never produced..... **9**

9. Microconidia oval to obclavate (growth rate on CZID greater than 5 cm diameter, grow on tannin-sucrose medium, produced AMC compound)..... ***F. subglutinans***

9. Microconidia pyriform, globose, oval to cylindrical. (Growth rate on CZID less than 5 cm diameter, not grow on tannin-sucrose medium, not produced AMC compound) ..... ***F. anthophilum***

Table 11: Diagnostic and differential physiological criteria within species of section Liseola.

Species (isolates)	CZID (D > 5)	TAN	AC	AMC	Urease	Pyrocatechol oxidase
F. acutatum (3)	-	+	-	-	+	+
F. anthophilum (4)	-	-	-	-	+	-
F. nisikadoi (2)	-	-	+	-	+	-
F. nygamai (8)	+	+	+	±	-	±
F. proliferatum (7)	+	+	±	±	+	-
F. pseudoanthophilum (3)	+	+	-	-	-	-
F. pseudonygamai (2)	+	+	-	-	-	-
F. subglutinans (8)	+	+	-	+	+	±
F. thapsinum (2)	+	-	+	-	+	+
F. verticillioides (9)	+	+	+	±	+	±

CZID: Czapek iprodione dichloran agar; D: colony diameter more than 5 cm; TAN: Tannin-sucrose medium; AC: acid from creatine-sucrose medium; AMC: acetylmethylcarbinol compound.

Section Martiella

The section Martiella was first proposed by Wollenweber (1913) for three species *Fusarium solani*, *F. martii* and *F. coeruleum*. Snyder & Hansen (1940) regarded the system as unworkable and reduced all the species in the Martiella and Ventricosum sections to one, *Fusarium solani.*

Section Sporotrichiella

Sporotrichiella include species with globose, pyriforme to clavate microconidia which are produced in abundance. Additionally all members of this sections are capable to produce peroxidase and phosphatase enzymes but not capable of producing acid on creatine sucrose medium. In the current work five species were identified in this section namely: *F. chlamydosporum*, *F. fusarioides*, *F. poae*, *F. sporotrichioides* and *F. tricinctum*.

I.2.6. Key for species within section Sporotrichiella

1. Colony reverse red……..……. **2**

1. Colony reverse pale to brown, microconidia spindle shaped.....…. ***F. chlamydosporum***

2. Microconidia produced from monophialidic conidiogenous cells…..……. **3**

2. Microconidia produced from mono- and polyphialidic conidiogenous cells.....…….. **4**

3. Microconidia globose or napiform, conidiogenous cells globose to dolliform-shaped (can't grow on tannin-sucrose medium and urease positive).....…..… ***F. poae***

3. Microconidia napiform, oval, pyriform, conidiogenous cells navicular to cylindrical (grow on tannin-sucrose medium and urease negative).....……..…..… ***F. tricinctum***

4. Microconidia pyriform, ellipsoid to fusoid, mesoconidia present may be up to 5-septate ……..…….....……..…… ***F. sporotrichioides***

4. Microconidia fusiform to clavate with a rounded apex, mesoconidia not present ……...…….....……...…..… ***F. fusarioides***

Table 12: Diagnostic and differential physiological criteria within species of section Sporotrichiella.

Species (isolates)	TAN	Urease
F. chlamydosporum (6)	+	-
F. fusarioides (6)	+	+
F. poae (8)	-	+
F. sporotrichioides (8)	+	+
F. tricinctum (5)	+	-

TAN: Tannin-sucrose medium.

2.2. Key for the studied species of the genus Fusarium based on macro- and microscopic characteristics

1. Microconidia abundant…….....……. **2**

1. Microconidia sparse or absent, macroconidia abundant…..……..…..…… **23**

2. Microconidia formed in chains, macroconidia sparse…….....……..…...… **3**

2. Microconidia not formed in chains…….....……..... **9**

3. Microconidia formed from monophialidic conidiogenous cells…….....…….. **4**

3. Microconidia formed from mono- and polyphialidic conidiogenous cells.....…..… **5**

4. Microconidia clavate, napiform, colony reverse usually yellow.....……. ***F. thapsinum***

4. Microconidia oval to clavate, colony reverse violet or colourless.....… ***F. verticillioides***

5. Chlamydospores present…….....……. **6**

5. Chlamydospores absent……..……..…… **7**

6. Microconidia formed in short chains, long oval to obovoid, clavate or pyriform, chlamydospores in chains (not in clusters).....…….…… ***F. pseudoanthophilum***

6. Microconidia formed in longer chains (up to 20 conidia), chlamydospores produced singly, in chains and in clusters.....…….…..…..…….…. ***F. nygamai***

7. Colony reverse orange, microconidia clavate (0-3 septate), pyriform (0-septate) …….....……..… ***F. nisikadoi***

7. Colony reverse violet or colourless.....……..…….…..…..…… **8**

8. Hyphal swellings (confusing with true chlamydospores) present, colony reverse orange to violet.....…….…… ***F. pseudonygamai***

8. Hyphal swellings not present, colony reverse violet or colourless.....… ***F. proliferatum***

9. Microconidia formed from monophialidic conidiogenous cells…….....…...…….. **10**

9. Microconidia formed from mono- and polyphialidic conidiogenous cells…..…... **17**

10. Colony reverse red……..….....…….…….. **11**

10. Colony reverse not red…….. ……..…… **12**

11. Conidiogenous cells globose to dolliform, microconidia globose or napifor.....… ***F. poae***

11. Conidiogenous cells navicular to cylindrical, microconidia napiform, oval, pyriform …….....…… ***F. tricinctum***

12. Colony reverse violet…….....…….. **13**

12. Colony reverse brownish or colourless…….....…….…… **16**

13. Conidiogenous cells short…….....…….…… **14**

13. Conidiogenous cells quite long…….....……..…….. ***F. solani***

14. Aerial mycelium felted or almost absent…….....…….…… ***F. udum***

14. Aerial mycelium abundant…….....…….…….. **15**

15. Microconidia strongly curved, chlamydospores absent…..…..…..… ***F. xylarioides***

15. Microconidia oval, elliptical, almost straight, chlamydospores abundant..… ***F. oxysporum***

16. Conidiogenous cells short, reverse colourless…….....…….…. ***F. oxysporum***

16. Conidiogenous cells quite long, reverse brownish…….....……..… ***F. solani***

17. Colony reverse violet or colourless, chlamydospores absent.....……. **18**

17. Colony reverse orange, brownish or red, chlamydospores abundant.....……. **19**

18. Microconidia oval to obclavate…..…….....…… ***F. subglutinans***

18. Microconidia globose, pyriform, oval to cylindrical…..…….....…… ***F. anthophilum***

19. Colony reverse red…….....…….…… **20**

19. Colony reverse orange or brownish…….....……..…… **21**

20. Microconidia pyriform, ellipsoid to fusoid, mesoconidia present (up to 5-septate) ……. ***F. sporotrichioides***

20. Microconidia fusiform to clavate with a rounded apex, mesoconidia not present …… ***F. fusarioides***

21. Colony reverse orange, macroconidia apical cells acute, chlamydospores formed slowly …… ***F. acutatum***

21. Colony reverse brownish…….. **22**

22. Microconidia ellipsoidal to clavate, 0-3 septate, polyphialidic conidiogenous cell commonly with 3 openings (croos-shaped), macroconidia abundant, curved and long…….. ***F. scirpi***

22. Microconidia spindle-shaped, straight, mostly 0-septate, macroconidia sparse, slightly curved …… ***F. chlamydosporum***

23. Microconidia sparse…….. **24**

23. Microconidia absent…….. **29**

24. Colony reverse red…….. **25**

24. Colony reverse not red…….. **26**

25. Macroconidia strongly curved into a sickle-shaped. 3-7 septate, common 5- septate, 30-60 x 3.5-5.5 µm, with elongated apical cell..... ***F. acuminatum***

25. Macroconidia curved, lanceolate, up to 50 x 4-5.5 µm, with pointed apical cell …… ***F. sambucinum***

26. Macroconidia straight, with beaked apical cell, up to 75 µm long, chlamydospores sparse, microconidia formed from monophilaidic conidiogenous cells..... ***F. lateritium***

26. Macroconidia curved, microconidia formed from mono- and polyphialidic conidiogenous cells…….. **27**

27. Macroconidia with pointed apical cell, never exceed 60 µm long, chlamydospores present …… **28**

27. Macroconidia with elongate apical cell, up to 80 µm long, chlamydospores absent …… ***F. avenaceum***

28. Macroconidia up to 40 µm long, microconidia formed from mono- and polyphialidic conidiogenous cells..... ***F. semitectum***

28. Macroconidia up to 55µm long, microconidia formed from monophialidic conidiogenous cells..... ***F. sambucinum***

29. Colony reverse red..... **30**

29. Colony reverse brownish or less commonly colourless..... **33**

30. Macroconidia 3-5 septate, up to 50 x 4-7 µm..... ***F. culmorum***

30. Macroconidia 3-7 septate, greater than 50 µm long……..……...…..... **31**

31. Macroconidia extremely long, 5-7 septate, 35-130 µm, with long, tapering and whip-like apical cell.....……..……..……..…… ***F. longipes***

31. Macroconidia with apical cell not as above.....…..……..……..……..… **32**

32. Macroconidia up to 65 µm long with tapered and cone-shaped apical cell …….....……..…..…….…… ***F. graminearum***

32. Macroconidia up to 82 µm long, with pointed or beaked apical cell..... ***F. stilboides***

33. Macroconidia not exceed 40 µm long…….....……...…… **34**

33. Macroconidia exceed 40µm long…….....…….…….. **35**

34. Macroconidia 3-5 septate, 14-27 x 5-6.5 µm.....…….…… ***F. trichothecioides***

34. Macroconidia 3-7 septate, 23-40 x 5-7 µm (mesoconidia not distinguishable from macroconidia, formed from mono- and polyphialidic conidiogenous cells…. ***F. camptoceras***

35. No. of septa of macroconidia 5.....……..…… **36**

35. No. of septa of macroconidia exceed 5.....……..…… **37**

36. Macroconidia fusoid to broadly falcate, 3-5 septate, 20-46 x 4.5-5 µm, with curved and pointed apical cell, chlamydospores abundant.....……....…… ***F. concolor***

36. Macroconidia curved, 3-5 septate, 20-55 x 3-4 µm, chlamydospores absent ……...…….....……..... ***F. heterosporum***

37. Macroconidia straight, 3-8 septate, 22-75 x 2-5 µm, chlamydospores present …….....……. ***F. lateritium***

37. Macroconidia long, slender, falcate, 3-7 septate, 22-60 x 3.5-5.5 µm with tapered and elongate or even whip-like apical cell, chlamydospores abundant.....…. ***F. equiseti***

Species descriptions

Thirty-four species were identified and described based on their macroscopic, microscopic and physiological characters. Of the identified taxa, 31 species were isolated during this study. Representatives of most of these species and other 3 species were kindly obtained from Assiut University Mycological Center (AUMC) and other mycologists and plant pathoologists. Keys were designed for sections, species within each section and for all species treated.

1. *Fusarium acuminatum* Ellis & Everhart 1895

See Plate 1.

Section: Gibbosum

Synonyms: *F. scirpi* Lamb. & Fatur. var. *acuminatum* (Ellis & Everhart) Wollenweber 1931

F. equiseti (Corda) Sacc. var. *acuminatum* (Ellis & Everhart) Bilai 1950

Teleomorph: *Gibberella acuminata* Wollenweber 1943

Isolates examined: 1, Deposited isolates: AUMC 1256

i. Macroscopic features

On PSA plates after 4 days: Growth rate 4.45 cm diameter, aerial mycelium floccose, white to pale red (M. 9A3) and pigmentation dark red (M. 10C8).

On PDA slants after 10 days: Growth rate 7.75 cm length, with floccose, white to pastel red (M. 9A4) aerial mycelia and reddish brown pigmentation (M. 9E5).

ii. Microscopic features

Macroconidia: Strongly curved into a sickle-shape, 3-7 septate, but commonly 5-septate, 30-60 x 3.5-5.5 µm, with elongate apical cell and distinct foot-shaped basal cell.

Microconidia: Sparce, fusiform, 0-1 septate, 10-15 x 2-4 µm, produced singly or in pairs from monophialidic conidiogenous cells.

Chlamydospores: Sparse, produced singly, in chains or in clusters.

iii. Physiological features

The one isolate tested of *F. acuminatum* proved to be able to:

1- Grow on G25N medium with growth rate more than 2 cm diameter and produce white aerial mycelium and grayish yellow pigmentation.

2- Grow on mannitol medium with growth rate less than 4 cm diameter and produce pale yellow mycelium and reddish yellow pigmentation.

3- Grow on CZID medium with growth rate more than 5 cm diameter and produced pale orange aerial mycelium and greyish yellow pigmentation.

4- Grow on tannin-sucrose agar.

5- Produce urease and phosphatase enzymes.

However, it was not capable of producing:

1- Peroxidase and pyrocatechol oxidase enzymes.

2- Acid on creatine-sucrose agar.

3- Acetylmethylcarbinol compound.

Fusarium acuminatum is most often confused with isolates of *F. avenaceum*. The shape of the macroconidia in *F. acuminatum* which has some dorsiventral curvature is a good criterion to differentiate it from *F. avenaceum*. Also, *F. avenaceum* isolates on PDA don't produce reddish pigmentation while those of *F. acuminatum* do. Moreover, *F. acuminatum* could produce urease enzyme while *F. avenaceum* could not. On G25N medium, growth rate of *F. acuminatum* exceeds 2 cm diameter while *F. avenaceum* does not. Growth rate for *F. acuminatum* on CZID medium exceeds 5 cm diameter while *F. avenaceum* does not.

In Egypt, it was isolated from different sources such as: soil (Abdel-Sater 1990), air and wheat plant (Ahmed *et al*. 1993), and seasonal variation of air above banana fields in Qena (El-Said & Abdel-Hafez 1995). *F. acuminatum* isolated from branched broomrape plants by Mohamed *et al*. (2004).

Fusarium acuminatum is more common in temperate areas, often in grassland and cultivated soils; it is less common in tropical areas (Lamprecht *et al*. 1986, Backhouse & Burgess 1995). Also, it has been isolated from a wide variety of plants and from several insects (Booth 1971), although *F. acuminatum* is generally regarded as a saprophyte and some isolates can cause severe root rot in some legume species and stem rot of maize (refer to Booth 1971, Leslie & Summerell 2006). *Fusarium acuminatum* may produce trace levels of trichothecenes (Wing *et al*. 1993, 1994). Also, it can produce enniatin B and steroids (Logrieco *et al*. 1994).

2. *Fusarium acutatum* Nirenberg & O' Donnell 1998

See Plate 2.

Section: Liseola

Teleomorph: Not known

Isolates examined: 3, Isolates deposited: AUMC 2051

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 4.45-5.25 cm diameter, with a mean ± SD = 4.9 ± 0.41, aerial mycelium white and pigmentation light orange (M. 5A4).

On PDA slants after 10 days: Growth rate varies from 7.45-7.9 cm length, with a mean ± SD = 7.72 ± 0.24, aerial mycelium white and pigmentation deep orange (M. 6A8).

ii. Microscopic features

Macroconidia: Sparse, falcate, thin walled, usually 3-septate, 30-54 x 2-3.5 µm with apical cell bent and foot-shaped basal cell.

Microconidia: Abundant, oval, fusoid, 0-septate, 5-10 x 1.5-2.5 µm, found only in false heads from mono- and polyphialidic conidiogenous cells.

Chlamydospores: Formed slowly, in chains and in clusters.

iii. Physiological features

The three isolates tested of *F. acutatum* proved to be able to:

1- Grow on G25N medium with growth rate less than 2 cm diameter and produce white aerial mycelium and yellow pigmentation.

2- Grow on mannitol medium and produce reddish white aerial mycelium and red pigmentation.

3- Grow on CZID medium with growth rate less than 5 cm diameter and produce white or reddish white aerial mycelium and orange pigmentation.

4- Grow on DCPA medium with growth rate not exceeding 5 cm.

5- Grow on tannin-sucrose medium.

6- Produce urease, peroxidase, phosphatase and pyrocatechol oxidase enzymes.

However, it was not capable of producing:

1- Acid on creatine-sucrose agar.

2- Acetylmethylcarbinol compound.

The most distinguished features of this species are the shape of macroconidia (falcate with acute apical cells) and the orange pigmentation. *F. acutatum* may be confused with the closely related *F. anthophilum* and *F. subglutinans* since all produce microconidia in false heads on mono- and polyphialidic conidiogenous cells. *F. acutatum* could be distinguished from both by its orange pigmentation and macroconidia with acute apical cells. Also, *F. acutatum* could be distinguished from *F. anthophilum* morphologically by their microconidial shape and physiologically by their different response for growth on tannin-sucrose medium and production of peroxidase and pyrocatechol oxidase enzyme. Moreover, it

could be distinguished from *F. subglutinans* by its inability to produce acetylmethylcarbinol compound. This species has been reported in the present work from sesame seeds and the rhizosphere of its plant.

This species was first described by Nirenberg & O'Donnell (1998) for those cultures forming acute or bent macroconidia. Leslie & Summerell (2006) stated that this species needs to be confirmed and validated with a large number of isolates from diverse sources. Also, this species is easy to confuse with *F. udum*, but the characteristic acute apical cell of its macroconidia rather than the uncinate apical cell of *F. udum* are diagnostic (Nirenberg & O'Donnell 1998, Leslie & Summerell 2006). Isolates of *F. acutatum* produce trace levels of beauvericin and fumonisins (Fotso *et al*. 2002, Leslie & Summerell 2006).

3. *Fusarium anthophilum* (A. Braun) Wollenweber 1917

See Plate 3.

Section: Liseola

Synonyms: *Fusarium moniliforme* Sheldon var. anthophilum (A. Braun) Wollenweber 1931

Fusisporium anthophilum A. Braun 1875

Teleomorph: Not known

Isolates examined: 4 isolates, Isolates deposited: MH 115, MH 116, MH 117, CBS 187.34 (AUMC 1257).

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 4.8-5.25 cm diameter with a mean ± SD = 5 ± 0.19 with white aerial mycelium and pigmentation colourless in 3 isolates and pale violet in one (M.15A3).

On PDA slants after 10 days: Growth rate varies from 7.8-8.35 cm length with a mean ± SD = 8.08 ± 0.25, aerial mycelium white and pigmentation colourless in 3 isolates and purple in one (M. 15A6). Sporodochia, found in one isolate, orange in colour.

ii. Microscopic features

Macroconidia: Often difficult to find, relatively slender with no distinct curvature, thin walled, 3-5 septate, 30-60 x 3-3.5 µm, with curved apical cell and foot-shaped basal cell.

Microconidia: Pyriform, globose, oval, usually 0-septate, 5-10 x 3.5-6 µm, but occasionally 1-septate, cylindrical 5-15 x 1.5-3 µm, they are produced only on false heads on mono- and polyphialidic conidiogenous cells.

Chlamydospores: Absent.

iii. Physiological features

The four isolates tested of *F. anthophilum* proved to be able to:

1- Grow on G25N medium with growth rate less than 2 cm and produce pinkish aerial mycelium and greyish orange pigmentation.

2- Grow on mannitol medium with growth rate less than 4 cm and produce reddish white or pale red mycelium and grayish red or reddish brown pigmentation.

3- Grow on CZID medium (growth rate less than 5 cm) and produce white or orange aerial mycelium and grayish brown or orange grey pigmentation.

4- Produce urease and phosphatase enzymes.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Acetylmethylcarbinol compound.

3- Colonies on tannin-sucrose agar.

4- Peroxidase and pyrocatechol oxidase enzymes.

Production of different microconidia types (pyriform, globose, ovoid and cylindrical) is the most distinguished character for *F. anthophilum*. It can be easily confused with *F. subglutinans*, but *F. anthophilum* produce different types of microconidia. Also, it could be distinguished from it by its inability to produce acetylmethylcarbinol compound and growing on tannin-sucrose medium. Moreover, its slower growth on CZID medium proved to be a diagnostic tool. This species has been reported in the present work from sorghum grains and lentil seeds. In Egypt, it was isolated from soil and wheat grains (refer to Moubasher 1993). This species was recognized by Wollenweber & Reinking (1935), Gerlach & Nirenberg (1982), Nelson *et al*. (1983), Leslie & Summerell (2006)

F. anthophilum has been reported to be recovered from a number of countries and host substrates, although it is not thought to be pathogenic to plants. This species is not associated with any human or animal diseases (refer to Leslie & Summerell 2006). Some strains of *F. anthophilum* have been reported to produce moniliformin (Chelkowski *et al*. 1990), others reported to produce fumonisins (Nelson *et al*. 1992, Proctor *et al*. 2004).

4. *Fusarium avenaceum* (Fries) Saccardo 1886

See Plate 4.

Section: Arthrosporiella

Synonyms: *F. rosum* LK emend. Snyd. & Hans. 'Avenaceum'

F. rosum LK emend. Snyd. & Hans. var. *avenaceum* (Sacc.) Snyd.& Hans.

Fusiporium avenaceum Fries, Syst., 1832

Teleomorph: *Gibberella avenacea* Cook 1967

Isolates examined: 12 isolates, Isolates deposited: CBS 143.25 (=AUMC 1255), MH 176, MH 177, MH 178, MH 179, MH 180.

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 5-5.8 cm with a mean ± SD = 5.39 ± 0.29, with abundant mycelia which varies from light yellow to yellowish brown (M. 4A5-5D5), yellowish brown sporodochia are formed in colony center, colony reverse is reddish golden (M. 6C7).

On PDA slants after 10 days: Rapid growth varies from 7.5-8.4 with a mean ± SD = 7.99 ± 0.32, with white to light yellow (M. 3A5) dense aerial mycelia, reverse light yellow (M. 6D6).

ii. Microscopic features

Macroconidia: Abundant in sporodochia, long, slender, straight to slightly curved, thin-walled, with elongate apical cell and well-marked foot cell, 4-7 septate but mostly 5-septate, 40-80 x 3.5-4 µm.

Microconidia: Produced only by some isolates, scarce, from monophialidic and polyphialidic conidiogenous cells, 1-to 3-septate 10-50 µm.

Chlamydospores: Absent.

iii. Physiological features

The six isolates tested of *F. avenaceum* proved to be able to:

1- Grow on G25N medium with growth rate less than 2 cm diameter and produce yellow aerial mycelium and orange pigmentation.

2- Grow on CZID medium with growth rate less than 5 cm diameter and produce white aerial mycelium and orange pigmentation.

3- Grow on DCPA medium with growth rate exceeding 5 cm diameter.

4- Grow on tannin-sucrose agar.

5- Produce phosphatase and peroxidase enzymes.

However, it was not capable of producing:

1- Acid creatine on creatine-sucrose agar.

2- Acetylmethylcarbinol compound.

3- Urease and pyrocatechol oxidase enzymes.

Fusarium avenaceum could be distinguished from *F. camptoceras* microscopically by their large macroconidia (up to 80 µm) which do not exceed 40 µm in both other species. Also, *F. avenaceum* never produce chlamydospores. It also could be distinguished from the

other 2 species (*F. camptoceras* and *F. semitectum*) by incapability of producing urease enzyme and its limited growth on G25N (< 2 cm diameter). However, it could be distinguished from *F. camptoceras* by its ability to produce phosphatase enzyme and its limited growth on mannitol agar medium and distinguished from *F. semitectum* by its inability to produce pyrocatechol oxidase enzyme. *F. avenaceum* in the present work was reported only from soil. In Egypt it has been reported from several substrates such as rhizosphere of sugarbeet (*Beta vulgaris*) (El-Abyad *et al*. 1988).

Fusarium avenaceum has a world-wide distribution wherever crops are grown and often a severe parasite of over wintering cereals. It also causes root rots of wheat, rye and maize as well as legumes, conifers and many other seedlings (Booth 1971, Domach *et al*. 1980 and Nelson *et al*. 1983). It has also been reported on more than 160 genera in different plant families. It has been recovered from cultivated, desert soils, grains, stems. It can cause economically important diseases of broccoli (Mercier *et al*. 1991), lentils (Hwang *et al*. 2000), raspberry (Hargreaves & Jarvis 1972) and peaches nectarines (Hartill & Broadhurst 1989). However has not been associated with any human or animal toxicoses (Marasas *et al*. 1984, Leslie & Summerell 2006).

5. *Fusarium camptoceras* Wollenweber & Reinking 1925 emend. Marasas & Logrieco 1998

See Plate 5.

Section: Arthrosporiella

Teleomorph: Not known.

Isolates examined: 6 isolates, Isolates deposited: MH 181, MH 182, MH 183, MH 184, MH 185, CBS 245.61 (=AUMC 1258).

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 4.5-5.8 cm diameter with a mean ± SD = 5.22±0.53, mycelia floccose to powdery vary from white-beige-yellowish white (M. 4C3-4C2), pigmentation light brownish yellow (M. 5C-D8), sporodochia cream to pale orange colour.

On PDA slants after 10 days: Growth rate varies from 7.2-8 cm length, with a mean ± SD = 7.5±0.3, mycelia white to beige (M. 4C3) and pigmentation brown (M. 5D8).

ii. Microscopic features

Macroconidia: Abundant in sporodochia, fusoid, lanceolate and slightly curved or broadly fusiform with pointed apical cell and conical to pointed basal cell, 3-7 septate, 23-40 x 5-7 µm.

Microconidia/Mesoconidia: These conidia are not clearly distinguished in shape from the macroconidia. They may be 0-6 septate. They are produced singly from monophalidic and polyphialidic conidiogenous cells.

Chlamydospores: Formed slowly and sparsely, produced singly, in pairs, chains or clusters, terminal or intercalary, globose, smooth-walled or verrucose.

iii. Physiological features

The six isolates tested of *F. camptoceras* proved to be able to:

1- Grow on G25N medium with growth rate more than 2 cm diameter and produce yellow aerial mycelium and yellow pigmentation.

2- Grow on mannitol medium with growth rate more than 4 cm diameter and produce yellow aerial mycelium and greyish yellow pigmentation.

3- Grow on CZID medium with growth rate less than 5 cm diameter and produce white aerial mycelium and brownish orange pigmentation.

4- Grow on DCPA medium with growth rate exceeding 5 cm diameter.

5- Grow on tannin-sucrose agar.

6- Produce urease and peroxidase enzymes.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Phosphatase and pyrocatechol oxidase enzymes.

On the other hand, different isolates gave variable responses towards the production of acetylmethylcarbinol compound.

F. camptoceras was described by Wollenweber & Reinking 1925. It is similar to *F. semitectum* but its macroconidia are more curved. It could be distinguished from *F. semitectum* by its inability to produce both phosphatase and pyrocatechol oxidase enzymes and its yellow pigments on G25N medium, while *F. semitectum* produce orange to brown pigmentation on this medium. Also, *F. camptoceras* could be distinguished from the other 2 species (*F. avenaceum* and *F. semitectum*) by its inability of producing phosphatase enzyme. Moreover, it could be distinguished from *F. avenaceum* by its ability to produce urease enzyme. *F. camptoceras* in the present work was reported only from soil. In Egypt it

has been reported from foodstuff and soil as reported by Hamed *et al*. (1984). Also *F. camptoceras* was isolated from branched broomrape plants (Mohamed *et al*. 2004).

It has been recovered from decaying banana and cacao in various tropical regions, but does not appear to have a role as a plant pathogen (Booth 1971, Leslie & Summerell 2006).

6. *Fusarium chlamydosporum* Wollenweber & Reinking 1935

See Plate 6.

Section: Sporotrichiella

Synonym: *F. sporotrichioides* Sherb. var. *chlamydosporum* (Wollenweber & Reinking) Joffe 1974

Teleomorph: Not known.

Isolates examined: 35 isolates, Isolates deposited: MH 146, MH 147, MH 148, MH 149, MH 150, CBS 145.25 (=AUMC 1259).

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 2.5-5.7 cm diameter with a mean ± SD = 4.52 ± 0.74, with abundant mycelia which vary from white to yellow (10 isolates) (M. 3A3), white-beige to brownish orange (25 isolates) (M. 4C3-5C4), sporodochia rarely formed. Pigmentation is light brown (M. 6D6).

On PDA slants after 10 days: Growth rate varies from 6.5-9.2 cm length with a mean ± SD = 7.84 ± 0.64, with dense, white to light yellow (21 isolates) (M. 4A5) or white with grayish orange aerial mycelium (14 isolates). The undersurface is generally light brown (27 isolates) (M. 6D4) or golden brown (8 isolates) (M. 5D6).

ii. Microscopic features

Macroconidia: Difficult to find if sporodochium production is rare, thick walled, curved, 3-5 septate, 25-55 x 2.5-4.5 µm, with short, curved and pointed apical cell, and foot shaped basal cell.

Microconidia: Straight, spindle shaped, abundant in the aerial mycelium, usually 0-septate, 1-2 septate microconidia may be observed. Microconidia may be produced singly, or sometimes in pairs from elaborate polyphialidic conidiogenous cells that result in branching conidiophores with a tree-like appearance.

Chlamydospores: Produced abundantly and rapidly, may occur singly, in pairs but are common in chains and in clusters, verrucose and pale brown in colour.

iii. Physiological features

The six isolates tested of *F. chlamydosporum* proved to be able to:

1- Grow on G25N medium with growth rate more than 2 cm diameter and produce white to pale yellow aerial mycelium and yellowish orange pigmentation.

2- Grow on mannitol sucrose medium and produce yellow aerial mycelium and brownish orange or grayish orange pigmentation.

3- Grow on CZID medium and produce white or yellowish aerial mycelium and yellowish pigmentation.

4- Grow on DCPA medium with growth rate exceeding 5 cm diameter.

5- Grow on tannin-sucrose agar.

6- Produce peroxidase and phosphatase enzymes.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Urease enzyme.

The most distinguished character of *F. chlamydosporum* is the spindle-shaped microconidia borne on polyphialidic conidiogenous cells. *F. fusarioides* (synonymized by Nelson *et al*. 1982 and Leslie & Summerell 2006 to this species) could be distinguished from *F. chlamydosporum* by the characteristic red colour pigmentation on PSA and PDA media, and its ability to produce urease enzyme and white to reddish white mycelium and red pigmentation on CZID medium. *F. chlamydosporum* has been reported in the present work from soil, sorghum grain, sesame seed, rhizosphere of lentil plants and rhizoplane of sesame plants.

In Egypt, until 1993, there was no report on its occurrence in soil (Moubasher 1993). *F. chlamydosporum* was isolated from cotton seeds by Abdel-Sater *et al*. (2003). Mohamed *et al*. (2004) isolated *F. chlamydosporum* from branched broomrape plants. Also, *F. chlamydosporum* was reported by Gherbawy *et al*. (2006).

This species is common in soil in warmer areas of the world and can be abundant in semi-arid and arid grassland soils (Leslie & Summerell 2006). *F. chlamydosporum* has been isolated occasionally from the tissues of various plants that it presumably colonized as a secondary invader (Tinline *et al*. 1988). *F. chlamydosporum* has been associated with tobacco where it may reduce seed quality and germination (Fajola 1983). It also is reported to cause damping off tea plants (Engelbrecht *et al*. 1983) and a stem canker of okra (Fugro 1999).

Fusarium chlamydosporum has been implicated in some human mycoses, particularly in immuno-compromised patients. It is resistant to most clinical antifungals. Some strains of this species produce moniliformin and other secondary metabolites such as acuminatopyrone, chlamdosporol, and steroids (refer to Leslie & Summerell 2006).

7. *Fusarium concolor* Reinking 1934

See Plate 7.

Section: Gibbosum

Teleomorph: Not known

Isolates examined: 15 isolates, Isolates deposited: MH 214, MH 215, MH 216, MH 217, MH 218, CBS 183.34 (= AUMC 1260).

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 3.9-4.7 cm diameter with a mean ± SD = 4.28 ± 0.3, with abundant aerial mycelium, cottony to floccose, mycelium white to light orange (M. 5A4-5) and pigmentation brownish orange (M. 5C3-5) in 9 isolates, while mycelium yellowish white to pale yellow (M. 3A2-3) and pigmentation golden brown (M. 5D7) in the other 6 isolates.

On PDA slants after 10 days: Growth rate varies from 7.55-8.45 cm length with a mean ± SD = 7.95 ± 0.25, with abundant floccose mycelia, mycelium white to brownish orange (M. 5C5) and pigmentation brown (M. 6D8) in 8 isolates, while mycelium brownish yellow (M. 5C7-8) and pigmentation dark brown (M. 6E6) in the other 7 isolates.

ii. Microscopic features

Macroconidia: Fusoid to broadly falcate, usually 3-5 septate, 20-46 x 4.5-5 µm, but occasionally up to 7 septate, with curved, pointed apical cell and well developed foot-shaped basal cell. Sporodochia in older isolates are developed, marked by the orange colour of the conidial mass.

Microconidia: Absent.

Chlamydospores: Produced in the hyphae, singly, in chains or in clumps, globose, smooth walled, but become brown with age. Occasionally they are formed in the conidia.

iii. Physiological features

The six isolates tested of *F. concolor* proved to be able to:

1- Grow on G25N medium with growth rate more than 2 cm diameter and produce yellowish aerial mycelium and yellow pigmentation.

2- Grow on mannitol medium with growth rate less than 4 cm diameter and produce yellowish orange or reddish yellow or yellow aerial mycelium and yellow pigmentation.

3- Grow on CZID medium and produce white or yellowish aerial mycelium and grayish orange or yellow or reddish orange pigmentation.

4- Grow on DCPA medium with growth rate exceeding 5 cm diameter.

5- Grow on tannin-sucrose medium.

6- Produce phosphatase enzyme.

However, it was not capable of producing:

1- Acid on creatine sucrose medium.

2- Acetylmethylcarbinol compound.

3- Urease and pyrocatechol oxidase enzymes.

Moreover, different isolates gave variable response towards the peroxidase enzyme production.

Fusarium concolor is similar to *F. equiseti* but dose not have the pronounced elongation of the apical cell often found in *F. equiseti*. It also could be distinguished *F. concolor* from other closely related species within section Gibbosum (*F. acuminatum*, *F. equiseti*, *F. longipes* and *F. scirpi*) by its inability of producing urease enzyme. *F. concolor* differs from *F. semitectum* in the absence of polyphialidic conidiogenous cells and in having a marked foot-shaped basal cell of the macroconidia. Moreover, *F. concolor* could not produce urease and pyrocatechol oxidase enzymes while *F. semitectum* could.

In the present work *F. concolor* has been recovered from soils only. Also, in Egypt it has been previously isolated from soil (Abdel-Fattah *et al*. 1977a, Moubasher & Abdel-Hafez 1978a). This species is predominantly a soil organism and it has been isolated from soil in Brazil and Canada and from barley roots in Uruguay (Booth 1971).

8. *Fusarium culmorum* (W.G. Smith) Saccardo 1895

See Plate 8.

Section: Discolor.

Synonym: *Fusisporium culmorum* W. G. Smith 1884

Fusarium sambucinum Fukel var. *cerealis* (Cooke) Raillo 1950

Teleomorph: Not known

Isolates examined: 14 isolates, Isolates deposited: MH 193, MH 194, MH 195, MH 196, MH 197, CBS 171.28 (=AUMC 1261), AUMC 158.

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 5.35-6.2 cm diameter with a mean ± SD = 5.79 ± 0.22, aerial mycelia abundant, orange white (M. 5A2) to pastel red (M. 8A4) (6 isolates) with brownish red pigmentation (M. 8C7), or reddish orange aerial mycelium (M. 8A7) (8 isolates) with reddish brown pigmentation (M. 9C6).

On PDA slants after 10 days: Growth rate varies from 7.85-9.5 cm length with a mean ± SD = 9.08 ± 0.36, 6 isolates produce orange red aerial mycelium (M. 8A8) and deep red pigmentation (M. 10C8), while 8 isolates produce brownish red aerial mycelium (M.8C7) and brown pigmentation (M. 7F7), sporodochia abundant, pale orange.

ii. Microscopic features

Macroconidia: Abundant in sporodochia, slightly curved, relatively short, thick walled 3-5 septate, 26-50 x 4-7 µm, with rounded and blunt apical cell and with notched or foot-shaped basal cell.

Microconidia: Absent.

Chlamydospores: Abundant, found in hyphae, singly, in clumps or chains, smooth or rough walled. They are also found in macroconidia.

iii. Physiological features

The seven isolates tested of *F. culmorum* proved to be able to:

1- Grow on G25N medium with growth rate exceed 2 cm diameter and produce orange aerial mycelium and yellow or brownish yellow pigmentation.

2- Grow on mannitol sucrose medium with growth rate exceed

4 cm diameter and produce yellow aerial mycelium and orange pigmentation.

3- Produce phosphatase and peroxidase enzymes.

However, it was not capable of:

1- Growing on tannin-sucrose agar.

2- Producing acid on creatine sucrose agar.

3- Producing acetylmethylcarbinol compound.

4- Producing urease and pyrocatechol oxidase enzymes.

The most distinguished feature of *Fusarium culmorum* is the shape of macroconidia (short and stout). *F. culmorum* may be confused with *F. sambucinum* but it could be distigushed by its rapid growth and reddish aerial mycelium and the red reverse on PDA and PSA media. *F. culmorum* could be distinguished physiologically from *F. sambucinum* by its inability to produce urease enzyme and its rapid growth on G25N (> 2 cm diameter). *F. culmorum* could also be distinguished from the closely related species *F. trichothecioides* by its larger macroconidia (up to 50 µm long versus 27 µm) and by its ability to produce acid from creatine agar medium. This species has been reported in the present work from soil, rhizosphere, rhizoplane and seasonally cultivated soil.

Fusarium culmorum is most common in temperate regions, and often is associated with cereal such as wheat and barley (Jacobson & Gordon 1990). It is effect to produce cortical

rots which cause pre- and post-emergence blight of cereals (Booth 1971). *F. culmorum* attacks maize chiefly as a stalk or cob rot. Also, it is a causal agent of diseases of carnations (Broadhurst 1990), hops (Sabo *et al*. 2002), and of reduced seed germination in sorghum (Patil & Padule 2000). *F. culmorum* produces steroids and mycotoxins such as moniliformin, deoxynivalenol and related trichothecenes, fusarin C, and zearalenone (refer to Leslie & Summerell 2006).

9. *Fusarium equiseti* (Corda) Saccardo 1886

See Plate 9.

Section: Gibbosum.

Synonyms: *F. scirpi* Lambotte & Fautr. var. *compactum* Wollenweber 1935

F. scirpi Lambotte & Fautr. var. *filiferum* (Preuss) Wollenweber 1935

F. gibbosum Appel & Wollenweber 1910

Teleomorph: *Gibberella intricans* Wollenweber 1931

Isolates examined: 24 isolates, Isolates deposited: MH 219, MH 220, MH 221, MH 222, MH 223, AUMC 757.

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 5.45-5.9 cm diameter with a mean ± SD = 5.71 ± 0.15, floccose aerial mycelium which become white to beige (M. 4C3) (10 isolates) or white to light yellow (M. 3A5) (5 isolates) or white to grayish orange (M. 5B5) (9 isolates). 12 isolates produce light brown pigmentation (M. 6D6), 5 isolates produce brownish orange pigmentation (M. 6C8) and the other 7 species gave yellowish brown pigmentation (M. 5D5).

On PDA slants after 10 days: Growth rate varies from 7.3-8.9 cm length with a mean ± SD = 8.11 ± 0.48, aerial mycelium light brown (M. 6D6) (10 isolates) or brownish orange (M.6C8) (14 isolates) with brown beige (M. 6E3) (12 isolates) or dark brown pigmentation (M. 6F6) (12 isolates). Sporodochia may appear as the culture ages.

ii. Microscopic features

Macroconidia: Abundant in sporodochia, long, slender, falcate, 3-7 septate, 22-60 x 3.5-5.5 µm, with tapered and elongate or even whip-like apical cell and a well-developed footshaped basal cell.

Microconidia: Absent.

Chlamydospores: Abundant, intercalary, solitary, in chains or in clumps, with brown colour and thick verrucose walls with age.

iii. Physiological features

The six isolates tested of *F. equiseti* proved to be able to:

1- Grow on G25N medium with growth rate not exceeding 2.5 cm diameter and produce orange aerial mycelium and orange pigmentation.

2- Grow on mannitol medium and produce yellow or yellowish white aerial mycelium and yellowish or reddish pigmentation.

3- Grow on CZID medium and produce orange aerial mycelium and orange or brown pigmentation.

4- Grow on tannin-sucrose agar.

5- Produce urease, phosphatase and pyrocatechol oxidase enzymes.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Acetylmethylcarbinol compound.

Moreover, different isolates gave variable response towards the peroxidase enzyme production.

Fusarium equiseti is easily confused with *F. scirpi* and *F. semitectum* but *F. scirpi* produces abundant microconidia on polyphialidic conidiogenous cell whereas *F. equiseti* produces no microconidia. *F. equiseti* never produces spindle-shaped macroconidia that are in *F. semitectum* from polyphialidic conidiogenous cells. Some isolates of *F. equiseti* produce very long macroconidiawith whip-like apical cells and may resemble the macroconidia formed by *F. longipes*; however PDA cultures of *F. equiseti* produce brown pigment while those of *F. longipes* produce red pigment. *F. equiseti* could also be distinguished from the other 4 species recorded within section Gibbosum (*F. acuminatum*, *F. concolor*, *F. longipes* and *F. scirpi*) by its ability to produce pyrocatechol oxidase enzyme.

In the present work *F. equiseti* has been isolated from soil, monthly fluctuation of cultivated soil and from monthly fluctuation of air. In Egypt, it was recovered previously from soil (Moubasher & Abdel-Hafez 1978a, Moubasher *et al*. 1985a,b, Abdel-Hafez *et al*. 1989, Moubasher *et al*. 1990), rhizoplane of damped-off cotton seedlings (Moubasher *et al*. 1984), rhizosphere, air, shells of peanut, wheat grains, onion seedlings (refer to Moubasher 1993). *Fusarium equiseti* is a cosmopolitan soil inhabitant that has been recovered from many parts of the world (Leslie & Summerell 2006). *F. equiseti* is especially common in drier areas such as Bahrain (Mandeel 1996), although it also can be recovered from soil near the Arctic Circle (Kommedahl *et al*. 1988). *F. equiseti* has been associated with a few diseases such as cankers of sour cherry trees (Olszak 1994), rots of cucurbit fruits in contact with soil (Adams *et al*.

1987), and diseases of date palm (Abbas *et al*. 1991). *F. equiseti* may be recovered as a human pathogen (Goldschmied-Reouven *et al*. 1993).

Fusarium equiseti is associated with toxicities to cattle, chickens, ducklings, mice, rabbits and rats (Marasas *et al*. 1984). Some strains of *F. equiseti* produce toxins such as beauvericin, trichothecenes, *equiseti* n and zearalenone (refer to Leslie & Summerell 2006).

10. *Fusarium fusarioides* (Fragoso & Ciferri) Booth 1971

See Plate 10.

Section: Sporotrichiella

Synonyms: *Dactylium fusarioides* Fragoso & Ciferri 1927

Teleomorph: Not known.

Isolates examined: 9 isolates, Isolates deposited: MH 151, MH 152, MH 153, MH 154, MH 155, AUMC 3181.

i. Macroscopic features

On PSA plates after 4 days: Growth rate ranges from 4.15-5.5 cm diameter with a mean ± SD = 4.84 ± 0.36, aerial mycelium white to pale red (M. 10A3–11A3) and pigmentation red (M. 11A-B6-7).

On PDA slants after 10 days: Growth rate ranges from 7.45-8.36 length with a mean ± SD = 7.9 ± 0.35, aerial mycelium reddish white to pink (M. 12A2-4) and pigmentation deep red (M. 11B-C7).

ii. Microscopic features

Macroconidia: May be difficult to find, curved, fusoid, 4-6 septate, 40-55 x 5-6 µm, with a narrowly rounded to pointed apical cell and foot-shaped basal cell.

Microconidia: Abundant, fusiform to clavate with a rounded apex, 0-1 septate, 13-15 x 3-4.5 µm, produced singly from mono- and polyphialidic conidiogenous cells.

Chlamydospores: Abundant, globose, smooth-walled, produced singly, in chains or in clumps.

iii. Physiological features

The six isolates tested of *F. fusarioides* proved to be able to:

1- Grow on G25N medium and produce pinkish aerial mycelium and reddish yellow or orange pigmentation.

2- Grow on mannitol medium and produce yellowish aerial mycelium and brownish pigmentation.

3- Grow on CZID medium and produce reddish white aerial mycelium and red pigmentation.

4- Grow on DCPA medium with growth rate exceeding 5 cm diameter.

5- Grow on tannin-sucrose medium.

6- Produce urease, peroxidase, phosphatase and pyrocatechol oxidase enzymes.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Acetylmethylcarbinol compound.

The PDA culture of *F. fusarioides* can be confused with other members of section sporotrichiella (*F. poae*, *F. sporotrichioides* and *F. tricinctum*). *F. fusarioides* and *F. sporotrichioides* produce microconidia from mono- and polyphialidic conidiogenous cells, which differentiate them from *F. poae* and *F. tricinctum*. Also, the presence of two types of microconidia distinguishes *F. sporotrichioides* from *F. fusarioides*. It also could be distinguished from the other closely related species *F. chlamydosporum* by the characteristic red pigmentation on both PSA & PDA media, and its ability to produce urease enzyme and white to reddish white aerial mycelia and red pigmentation on CZID medium.

11. *Fusarium graminearum* Schwabe 1838

See Plate 11.

Section: Discolor

Teleomorph: *Gibberella zeae* (Schweinitz) Petch 1936

Sphaeria zeae Schweinitz 1823

Isolates examined: 6 isolates.

i. Macroscopic features

On PSA plates after 4 days: Growth rate ranges from 7.15-8.35 cm diameter with a mean ± SD = 7.72 ± 0.43, aerial mycelium floccose, white to greyish rose (M. 12B4-5) (4 isolates) or white to vivid red (M. 11A-B8) (2 isolates), and pigmentation deep red (M. 11C8) in all isolates.

On PDA slants after 10 days: Growth rate varies from 8.5-9.5cm length with a mean ± SD = 9.19 ± 0.41, with dense aerial mycelia that varies from white to grayish red (M. 11C-D5) (3 isolates) or white to brownish red (M. 8C7) (3 isolates). Pigmentation for all isolates tested deep red (M. 10C8). Sporodochia pale orange, but often rare or difficult to find.

ii. Microscopic features

Macroconidia: Slender, falcate to straight, thick walled, 3-7 septate, 25-65 x 2.5-5 µm, with tapered and cone-shape apical cell and well developed foot-shape basal cell.

Microconidia: Absent.

Chlamydospores: Variable, but often very slow to form, produced singly, in chains or in clusters, globose, finely rough, hyaline to pale brown.

iii. Physiological features

The six isolates tested of *F. graminearum* proved to be able to:

1- Grow on G25N medium with growth rate exceeds 2 cm diameter and produce orange aerial mycelium and golden yellow or orange pigmentation.

2- Grow on mannitol medium with growth rate exceeds 4 cm diameter and produce orange or yellow aerial mycelium and orange pigmentation.

3- Grow on CZID medium with growth rate exceeds 5 cm diameter and produce reddish aerial mycelium and reddish orange to brownish red or brownish red pigmentation.

4- Produce phosphatase and peroxidase enzymes.

However, it was not capable of:

1- Growing on tannin-sucrose agar.

2- Producing acid on creatine sucrose agar.

3- Producing acetylmethylcarbinol compound.

4- Producing urease enzyme.

However, different isolates gave variable responses towards the production of pyrocatechol oxidase enzyme.

F. graminearum could be easily distinguished from *F. culmorum* by its macroconidia morphology. Also, this species can be confused with species within section sporotrichiella (*F. fusaioides*, *F. poae*, *F. sporotrichioides* and *F. tricinctum*) by their growth morphology on PDA. However, it could be distinguished from these species by the absence of microconidia. Additionally, it could be distinguished from *F. fusaioides*, *F. poae* and *F. sporotrichioides* by its inability to produce urease enzyme. Also, its inability to grow on tannin-sucrose agar medium separates it from *F. fusarioides*, *F. sporotrichioides* and *F. tricinctum*. Growth rate on mannitol agar medium could also be useful as a diagnostic tool to distinguish it from *F. tricinctum*. In the current work it was isolated from sesame seeds and seasonally collected soil.

Fusarium graminearum occurs predominantly on cereals although it has also been reported on a wide range of other hosts (Booth 1971). It can causes diseases of aerial plant

parts such as head blight (head scab) of wheat (Gilbert & Fernando 2004), barley (Mathre 1997), oats (Tekauz *et al*. 2004), and wild rice (Nyvall *et al*. 1999), stalk and cob rot of maize (White 1999), sorghum grain mold (Menkir *et al*. 1996), and branch dieback of Acacia and Eucalyptus (Roux *et al*. 2001).

F. graminearum is not usually associated with humans as a direct pathogen (Leslie & Summerell 2006). Isolates of *F. graminearum* may produce three important mycotoxins, zearalenone, nivalenol and deoxynivalenol (Marasas *et al*. 1984), as well as aurofusarin (refer to Leslie &Summerell 2006).

12. *Fusarium heterosporum* Nees ex Fries 1818

See Plate 12.

Section: Discolor

Synonyms: *Fusarium reticulatum* Mont. 1843

Fusarium reticulatum Mont. var. *negundinis* (Sherb.) Wollenweber 1931

Teleomorph: *Gibberella cyanea* (Sollm.) Wollenweber 1863

Isolates examined: 1 isolate, Isolates deposited: AUMC 1263

i. Macroscopic features

On PSA plates after 4 days: Growth rate 5.75 cm diameter, with white aerial mycelium colourless pigmentation.

On PDA slants after 10 days: Growth rate 8.3 cm length, with white aerial mycelium and no obvious pigmentation.

ii. Microscopic features

Macroconidia: Thin walled, slender, straight or gently curved, 3-5 septate, 20-55 x 3-4 µm, with tapered apical cell and foot-shaped or notched basal cell.

Microconidia: Absent.

Chlamydospores: Absent.

iii. Physiological features

The isolate tested of *F. heterosporum* proved to be able to:

1- Grow on G25N medium with growth rate exceed 2 cm diameter and produce reddish white aerial mycelium and orange pigmentation.

2- Grow on mannitol medium with growth rate exceed 4 cm diameter and produce light yellow aerial mycelium and orange pigmentation.

3- Grow on CZID medium with growth rate exceed 25cm diameter and produce white aerial mycelium and light yellow pigmentation.

4- Produce phosphatase enzyme.

However, it was not capable of producing:

1- Colonies on tannin-sucrose agar.

2- Acid on creatine-sucrose agar.

3- Acetylmethylcarbinol compound.

4- Urease, peroxidase and pyrocatechol oxidase enzymes.

F. heterosporum could be confused with *F. avenaceum* in their macroconidia morphology but those of *F. heterosporum* are shorter (up to 55 µm versus 80 µm). *F. heterosporum* was the only species within section discolor that could produce peroxidase enzyme and reddish white aerial mycelium on G25N medium. This isolate was kindly obtained from Assiut University Mycological center (AUMC). In Egypt there is no available record on its occurrence on soil (Moubasher 1993). However, it was recovered from agricultural soil in Qatar (Moubasher & Al-Subai 1987).

Fusarium heterosporum is a head blight parasite of cereals and grasses. It appears to be particularly widespread throughout Africa on millets, in which up to 100% of the seed may be destroyed in infected heads (Booth, 1971). *F. heterosporum* also occurs associated with root rots and affecting seed germination of trees, Gramineae and Leguminosae (Dorokhova 1965, Kalninya 1959). *F. heterosporum* may be used as a food source by some insects (Carrion & Bonet 2004). It also may function as a biological control agent of white mold (Sclerotinia sclerotiorum) on bean (Boland & Inglis 1989, Inglis & Boland 1992). *F. heterosporum* usually is regarded as nontoxic but some strains can produce fusaric acid (Bacon *et al*. 1996).

13. *Fusarium lateritium* Nees 1817

See Plate 13.

Section: Lateritium

Teleomorph: *Gibberella baccata* (Wallroth) Saccardo 1883

Sphaeria baccata Wallroth 1833

Isolates examined: 39 isolates, Isolates deposited: MH 224, MH 225, MH 226, MH 227, MH 228, MH 229, MH 229, MH 230, CBS 134.24 (AUMC 1253).

i. Macroscopic features

On PSA plates after 4 days: Growth rate ranges from 3.85-4.75 cm diameter, with a mean ± SD = 4.18 ± 0.7, aerial mycelium in 3 isolates white to pale yellow (M. 3A3) and pigmentation colourless, in 21 isolates aerial mycelium white to pale orange (M. 5-6A3)

and pigmentation reddish orange (M. 7AB6-8) and in the other 15 isolates aerial mycelium pastel red (M. 8A4) and pigmentation brownish orange (M. 7C6-8).

On PDA slants after 10 days: Growth rate ranges from 7.6-8.9 cm diameter, with a mean ± SD = 8.17 ± 0.39, aerial mycelium in 3 isolates white to yellow (M. 4A3) and pigmentation light yellow (M. 4A5), in 17 isolates aerial mycelium white to light orange (M. 5A4-5) and pigmentation brownish orange (M. 6C8) and the other 19 isolates produce orange red aerial mycelium (M. 8A-B7-8) and light brown pigmentation (M. 7D6-8).

ii. Microscopic features

Macroconidia: Straight to gently curved, thin walled, 3-7 septate, but predominantly 5 septate, 22-75 x 2.5-5 µm, with hooked or beaked apical cell and foot-shaped basal cell. Sporodochia are abundant and pale orange.

Microconidia: Generally absent, but in some isolates may be present in abundance, spindle or clavate-shaped, 0-3 septate, 10-30 x 2-3 µm, produced from monophialidic conidiogenous cells.

Chlamydospores: Sparse, oval to globose, singly or in chains.

iii. Physiological features

The eight isolates tested of *F. lateritium*i proved to be able to:

1- Grow on G25N medium with growth rate more than 2 cm diameter and produce grayish orange or orange aerial mycelium and orange or brown pigmentation.

2- Grow on mannitol sucrose medium and produce reddish aerial mycelium and red pigmentation.

3- Grow on CZID medium with growth rate less than 5 cm diameter and produce white or orange aerial mycelium and orange or grayish orange or light brown pigmentation.

4- Grow on DCPA medium with growth rate less than 5 cm diameter.

5- Grow on tannin-sucrose agar.

6- Produce urease, peroxidase, phosphatase and pyrocatechol oxidase enzymes.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Acetylmethylcarbinol compound.

F. lateritum is sometimes confusing with the related *F. stilboides* but dose not have the characteristic red colour pigmentation. In addition, *F. lateritum* could be distinguished from *F. stilboides* by its ability to produced urease enzyme, its faster growth rate on G25N medium, and slower growth on CZID medium. In addition to their morphology *F. lateritum* and *F. stilboides* could be distinguished from the other two species within section lateritium

(*F. udum* and *F. xylarioides*) by their capability of producing pyrocatechol oxidase enzyme. In the present work *F. lateritium* has been recovered from soil, rhizophere and rhizoplane of lentil plant, monthly fluctuation of cultivated soil and air. In Egypt, it was isolated from soil and healthy rice seeds (refer to Moubasher 1993).

F. lateritium has been isolated from numerous woody trees and shrubs where it may cause wilt, tip or branch dieback, or cankers. Hosts include citrus, hard-wood, coffee, plum, apple and mulberry trees (refer to Leslie & Summerell 2006).

F. lateritium is being developed as a potential biological control of Sclerotinia sclerotiorum on lettuce (Sitepu & Wallace 1984), and *Eutypa* spp. on graps (Munkvold & Marois 1993) and apricots (Carter 1983). *F. lateritium* has not been associated with human or animal toxicoses. *F. lateritium* is reported to produce enniatins and lateropyrone (refer to Leslie & Summerell 2006).

14. *Fusarium longipes* Wollenweber & Reinking 1925

See Plate 14.

Section: Gibbosum

Synonyms: *F. scirpi* Lamb & Fautr. var. *longipes* (Wollenweber & Reinking) Wollenweber 1931

F. equiseti (Corda) Sacc. var. *longipes* (Wollenweber & Reinking) Joffe 1974

Teleomorph: Not known.

Isolates examined: 2 isolates.

i. Macroscopic features

On PSA plates after 4 days: Growth rate ranges from 5.6-5.9 cm diameter with a mean ± SD = 5.75 ± 0.21, with white to greyish rose aerial mycelium (M. 9C4) and greyish red pigmentation (M. 10C5).

On PDA slants after 10 days: Growth is rapid and ranges from 9-9.3 cm length with a mean ± SD = 9.15 ± 0.21, with dense greyish red aerial mycelium (M. 9C5) and deep red pigmentation (M. 10C8). Tan to orange sporodochia usually develop in the center of the colony as the colony ages.

ii. Microscopic features

Macroconidia: Thin, extremely long, 5- to 7-septate, 36-130 x 2-4.5 µm, with thick walls and pronounced dorsi-ventral curvature, apical cell long, tapering and whip-like and elongated foot-shaped basal cell.

Microconidia: Absent.

Chlamydospores: Formed relatively abundantly and rapidly, produced singly, in chains and in clusters, smooth-walled to verrucose and brownish with age.

iii. Physiological features

The two isolates tested of *F. longipes* proved to be able to:

1- Grow on G25N medium with growth rate less than 2 cm diameter and produce deep orange aerial mycelium and orange pigmentation.

2- Grow on mannitol medium with growth rate more than 4 cm diameter with yellow aerial mycelium and grayish yellow pigmentation.

3- Grow on CZID medium with growth rate more than 5 cm diameter and produce white or pale red aerial mycelium and brownish red and dull red pigmentation.

4- Grow on DCPA medium with growth rate exceeding 5 cm diameter.

5- Grow on tannin-sucrose agar.

6- Produce urease, peroxidase and phosphatase enzymes.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Acetylmethylcarbinol compound.

3- Pyrocatechol oxidase enzyme.

Some isolates of *F. equiseti* can produce macroconidia that resemble those of *F. longipes*, but *F. longipes* produces red pigment while *F. equiseti* produces brown pigment on PDA & PSA media. Also, *F. longipes* had not the potentiality to produce pyrocatechol oxidase while *F. equiseti* had. Moreover *F. longipes* could be distinguished from the other 4 species within section Gibbosum (*F. acuminatum*, *F. equiseti* and *F. scirpi*) by its limited growth (not exceed 2 cm diameter) on G25N.

In the present work *F. longipes* has been recovered from rhizoplane of sesame plant. According to the available literatures *F. longipes* is a new record in Egypt. *F. longipes* is a tropical species (Backhouse & Burgess 1995) and has been recovered from many locations throughout the tropics (refer to Leslie & Summerell 2006) but also occurs in subtropical areas (Nelson *et al*. 1983). *F. longipes* has been associated with a disease of guava in India (Dwivedia *et al*. 1988, Dwivedi 1996) and with crown rot of wheat in southern Africa (Javaid & Ashraf 1977, van Wyk *et al*. 1987), but is generally regarded as a saprophytic fungus. Some strains of *F. longipes* are reported to produce beauvericin (Logrieco *et al*. 1998), but this species is generally thought to be nontoxigenic (Wing *et al*. 1994).

15. *Fusarium nisikadoi* T. Aoki & Nirenberg 1997

See Plate 15.

Section: Liseola

Teleomorph: Not known.

Isolates examined: 2 isolates.

i. Macroscopic features

On PSA plates after 4 days: Growth rate ranges from 5.45-5.9 cm diameter, with a mean ± SD = 5.65 ± 0.35, aerial mycelium white with orange pigmentation (M. 6A6).

On PDA slants after 10 days: Growth rate ranges from 8.5-8.75 cm length, with a mean ± SD = 8.63 ± 0.17, aerial mycelium white to pale yellow (M. 4A5) with brownish orange pigmentation (M. 6C6).

ii. Microscopic features

Macroconidia: Long, straight to falcate, 3-7 septate, 32-70 x 3.5-5µm, with acute apical cell and foot shaped basal cell, produced 2-3 weeks of incubation.

Microconidia: Abundantly clavate 0-3 septate, 6-22 x 2.5-4 µm, but occasionally pyriform 0- septate, 7.5-11.5 x 5-9.5 µm. Microconidia are produced in long chains and false heads on mono- and polyphialidic conidiogenous cells.

Chlamydospores: Absent.

iii. Physiological features

The two isolates tested of *F. nisikadoi* proved to be able to:

1- Produce acid on creatine sucrose agar.

2- Grow on G25N medium with growth rate not exceed 2 cm diameter and produce orange aerial mycelium and pigmentation.

3- Grow on mannitol sucrose medium and produce reddish aerial mycelium and pastel red pigmentation.

4- Grow on CZID medium with growth rate less than 5 cm diameter and produce white aerial mycelium and yellowish brown or golden yellow pigmentation.

5- Produce urease, phosphatase and peroxidase enzymes.

However, it was not capable of:

1- Growing on tannin-sucrose agar.

2- Producing acetylmethylcarbinol compound.

3- Producing pyrocatechol oxidase enzyme.

The presence of microconidia up to 3-septate is the most distinguished character in *F. nisikadoi* and these feature allow easy differentiation of this species with *F. verticillioides*, *F. thapsinum* and *F. proliferatum*. Also, *F. nisikadoi* can't grow on tannin-sucrose medium, but *F. proliferatum* and *F. verticillioides* can grow. Moreover, *F. nisikadoi* can be differentiated from the closely related species *F. thapsinum* by their conidiogenus cells, its limited growth on G25N (< 2 cm diameter) and its inability to produce pyrocatechol oxidase enzyme. In the present work this species has been reported from maize and sorghum grains, and this is to be a first reported of *F. nisikadoi* in Egypt.

F. nisikadoi was isolated for the first time from Phyyostachys nigra var. henonis (bamboo) and Triticum sativum (wheat) in Japan by Nirenberg & Aoki (1997). Isolates of *F. nisikadoi* produce trace amounts of moniliformin (Fotso *et al*. 2002).

16. *Fusarium nygamai* Burgess & Trimboli 1986

See Plate 16.

Section: Liseola

Teleomorph: *Gibberella nygamai* Klaasen & Nelson 1996

Gibberella fujikuroi (Sawada) Ito 1931 mating population G

Isolates examined: 62 isolates.

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 4.7- 5.65 cm diameter, with a mean ± SD = 5.06 ± 0.36, aerial mycelium in 5 isolates white to pale orange (M. 6A3) and light orange pigmentation (M. 6A5), in 27 isolates white mycelium to violet grey (M. 17C3) and light lilac pigmentation (M. 16A5), or white mycelium with pale violet (M. 17A3) and pigmentation lilac (M. 16B3) in 30 isolates.

On PDA slants after 10 days: Growth rate varies from 7.57-8.65 cm length, with a mean ± SD = 7.87 ± 0.18, aerial mycelium in 5 isolates white to light orange (M. 6A4) and deep orange pigmentation (M. 6A8), aerial mycelium in 24 isolates white to grayish Magenta (M. 13C3) with grayish Magenta pigmentation (M. 14D4), or aerial mycelium in 33 isolates purplish gray (M. 14C2) with purple pigmentation (M. 15B6).

ii. Microscopic features

Macroconidia: Slender, hyaline, straight to slightly curved, thin walled, 3-5 septate, 25-55 x 2.5-4 µm, with short and tapered apical cell and notched or foot-shaped basal cell.

Microconidia: Oval or clavate shaped. 0-1 septate, 5-15 x 1.5-2.5 µm, commonly in false heads and in short chains on mono- and polyphialidic conidiogenous cells.

Chlamydospores: Formed singly, in chains and in clusters, intercalary, smooth or rough walled.

iii. Physiological features

The eight isolates tested of *F. nygamai* proved to be able to:

1- Grow on G25N medium and produce pale red or pinkish aerial mycelium and orange white or grayish orange pigmentation.

2- Grow on mannitol sucrose medium and produce reddish white or pale red aerial mycelium and red or pastel red pigmentation.

3- Grow on CZID medium with growth rate exceed 5 cm diameter and produce white or pinkish or pale red aerial mycelium and reddish grey or pastel red or grayish brown pigmentation.

4- Grow on tannin-sucrose agar.

5- Produce acid on creatine sucrose agar.

6- Produce phosphatase enzyme.

However, it was not capable of producing urease enzyme

Moreover, different isolates gave variable responses towards the production of:

1- Acetylmethylcarbinol compound.

2- Peroxidase and pyrocatechol oxidase enzymes.

This species is characterized by formation of chlamydospores and production of microconidia from mono- and polyphialidic conidiogenous cells. Morphologically *F. nygamai* is intermediate between *F. verticillioides*, *F. thapsinum* and *F. oxysporum*. All of these species produce violet pigmentation in colonies on PDA and PSA. However, *F. nygamai* can be differentiated from *F. verticillioides* and *F. thapsinum* by the formation of chlamydospores and polyphialidic conidiogenous cells. *F. nygamai* can be differentiated from *F. oxysporum* by the formation of microconidia in long chains on mono- and polyphialidic conidiogenous cells. Moreover, *F. nygamai* can grow on tannin-sucrose medium, while *F. thapsinum* can't. *F. nygamai* can't produce urease enzyme while *F. verticillioides*, *F. thapsinum* and *F. oxysporum* produce it. This species has been reported in the present work from soil, sorghum grains, lentil seeds, rhizoplane of lentil and rhizosphere of lentil and sesame plants, air and monthly fluctuation soil.

F. nygamai was first observed during surveys of fungi associated with basal stalk and root rot of sorghum grains in New South Wales in 1977 and 1978 (Trimboli & Burgess 1985) when it was identified as *F. moniliforme*. *F. nygamai* is abundant in hot dry areas and tropical regions (refer to Leslie & Summerell 2006). *F. nygamai* can cause a root rot of broad beans

(Vicia faba) in the Sudan (Kurmut *et al*. 2002) and is associated with asparagus (Elmer *et al*. 1997), cotton (Zhang *et al*. 1996), maize (Etcheverry 1999), millet (Balmas *et al*. 2000), rice (Onyike *et al*. 1991), and sorghum (Onyike & Nelson 1992). Some strains of this species are pathogenic towards sorghum in an in vitro seedling pathogenicity assay (Leslie *et al*. 2005). Also, strains of *F. nygamai* are toxic to ducklings (Leslie *et al*. 2005) and may cause systemic infections in humans (Krulder *et al*. 1996). This species can produce beauvericin (Logrieco *et al*. 1996) and a number of variants of fusaric acid (Capasso *et al*. 1996, Amalfitano *et al*. 2002). Moreover, some strains of *F. nygamai* produce high levels of fumonisins (refer to Leslie & Summerell 2006).

17. *Fusarium oxysporum* Schlechtendahl 1824 emend. Snyder & Hansen 1940

See Plate 17.

Section: Elegans

Synonyms: *F. redolens* Wollenweber 1913

F. oxysporum Schlecht. emend. Snyd. & Hans. var. *redolens* Wollenweber) Gordon 1952

F. oxysporum Schlechtendahl 1824

(For more synonyms see Booth 1971, Gerlach & Nirenberg 1982, Nelson *et al*. 1983).

Teleomorph: Not known.

Isolates examined: 91 isolates, Isolates deposited:MH 100, MH 101, MH 102, MH 103, MH 104, MH 105, MH 106, AUMC 870, AUMC 1403.

i. Macroscopic features

On PSA plates after 4 days: Growth rate of isolates ranges from 4.5-6.35 cm diameter with a mean ± SD = 4.09 ± 0.52. Mycelium delicate white with purplish pink (M. 14A4) (55 isolates) or grayish Magenta (M. 13D4) (20 isolates) or white (16 isolates) with a purple pigmentation M. (13D5) in all isolates examined (91 isolates).

On PDA slants after 10 days: Growth rate on slants ranged from 7-8.25 cm length with a mean ± SD = 7.05 ± 0.43. Mycelia sparse or abundant ranged in colour from white (13 isolates) to pale violate (M. 15A3) (25 isolates) or violate white (M. 15A2) (53 isolates). Small pale brown, blue or violet sclerotia may be produced abundantly by some isolates. *F. oxysporum* usually produce pigmentation with a pale violet (M. 15A3) (17 isolates) or Magenta (M. 13C8) (74 isolates).

ii. Microscopic features

Macroconidia: Straight to slightly curved, thin walled, usually 3-5 septate, 27-60 x 3-5 µm. The 3 septate is most commonly found, with tapering and curved apical cell and foot shaped basal cell. Macroconidia sparse in some strains, but usually abundant in sporodochia.

Microconidia: Abundant, oval, elliptical, straight to curved, usually 0- septate, 5-12 x 2-3.5 µm. Produced in false heads on short monophialidic conidiogenous cells.

Chlamydospores: Formed abundantly and quickly, usually singly, in pairs, in clusters or in short chains. Chlamydospores may be terminal or intercalary with smooth or rough walled.

iii. Physiological features

The nine isolates tested of *F. oxysporum* proved to be able to:

1- Grow on G25N medium and produce white or pale yellow aerial mycelium and yellow pigmentation.

2- Grow on mannitol sucrose medium and produce white or reddish white or red aerial mycelium and red or brownish red or grayish red pigmentation.

3- Grow on CZID medium and produce white or pinkish white or pink aerial mycelium and brownish grey or purplish grey pigmentation.

4- Grow on tannin-sucrose agar.

5- Produce urease and phosphatase enzymes.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Acetylmethylcarbinol compound.

Also, different isolates showed variable response towards production of peroxidase and pyrocatechol oxidase enzymes.

Fusarium oxysporum is quiet distinct in the production of microconidia in false heads on short conidiogenous cells of monophialidic type and the production of chlamydospores. However, isolates of *F. oxysporum* are most difficult to distinguish from those of *F. solani* and *F. subglutinans* but *F. solani* forms microconidia in false heads on very long monophialidic conidiogenous cells. *F. subglutinans* is distinguished from *F. oxysporum* by the formation of microconidia from mono- and polyphialidic conidiogenous cells and the absence of chlamydospores. Also, *F. oxysporum* can produce urease enzyme but *F. solani* not produce. *F. subglutinans* could produce acetylmethylcarbinol compound but *F. oxysporum*

could not. In the present work *F. oxysporum* has been recovered from soil, air, maize grains, lentil seeds, rhizosphere and rhizoplane of lentil and sesame plants.

In Egypt, El-Abyad *et al*. (1988) isolated *F. oxysporum* from rhizosphere of sugarbeet. Also, it was isolated from various types of soils (cultivated, desert, salt march and reclaimed), rhizoplane and rhizosphere of many plants, air, wheat, barley and sorghum grains (refer to Moubasher 1993). Also, *F. oxysporum* was isolated from rhizosphere and rhizoplane of wheat plants cultivated in El-Minya Governorate (Abdel-Hafez *et al*. 1993), from rhizosphere soils and rhizoplane of sugarcane (Abdel-Hafez *et al*. 1995). *F. oxysporum* was reported from keratitis casa of 58 years old farmer from Assiut (Al-Hussaini *et al*. 2010). Kamel *et al*. (2007) isolated *F. oxysporum* from diseased tomato plants growing in different localities in Egypt.

F. oxysporum is the most widely dispersed of the *Fusarium* species and can be recovered from most soils - Arctic, tropical or desert, and cultivated or not (refer to Leslie & Summerell 2006). *F. oxysporum* includes many representatives that are pathogenic to plants often causing vascular wilt diseases (Beckman 1987). Many of *F. oxysporum* isolates appear to be host specific, which has resulted in the subdivision of the species into formae speciales and races that reflect the apparent plant pathogenic specialization (Booth 1971).

F. oxysporum has been associated with various human infections that include corneal infections (Rosa *et al*. 1994), various types of dermatitis (Uchiyama *et al*. 1987), burn wounds (Wheeler *et al*. 1981), and localized and systemic internal infections (refer to Leslie & Summerell 2006). *F. oxysporum* are generally viewed as non-toxigenic, but there are reports of a few strains of *F. oxysporum* that can produce zearalenone and one or more of the trichothecene mycotoxins. Also, it has been reported to produce beauvericin, fusaric acid, fusarin C and moniliformin (refer to Leslie & Summerell 2006).

18. *Fusarium poae* (Peck) Wollenweber 1913

See Plate 18.

Section: Sporotrichiella

Synonyms: *Sporotrichum poae* Peck 1902

Fusarium poae (Peack) Wollenweber f. *pallens* Wollenweber 1930

Teleomorph: Not known.

Isolates examined: 25 isolates, Isolates deposited: MH 156, MH 157, MH 158, MH 159, MH 160, MH 161, MH 162, MH 163.

i. Macroscopic features

On PSA plates after 4 days: Growth rate ranges from 5.15-5.85 cm diameter with a mean ± SD = 5.52 ± 0.21. Aerial mycelium appears hairy to felt and assumes a powdery appearance with the formation of microconidia. Aerial mycelium white to brownish red (M. 9C7) (10 isolates), white with pastel red (M. 9A4) (5 isolates) or white to reddish brown (M. 9E7) (10 isolates). Pigmentation dark red (M. 10C8) (15 isolates) or brown red pigmentation (M. 10D8) (10 isolates).

On PDA slants after 10 days: Growth rate ranged from 7.15-8.65 cm length with a mean ± SD = 7.96 ± 0.47. The aerial mycelium for 18 isolates were white to reddish brown (M.9E7) and for the other 7 isolates were white to grayish rose (M.11B5). All isolates produce reddish pigmentation. Sixteen isolates produce pigmentation red (M.11C8), but with golden yellow (M. 5C8) in 16 isolates or brownish orange (M. 6C8) in 9 isolates.

ii. Microscopic features

Macroconidia: Slender, relatively short, and falcate to almost lunate, 3-5 septate, but mainly 3- septate, 20-40 x 3-4.5 µm. The apical cell curved and tapering and the basal cell with well-developed foot cell. Sporodochia are not formed by all strains.

Microconidia: Abundant, globose or napiform, sometimes with a distict papilla, and usually 0- but occasionally 1-septate, 7-12 x 7-10 µm. Found in clusters that look like bunches of grapes, produced on globose to dolliform monophialides.

Chlamydospores: Formed very infrequently and not a reliable taxonomic character. Found in clumps or chains, in mycelia of older cultures.

iii. Physiological features

The eight isolates tested of *F. poae* proved to be able to:

1- Grow on G25N medium and produce pale yellow, pale orange aerial mycelium and orange, orange-red pigmentation.

2- Grow on CZID medium and produce reddish white aerial mycelium and brownish red pigmentation.

3- Grow on mannitol medium and produce grayish, brownish yellow pigmentation.

4- Produce urease, peroxidase and phosphatase enzymes.

However, it was not capable of:

1- Producing acid on creatine-sucrose agar.

2- Producing acetylmethylcarbinol compound.

3- Growing on tannin-sucrose agar.

The most distinguished character of this species is the small globose to dolliforme monphialidic conidiogenous cells. Culture of *F. poae* may resemble *F. sporotrichioides*, *F. fusarioides* and *F. tricinctum* on PDA or PSA medium. The lack of polyphialides in *F. poae* and *F. tricinctum* differentiates them from *F. sporotrichioides* and *F. fusarioides*. The distinctive conidiogenous cells of *F. poae* (globose to dolliform-shaped) differentiate it from *F. tricinctum*. Moreover, it could be distinguished *F. poae* from the other species recorded within section Sporotrichiella (*F. chlamydosporum*, *F. sporotrichioides*, *F. fusarioides* and *F. tricinctum*) by its incapability of growth on tannin-sucrose medium. In the present work *F. poae* has been reported from soil, rhizosphere and rhizoplane of sesame plants, monthly fluctuated soil samples and air.

In Egypt, it was isolated from barley grains collected from different places in Upper Egypt (Abdel-Hafez & Abdel-Kader 1980). Also, it was isolated from soil cultivated with wheat plant (Gherbawy *et al*. 2006). *F. poae* is regularly recovered from a variety of grains and the seeds of numerous native and domesticated plant species (refer to Leslie & Summerell 2006). It is usually considered a weak pathogen and although associated with head blight of wheat (Toth *et al*. 1993, Salas *et al*. 1999).

Many isolates of *F. poae* are weakly toxic or non-toxic. *F. poae* has been recovered from human tonsils (Maher *et al*. 1982). *F. poae* can produce fusarenone-X and nivalenol if inoculated onto maize and when inoculated onto barley, nivalenol is produced. Also, isolates of *F. poae* can produce beauvericin and fusarin C (refer to Leslie & Summerell 2006).

19. *Fusarium proliferatum* (Matsushima) Nirenberg 1976

See Plate 19.

Section: Liseola

Synonyms: *Cephalosporium proliferatum* Matsushima 1971

Teleomorph: *Gibberella intermedia* (Kuhlman) Samuels, Nirenberg & Seifert 2001

Gibberella fujikuroi var. *intermedia* Kuhlman 1982

Fusarium moniliforme var. *intermedium* Neish & Leggett 1981

Isolates examined: 10 isolates, Isolates deposited: MH 126, MH 127, MH 128, MH 129, MH 130, CBS 115.97 (AUMC 1265), AUMC 3190.

i. Macroscopic features

On PSA plates after 4 days: Growth rate ranges from 5.15-5.9 cm diameter with a mean ± SD = 5.45 ± 0.28. Mycelium grows rapidly, 3 isolates are white and the under surface

colourless and 7 isolates with white to lilac (M. 16C3) aerial mycelium and deep violet pigmentation (M. 16D8). Sporodochia when present, they may be tan to orange.

On PDA slants after 10 days: Growth rate of isolates ranges from 7.9-8.7 cm length with a mean ± SD = 8.38 ± 0.29. Abundant aerial mycelium, 3 isolates produce white aerial mycelium and no pigmentation, while the other seven isolates produce white with purple aerial mycelium (M.15A6) and dark Magenta pigmentation (M. 13F3).

ii. Microscopic features

Macroconidia: Slender, relatively straight, thin-walled, 3-5 septate, 25-50 x 2.5-4 µm, with curved apical cell and poorly developed basal cell.

Microconidia: Abundant, clavate shaped with a flattened base; 0- septate, 5-10 x 1.5-2.5 µm. Pyriform microconidia also may occur but generally are rare. Microconidia found in chains of varying, but usually moderate, length or false heads, from monoand polyphialidic conidiogenous cells.

Chlamydospores: Absent.

iii. Physiological features

The seven isolates tested of *F. proliferatum* proved to be able to:

1- Grow on G25N medium and produce orange aerial mycelium and orange or grayish orange pigmentation.

2- Grow on mannitol sucrose medium and produce white or reddish white or pale red aerial mycelium and red or grayish red pigmentation.

3- Grow on CZID medium and produce white or pastel pink aerial mycelium and grayish red or grayish brown pigmentation.

4- Grow on tannin-sucrose agar.

5- Produce urease, phosphatase and peroxidase enzymes.

However, it was not capable of producing pyrocatechol oxidase enzyme. *F. proliferatum* is characterized by the presence of polyphialidic conidiogenous cells and shorter chains of micrconidia. It is likely to be confused with *F. oxysporum*, *F. thapsinum* and *F. verticillioides* because PDA or PSA cultures often appear similar for these species. *F. proliferatum* can be differentiated from *F. oxysporum* by the presence of microconidia in chains (on mono- and polyphialidic conidiogenous cells) for *F. proliferatum* and presence of chlamydospores and microconidia in false heads (on monophialidic conidiogenous cells) for *F. oxysporum*. Morover, *F. proliferatum* can be differentiated from *F. thapsinum* and *F. verticillioides* by the presence of polyphialidies and shorter chains of microconidia. Also, *F. proliferatum* lacks the ability of producing pyrocatechol oxidase enzyme while

F. thapsinum produce this enzyme. This species has been reported in the present work from soil and maize grains. In Egypt, it was isolated from a case of a house-wife from Sohag suffering fungal keritites (Al-Hussaini *et al*. 2010). Gherbawy *et al*. (2006) isolated *F. proliferatum* from wheat field. Also, Aziz *et al*. (2007) isolated it from wheat, maize and barley grains.

F. proliferatum was first described as a Cephalosporium species by Matsusshima (1971) and described as a *Fusarium* species by Nirenberg (1976), Gerlach & Nirenberg (1982), Nelson *et al*. (1983), and Leslie & Summerell 2006).

F. proliferatum has been recovered from numerous environments, worldwide. It is a cause of root rot of pine seedlings (Ocamb *et al*. 2002), *Fusarium* crown and root rot of asparagus (Schreuder *et al*. 1995), stalk and rot of maize (Logrieco *et al*. 1995b, White 1999) and date palm decline (Abdalla *et al*. 2000). *F. proliferatum* may be endophytic in wheat, and alters the defense response in those plants (refer to Leslie & Summerell 2006). *F. proliferatum* may be mycoparasitic and is being evaluated as a biological control of Plasmopara viticola, the causel agent of grape downy mildew (Falk *et al*. 1996, Bakshi *et al*. 2001). Isolates of *F. proliferatum* can produce gibberellic acid and a wide variety of mycotoxins often at high levels including beauvericin, fusaproliferin, fusaric acid, fusarins, fumonisins and moniliformin (refer to Leslie & Summerell 2006).

20. *Fusarium pseudoanthophilum* Nirenberg & O' Donnell &Mubatanhema 1998

See Plate 20.

Section: Liseola

Teleomorph: Not known.

Isolates examined: 3 isolates.

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 5.35-5.65 cm diameter, with a mean ± SD = 5.52 ± 0.15, aerial mycelium white to pale orange (M. 6A3) to dull violet (M. 15D3) with pigmentation light orange (M. 6A4) to dull lilac (M. 16C3).

On PDA slants after 10 days: Growth rate varies from 8.75-9.5 cm length, with a mean ± SD = 9.02 ± 0.42, aerial mycelium white to pale orange (M. 5A3) to dull violet (M. 15D4) with pigmentation orange (M. 5A5) to dull violet (M. 15B3).

ii. Microscopic features

Macroconidia: Slender, falcate, thin walled, 3-5 septate, 30-55 x 2.5-4 µm with bent or pointed apical cell and foot-shaped basal cell.

Microconidia: Abundant, long-oval to obovoid, clavate or pyriform, 0-1 septate, 5-15 x 1.5-2.5 µm, formed in false heads and short chains on mono- and polyphialidic conidiogenous cells.

Chlamydospores: Not abundant, produced in chains. They may require up to two months of incubation to be formed.

iii. Physiological features

The three isolates tested of *F. pseudoanthophilum* proved to be able to:

1- Grow on G25N medium with growth rate less than 2 cm diameter, produce yellowish white aerial mycelium and yellow pigmentation.

2- Grow on mannitol sucrose medium and produce reddish white aerial mycelium and red or reddish brown pigmentation.

3- Grow on CZID medium with growth rate more than 5 cm diameter, and produce white or pinkish aerial mycelium and pastel red or reddish grey pigmentation.

4- Grow on tannin-sucrose agar.

5- Produce phosphatase enzyme.

However, it was not capable of producing:

1- Acid on creatine-sucrose agar.

2- Acetylmethylcarbinol compound.

3- Urease, peroxidase and pyrocatechol oxidase enzymes.

F. pseudoanthophilum is characterized by the production of mostly 0-septate, obovoid to clavate and some pyriform conidia that adhere in false heads and some times in very short chains and polyphialidic conidiogenous cells and by chains of chlamydospores. *F. pseudoanthophilum* resembles *F. anthophilum* in the formation of pyriforme conidia from both mono- and polyphialidic conidiogenous cells. However, *F. pseudoanthophilum* produces very short chains of microconidia and chlamydospores in chains, characters that are never observed for *F. anthophilum*. Also, *F. pseudoanthophilum* can grow on tannin-sucrose medium while *F. anthophilum* can't. Moreover, *F. pseudoanthophilum* lacks the ability to produce urease enzyme while *F. anthophilum* produces it. In addition to the distinct morphological characters, *F. pseudoanthophilum* could also be distinguished from *F. verticillioides* by the ability of producing acid from creatine and urease enzyme. This

species has been reported in the present work from sorghum grains and monthly fluctuated soils. According to the literatures available, this is the first report of this species in Egypt.

This species was first described by Nirenberg *et al*. (1998) from isolates recovered from maize; however it is not known if a pathogen or saprophyte is. Isolates of *F. pseudoanthophilum* can produce low levels of beauvericin (Fotso *et al*. 2002).

21. *Fusarium pseudonygamai* O'Donnell & Nirenberg 1998

See Plate 21.

Section: Liseola

Teleomorph: Not known.

Isolates examined: 2 isolates.

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 5.25-5.8 cm diameter, with a mean ± SD = 5.53 ± 0.39, aerial mycelium white to pale violet (M. 17A5) with grayish violet pigmentation (M. 17C5).

On PDA slants after 10 days: Growth rate in slants varies from 8.5-8.95 cm length, with a mean ± SD = 8.73 ± 0.32, aerial mycelium white to pastel violet (M. 18A4), pigmentation grayish violet (M. 17C4).

ii. Microscopic features

Macroconidia: Rarely formed, fusoid, 3-5 septate, 20-50 x 2.5-4 µm, with tapering apical cell and poorly developed basal cell.

Microconidia: obovoid to clavate, 0- septate, 10-15 x 1.5-2.5 µm, formed in false heads and chains of short to medium length on mono- and polyphialidic conidiogenous cells.

Chlamydospores: Absent, but only hyphal swellings may be observed.

iii. Physiological features

The two isolates tested of *F. pseudonygamai* proved to be able to:

1- Grow on G25N medium and produce white or pale orange aerial mycelium and yellow pigmentation.

2- Grow on mannitol sucrose medium and produce white aerial mycelium and pale red pigmentation.

3- Grow on CZID medium with growth rate more than 5 cm diameter, produce white to reddish grey aerial mycelium and grayish Magenta pigmentation.

4- Grow on tannin-sucrose agar.

5- Produce phosphatase enzyme.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Acetylmethylcarbinol compound.

3- Urease, peroxidase and pyrocatechol oxidase enzymes.

F. pseudonygamai is morphologically very similar to *F. nygamai* but can be differentiated from it by the absence of true chlamydospores in *F. pseudonygamai* and the presence of slightly longer microconidial chains. Also, *F. pseudonygamai* is not capable of producing acid on creatine sucrose medium while *F. nygamai* produce acid. In the present work, this species was recovered from soil and sorghum grains. According to the literatures available, this is the first report of this species in Egypt.

This species was first described by Nirenberg & O' Donnell (1998) from cultures previously recorded as *F. nygamai* (Marasas *et al*. 1988). Strains of *F. pseudonygamai* are toxic to ducklings and can produce moniliformin, but little or no fumonisins (Fotso *et al*. 2002, Leslie *et al*. 2005). Some strains of this species are pathogenic towards sorghum in an in vitro seedling pathogenicity assay (Leslie *et al*. 2005).

22. *F. sambucinum* Fückel 1869

See Plate 22.

Section: Discolor

Synonyms: *F. sulphureum* Schlecht 1824

Fusarium sambucinum Fuckel var. *minus* Wollenweber 1931

F. sambucinum Fuckel var. *trichothecioides* (Wollenweber) Bilai 1955

Teleomorph: *Gibberella pulicaris* (Fries) Saccardo 1877 var. pulicaris.

Isolates examined: 10 isolates, Isolates deposited: MH 203, MH 204, MH 205, MH 206, MH 207, AUMC 893, AUMC 1405, CBS 118.13 (=AUMC 1266).

i. Macroscopic features

On PSA plates after 4 days: Growth rate ranges from 5-5.65 cm diam. with a mean ± SD = 5.37 ± 0.21. Aerial mycelium floccose, white to golden yellow (M. 5B7). For all isolates pigmentation were light brown (M. 6D6).

On PDA after 10 days: Growth rate of isolates ranges from 7.5-8.15 cm length with a mean ± SD = 7.81 ± 0.22. Aerial mycelium abundant, dense, white with brownish yellow (M. 5C8) and pigmentation brown (M. 6D8). Light orange sporodochia are common.

ii. Microscopic features

Macroconidia: Curved, fusoid, lanceolate, 3-5 septate, 30-55 x 4-5.5 µm with pointed apical cell and foot-shaped basal cell.

Microconidia: Very rare, if present oval, 0-1 septate, produced singly or in small false heads on monophialidic conidiogenous cells.

Chlamydospores: Sparse, intercalary or terminal in hyphae, in chains and in clusters and with smooth walled. They are also found in cells of the macroconidia.

iii. Physiological features

The eight isolates tested of *F. sambucinum* proved to be able to:

1- Grow on G25N medium with growth rate not exceed 2 cm diameter, produce white or yellowish white aerial mycelium and yellow or orange yellow pigmentation.

2- Grow on mannitol sucrose medium with growth rate exceed 4 cm diameter, produce yellowish or orange white aerial mycelium and orange or dark yellow pigmentation.

3- Produce urease, phosphatase and peroxidase enzymes.

However, it was not capable of:

1- Growing on tannin-sucrose agar.

2- Producing acid on creatine sucrose agar.

3- Producing acetylmethylcarbinol compound.

4- Producing pyrocatechol oxidase enzyme.

F. sambucinum is the type species of the genus *Fusarium* and thus of particular importance in *Fusarium* taxonomy (Gams *et al*. 1997). It is characterized by curved, fusoid, lanceolate macroconidia with pointed apical cell and foot-shaped basal cell and sparse microconidia production on monophialidic conidiogenous cells and also sparse chlamydospores. *F. sambucinum* could be distinguished from the other 4 species within section discolor (*F. culmorum*, *F. graminearum*, *F. heterosporum* and *F. trichothecioides*) by its ability to produce urease enzyme and relatively limited growth on G25N medium. Also, it could be distinguished from the related species *F. trichothecioides* by its longer macroconidia, growth and colony colour on G25N medium and inability to produce acid on creatine-sucrose medium. In the present work it was isolated from soil and rhizosphere. In Egypt, Abdel-Hafez *et al*. (1995) isolated *F. sambucinum* from seasonal rhizosphere soils and rhizoplane of sugarcane.

Fusarium sambucinum is reported as a canker-causing organism of woody trees, forming cankers that result in death of the stem or branch as they become girdled (Booth 1971). Also, it has been reported, attacking seedlings of cereals (barley, maize, and oats),

forest trees, tomato and strawberry. It is more common in temperate parts of the world and has been recovered from the seeds and roots of a number of plants including alfalfa, cereals, cowpea, beet root, cabbage, Medicago spp. and soybeans (refer to Leslie & Summerell 2006). Also it was associated with deterioration of avocado fruits (Zauberman & Schiffmann-Nadel 1977, Darvas *et al*. 1987), fruit blotch of strawberry (Hunter & Jordan 1974)), and stem rot of pigweed (Blodgett *et al*. 1998, 2004). Trichothecenes and other mycotoxins are reported by many strains of *F. sambucinum* (Nelson *et al*. 1983, Leslie & Summerell 2006).

23. *Fusarium scirpi* Lambotte & Fautrey 1894

See Plate 23.

Section: Gibbosum

Synonyms: *F. chenopodium* Wollenweber and Reinking 1935

Teleomorph: Not known.

Isolates examined: 1 isolate, Isolates deposited: CBS 448.84 (=AUMC 1254).

i. Macroscopic features

On PSA plates after 4 days: Growth rate 4.65 cm diameter, with dense, white aerial mycelium and light brown pigmentation (M. 7D6).

On PDA slants after 10 days: Growth rate 8.5 cm length, aerial mycelium abundant, white to light brown (M. 6D6), pigmentation brown (M. 6E7).

ii. Microscopic features

Macroconidia: Relatively slender, but widest at the center, sickle-shaped, with a distinctive curvature, with tapering and elongate apical cell and well-developed foot shaped basal cell, 6-7 septate, 25-70 x 3.5-4.5 µm.

Microconidia: Ellipsoidal to clavate, 0-3 septate, 6-13 x 1.5-2.5 µm, produced singly or in false heads from mono- and polyphialidic conidiogenous cells. Cross-shaped polyphialides with three openings are common and diagnostic.

Chlamydospores: Abundant in old culture, smooth walled, in clumps and in chains, hyaline but become yellow or brown with age.

iii. Physiological features

The one isolate tested of *F. scirpi* proved to be able to:

1- Grow on G25N medium with growth rate more than 2 cm diameter; produce orange aerial mycelium and pigmentation.

2- Grow on mannitol medium with growth rate more than 4 cm diameter; produce yellowish white aerial mycelium and reddish yellow pigmentation.

3- Grow on CZID medium with growth rate more than 5 cm diameter, produce white aerial mycelium and light yellow pigmentation.

4- Grow on DCPA medium with growth rate exceed 5 cm diameter.

5- Grow on tannin-sucrose medium.

6- Produce urease, peroxidase and phosphatase enzymes.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Acetylmethylcarbinol compound.

3- Pyrocatechol oxidase enzyme.

F. scirpi is confusing with *F. equiseti* as their PDA cultures and macroconidia size and shape are similar. *F. scirpi* produces abundant microconidia on mono- and polyphialidic (with three openings) conidiogenous cells whereas *F. equiseti* produces no microconidia. Moreover, *F. scirpi* is not capable of producing pyrocatechol oxidase enzyme while *F. equiseti* produce it.

F. scirpi have been recovered from a number of countries including Australia, India, Iran, South Africa and Turkey, all of which are characterized by a semi-arid to arid climate (refer to Leslie & Summerell 2006).

F. scirpi probably is a saprophyte, but there are records of it association with decay of fruit of cucurbits (Reddy & Reddy 1983) and papaya (Gupta & Pathak 1990). *F. scirpi* usually is regarded as having little or no toxicity; especially relative to other species in section Gibbosum that can produce trichothecenes (refer to Leslie & Summerell 2006).

24. *Fusarium semitectum* Berkeley & Ravenel 1875

See Plate 24.

Section: Arthrosporiella

Synonyms: *Pseudofusarium semitectum* (Berkeley & Ravenel) Matsushima 1975

Fusarium pallidoroseum (Cooke) Saccardo

Fusarium incarnatum (Roberge) Saccardo 1848

Teleomorph: Not known.

Isolates examined: 27 isolates.

i. Macroscopic features

On PSA plates after 4 days: Growth rate ranges from 5.3-5.95 cm diameter with a mean ± SD = 5.63 ± 0.19, aerial mycelium floccose, white to grayish yellow (M. 4B3) (10

isolates) or white to brownish yellow (M. 5C7) (17 isolates). All isolates tested gave light brown pigmentation (M. 6D6).

On PDA slants after 10 days: Growth rate of isolates ranges from 7.5-8.75 cm length with a mean ± SD = 8.07 ± 0.37, aerial mycelium abundant dense, light brown (M. 5D5) (15 isolates) or white with brownish yellow (12 isolates) (M. 5C8). All isolates produce brown pigmentation (M. 6E5).

ii. Microscopic features

Macroconidia: Abundant with age, relatively slender with a curved dorsal surface and a straight ventral surface, apical cell curved and tapering to a point, and basal cell foot-shaped, 3-5 septate, 17-40 x 2.5-4 µm.

Microconidia/Mesoconidia: Scarce and often are difficult to find, pyriform to obovate, usually 1- septate, 10-20 x 2.5-3.5 µm. Mesoconidia are abundant in aerial mycelium, fusoid and 3-5 septate. Microconidia/Mesoconidia are produced on mono- and polyphialidic conidiogenous cells.

Chlamydospores: Found singly and in chains, globose and smooth, hyaline but may turn light yellow with age.

iii. Physiological features

The eight isolates tested of *F. semitectum* proved to be able to:

1- Grow on G25N medium with growth rate exceed 2 cm diameter, produce yellowish aerial mycelium and light brown or brownish orange or light orange pigmentation.

2- Grow on mannitol sucrose medium and produce yellow and yellowish orange aerial mycelium and yellow or grayish yellow pigmentation.

3- Grow on tannin-sucrose agar.

4- Produce urease, peroxidase, phosphatase and pyrocatechol oxidase enzymes.

However, it was not capable of producing

1- Acid on creatine-sucrose agar.

2- Acetylmethylcarbinol compound.

It was first described in 1875 by Berkeley and was recognized by Wollenweber & Reinking (1935), Booth (1971), Gerlach & Nirenberg (1982) and Nelson *et al*. (1983). Booth & Sutton (1984) proposed the name *F. pallidoroseum* for this species, but as pointed out by Subramanian (1971) and Nirenberg (1990) the species epithet *incarnatum* predates *pallidoroseum* by ~30 years and if the epithet were to change then it should be to *F. incarnatum*. Given this nomenclatural difficulty, we prefer to follow Leslie and Summerell and to use the more widely recognized name of *F. semitectum*. In addition to morphological

feature of macroconidia separating it from the other two species within section arthrosporiella it could also be distinguished based on physiologically criteria presented here by its capability of producing pyrocatechol oxidase enzyme. Also it could be distinguished from *F. camptoceras* by its ability to produce phosphatase enzyme and from *F. avenaceum* by its ability to produce urease enzyme and its rapid growth on G25N medium (> 2 cm diameter). In the present work *F. semitectum* has been reported from soil, sorghum, grain, rhizoshere of sesame plant and air. In Egypt it has been reported from soil, the air of Assiut, wheat and barley grains, rhizosphere of broad bean and it was reported to cause dampimg-off disease of tomato and stalk rot of maize (refer to Moubasher 1993).

F. semitectum has stated by Booth (1971) and Domach *et al*. (1980) is extremely common, particularly from tropical and subtropical countries. It is commonly isolated from cultivated and desert soils, from diverse aerial plant parts, e.g., banana fruits and palm fronds (Leslie & Summerell 2006). It has been reported to cause storage rot problems of mushrooms (Seth & Shandilya 1978), bananas and other fruits (Griffee 1976, Griffee & Burden 1976, Marin *et al*. 1996), and is one of the dominant fungi on the grain of pearl millet (Wilson *et al*. 1993, Wilson 2002).

F. semitectum may be a biological control of ergot on pearl millet by reducing sclerotia formation and development (Rao & Thakur 1988). *F. semitectum* has been associated with bovine pulmonary emphysema (Linnabary & Tarrier 1988). A list of toxins produced by *F. semitectum* and could be found in Leslie & Summerell (2006).

25. *Fusarium solani* (Martius) Appel & Wollenweber emend. Snyder & Hansen 1941

See Plate 25.

Section: Martiella

Synonyms: *Fusisporium solani* Martius 1842

Fusarium javanicum Koorders 1907

Fusarium ventricosum Appel & Wollenweber 1910

Fusarium tumidum Sherb. 1928

Fusarium tumidum var. *coeruleum* Bugn. 1939

Fusarium illudens Booth 1971

Telemorph: *Haemanectria haematococca* (Berkeley & Broome) Samuels & Nirenberg 2001

Nectria haematococca Berkeley & Broome 1873

Isolates examined: 202 isolates, Isolates deposited: MH 107, MH 108, MH 109, MH 110, MH 111, MH 112, MH 113, MH 114.

i. Macroscopic features

On PSA plates after 4 days: Growth rate of isolates ranges from 4-7.2 cm diameter, with a mean ± SD = 6.25 ± 5.58, abundant aerial mycelium, white in 88 isolates and no pigments, while 60 isolates produce yellowish white (M. 4A2-6) aerial mycelium and pigmentation orange grey (M. 5B3-6). Cultures of 52 isolates had pale yellow (M. 3A3-5) mycelia and light brown (M. 7D4-8) pigmentation. One isolate produce white aerial mycelium and white with grayish green (M. 25D5) pigmentation, also one isolate produce white aerial mycelium and white with deep blue (M. 21D8) pigmentation.

On PDA slants after 10 days: Growth rate varies from 7.2-9.55 cm length, with a mean ± SD = 8.35 ± 6.05, abundant aerial mycelium, white in 88 isolates and no pigments, while 60 isolates produce pale yellow (M. 3A2-3) aerial mycelium and pigmentation golden yellow (M. 5B7-8). Cultures of 52 isolates had light yellow (M. 4A4-5) mycelia and light brown (M. 7E4-8) pigmentation. One isolate produce white aerial mycelium and white with grayish green (M. 25D6) pigmentation, also one isolate produce white aerial mycelium and white with deep blue (M. 21D9) pigmentation.

ii. Microscopic features

Macroconidia: Abundant in sporodochia, relatively wide, straight, stout, 3-7 septate, 35-55 x 4.5-6 µm, with blunted and rounded pointed and somewhat beaked apical cell and poorly developed or well-marked foot-shaped or rounded basal cell.

Microconidia: Abundant, oval, ellipsoid, reniform and fusiform, 0-1 septate, occasionally 2 septate, 8-16 x 2-4 µm, produced in false heads from quite long monophialidic conidiogenous cells.

Chlamydospores: Formed rapidly, globose to oval, smooth or rough walled, usually singly, in pairs, or in short chains.

iii. Physiological features

The eight isolates tested of *F. solani* proved to be able to:

1- Grow on G25N medium with growth rate less than 2 cm diameter, produce white or orange aerial mycelium and yellowish orange or orange gray or orange pigmentation.

2- Grow on mannitol medium and produce yellowish or orange mycelium and orange pigmentation.

3- Grow on CZID medium and produce white aerial mycelium and light yellow to brown or brownish grey or dull green pigmentation.

4- Grow on DCPA with growth rate exceeding 5 cm diameter.

5- Grow on tannin-sucrose agar.

6- Produce peroxidase, phosphatase and pyrocatechol oxidase enzymes.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Acetylmethylcarbinol compound.

3- Urease enzyme.

Fusarium solani is one of the few *Fusarium* species easily identifiable. The most distinguished character is long monophialidic conidiogenous cells. It could be confused with *F. oxysporum* in many aspects of morphology; however it can be distinguished by the long monophialidic conidiogenous cells. Also, microconidia of *F. solani* are wider, more oval in shape, and thicker walls than those of *F. oxysporum.* Moreover, they could be distinguished by the characteristic orange pigmentation of *F. solani* versus the reddish pigmentation of *F. oxysporum* on mannitol agar medium. *F. solani* is not capable of producing urease enzyme while *F. oxysporum* is. This species has been reported in the present work from soil, maize and sorghum grains, sesame seeds, monthly fluctuations of soil and air, rhizoplane and rhizosphere of lentil and sesame plants. In Egypt, it has been reported from soil, rhizosphere, rhizoplane and phyllosphere of broad bean cultivated in the Oases, Western Desert, wheat and barley grains and several others (refer to Moubasher 1993). Abdel-Hafez (1974) and Abdel-Hafez *et al*. (1990a,c, 1993, 2000) isolated it from diiferent substrates. Also, Mohamed *et al*. (2004) isolated *F. solani* from branched broomrape plants. *F. solani* was reported from 18 years old man student from Assiut suffering from keratitis (Al-Hussaini *et al*. 2010).

F. solani has a cosmopolitan distribution. It can be found in numerous soils (refer to Leslie & Summerell 2006) and is one of the few species of *Fusarium* that can be found at high frequency from soils in rain forest habitats (Summerell *et al*. 1993).

F. solani is, however, well documented as a pathogen of a number of legumes and other tropical plants where it often is associated with cankers and dieback problems of trees (Nelson *et al* 1981). Some economically important plants with significant diseases caused by *F. solani* include avocado, beans, citrus, cowpeas, potato, and squash (refer to Leslie & Summerell 2006). The fungus may serve as a food source for some tree-boring insects (Hara & Beardsley 1979). With respect to human pathogenicity, *F. solani* has been recovered from eyes, nails and skin, infected wounds, and systemically infected cancer (refer to de Hoog *et al*. 2000, Leslie & Summerell 2006). Some strains of *F. solani* produce the immunosuppressive compound cyclosporine A, which could increase the pathogenic potential of this fungus

towards animals, especially in a direct infection. Other compounds known to be synthesized by *F. solani* include fusalanipyrone, fusaric acid, and moniliformin (refer to Leslie & Summerell 2006).

26. *Fusarium sporotrichioides* Sherbakoff 1915

See Plate 26.

Section: Sporotrichiella.

Synonyms: *F. sporotrichiella* var. *sporotrichioides* (Corda) Bilay 1955

F. sporotrichioides var. *minor* Wollenweber 1935

Teleomorph: Not known.

Isolates examined: 29 isolates, Isolates deposited: MH 164, MH 165, MH 166, MH 167, MH 168, MH 169, MH 170, MH 171.

i. Macroscopic features

On PSA in plates after 4 days: Growth rate ranges from 3.95-5.65 cm diameter, with a mean ± SD = 5.2 ± 0.16, with floccose, white to pastel pink (M. 11A4) aerial mycelium and red pigmentation (M. 11B8).

On PDA in slants after 10 days: Growth rate varies from 7.55-8.6 cm length, with a mean ± SD = 8.03 ± 0.26, with floccose, white to pale red (M. 11A3) aerial mycelium and dark red pigmentation (M. 11C8).

ii. Microscopic features

Macroconidia: Falcate to curved, 3-5 septate, commonly 3 septate, 25-55 x 3.5-5 µm, with curved and tapering apical cell and a pedicellate basal cell.

Microconidia/Mesoconidia: Abundant, microconidia pyriform, ellipsoid to fusoid, 0-1 septate, 7-10 x 3-5 µm.

Mesoconidia fusoid, may be up to 5-septate. Produce singly, in small clumps or in false heads from mono- and polyphialidic conidiogenous cells.

Chlamydospores: Formed rapidly, globose, smooth, singly and in chains, becoming a light brown with age.

iii. Physiological features

The eight isolates tested of *F. sporotrichioides* proved to be able to:

1- Grow on G25N medium with growth rate more than 2 cm diameter, produce yellow or orange aerial mycelium and brown or golden brown pigmentation.

2- Grow on mannitol medium and produce yellow or orange yellow or reddish yellow mycelium and grayish yellow or grayish orange or reddish yellow pigmentation.

3- Grow on CZID medium with growth rate more than 5 cm diameter, produce reddish white aerial mycelium and reddish brown or pastel red pigmentation.

4- Grow on tannin-sucrose agar.

5- Produce urease, peroxidase, phosphatase and pyrocatechol oxidase enzymes.

However, it was not capable of producing:

1- Acid on creatine-sucrose agar.

2- Acetylmethylcarbinol compound.

The presence of two types of microconidia and the presence of polyphialidic conidiogenous cells are the most distinguished characters in *F. sporotrichioides*. Culture of *F. sporotrichioides* on PDA or PSA can be confused with the closely related species *F. poae*, *F. fusarioides* and *F. tricinctum*. The presence of polyphialidic conidiogenous cells distinguishes it from *F. poae* and *F. tricinctum*, while the presence of two types of microconidia distinguishes it from *F. fusarioides*. Moreover, isolates *F. sporotrichioides* were capable of producing urease enzyme and this differentiating them from those of *F. tricinctum*. In the present work *F. sporotrichioides* has been reported from soil, rhizosphere of lentil plants and monthly collected cultivated soil.

In Egypt, *F. sporotrichioides* has been recovered from horse-hair fragments (Abdel-Hafez *et al*. 1990b) and from different wheat plants (rhizosphere and rhizoplane) (Gherbawy *et al*. 2006). *F. sporotrichioides* is widespread but somewhat sparse on a wide variety of plants and in soil throughout the temperate regions of the world. It has also been recorded from soil in India and seeds in Canada, Korea and Poland (refer to Leslie & Summerell 2006). *F. sporotrichioides* has also been implicated in a variety of very serious animal diseases, including scabby grain intoxication and bean hull poisoning in Japan, mouldy corn toxicosis in the USA, and fescue foot in the USA, Australia and New Zealand (Marasas *et al*. 1984).

F. sporotrichioides can produce trichothecenes, butenolide, fusarin C, moniliformin, scirpentriol, steroids, and zearalenone. It also synthesizes the enzyme cyclophilin, which can degrade cyclosporin A (refer to Leslie & Summerell 2006).

27. *Fusarium stilboides* Wollenweber 1924

See Plate 27.

Section: Lateritium

Synonyms: *F. lateritium* var. *longum* Wollenweber 1931

F. stilboides var. *minus* Wollenweber 1931

Telemorph: *Gibberella stilboides* Gordon ex Booth 1971

Isolates examined: 2 isolates.

i. Macroscopic features

On PSA plates after 4 days: Growth rate ranges from 5.3-5.55 cm diameter, with a mean ± SD = 5.43 ± 0.18, floccose, with white to reddish brown aerial mycelium (M. 9C6-7) and dark red pigmentation (M. 10C8).

On PDA slants after 10 days: Growth rate varies from 7.05-7.76 cm length, with a mean ± SD = 7.41 ± 0.5, floccose, with white to brownish red aerial mycelium (M. 10D7) and dark red pigmentation (M. 11C8).

ii. Microscopic features

Macroconidia: Fusoid and straight to slightly curved with the widest point above the center, 3-7 septate, 20-82 x 3-5 µm, with pointed or beaked apical cell and a distinctly pedicellate foot-shaped basal cell.

Microconidia: Absent.

Chlamydospores: Formed sparsely, globose, smooth, singly, in pairs or in chains.

iii. Physiological features

The two isolates tested of *F. stilboides* proved to be able to:

1- Grow on G25N medium with growth rate less than 2 cm diameter, produce orange white aerial mycelium and orange pigmentation.

2- Grow on mannitol medium and produce yellow or reddish yellow aerial mycelium and greyish yellow or orange pigmentation.

3- Grow on CZID medium with growth rate more than 5 cm diameter, produce pinkish white aerial mycelium and brownish red pigmentation.

4- Grow on DCPA medium with growth rate more than 5 cm diameter.

5- Grow on tannin-sucrose agar.

6- Produce peroxidase, phosphatase and pyrocatechol oxidase enzymes.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Acetylmethylcarbinol compound.

3- Urease enzyme.

F. stilboides is separated from *F. lateritium* on the basis of the red pigmentation of the PSA and PDA cultures. Also, *F. stilboides* could be distinguished from the other closely related species *F. lateritium* and *F. xylarioides* by its inability to produce urease enzyme and from *F. udum* by its ability to produce pyrocatechol oxidase enzyme. It could also be differentiated from the other 3 species within section Lateritium by its faster growth rate on

DCPA and CZID media. In the present work *F. stilboides* has been isolated from soil. *Fusarium stilboides* has been found attacking immature berries of *Coffea liberica* in Trinidad by Gordon (1956) and both berries and leaves of *C. arabica* in Malawi by Siddiqi & Corbett (1963), but this type of damage appears to be unimportant.

28. *Fusarium subglutinans* (Wollenweber & Reinking) Nelson, Toussoum & Marasas 1983

See Plate 28.

Section: Liseola

Synonyms: *F. moniliforme* var. *subglutinans* Wollenweber & Reinking 1925

Teleomorph: *Gibberella subglutinans* (Edwards) Nelson, Toussoum & Marasas 1983

Gibberella fujikuroi var. *subglutinans* Edwards 1933

Isolates examined: 21 isolates, Isolates deposited: MH 131, MH 132, MH 133, MH 134, MH 135, MH 136, MH 137, CBS 215.76 (=AUMC 1268).

i. Macroscopic features

On PSA plates after 4 days: Growth rate ranges from 4.7-5.6 cm diameter, with a mean ± SD = 5.1 ± 0.28, aerial mycelium floccose, with white aerial mycelium and colourless pigmentation in 7 isolates, aerial mycelium violet white (M. 17A2) and pigmentation grayish violet (M. 16B-C4-5) in 10 isolates, and in the other 4 isolates mycelium pale violet (M. 15A3) and pigmentation deep violet (M. 16D7).

On PDA slants after 10 days: Growth rate ranges from 7.55-9.15 cm length, with a mean ± SD = 8.57 ± 0.39, aerial mycelium abundant, white and pigmentation colourless in 7 isolates, aerial mycelium pastel violet (M. 15A4) and pigmentation violet (M. 17B-C6-7) in 8 isolates, and in 6 isolates mycelium lilac (M. 16B4) and pigmentation deep violet (M. 16DE5- 6).

ii. Microscopic features

Macroconidia: Usually rare, relatively slender, slightly falcate, thin-walled, 3-5 septate, 30-55 x 3-4.5 µm, with curved apical cell and foot-shaped basal cell.

Microconidia: Abundant, oval to obclavate, 0-septate, 8- 12 x 2.5-3 µm, produced only in false heads from mono- and polyphialidic conidiogenous cells.

Chlamydospores: Absent.

iii. Physiological features

The eight isolates tested of *F. subglutinans* proved to be able to:

1- Grow on G25N medium and produce white or pale red aerial mycelium and orange pigmentation.

2- Grow on mannitol medium and produce white or reddish aerial mycelium and reddish brown or grayish red or red pigmentation.

3- Grow on CZID medium with growth rate more than 5 cm diameter, produce white or pinkish or grayish rose aerial mycelium and grayish ruby or pinkish or reddish grey pigmentation.

4- Grow on tannin-sucrose medium.

5- Acetylmethylcarbinol compound.

6- Produce urease and phosphatase enzymes/

However, it was not capable of producing acid on creatine sucrose agar. Also, different isolates gave variable response towards the production of peroxidase and pyrocatechol oxidase enzymes.

F. subglutinans is characterized by the production of microconidia only in false heads, which distinguished it from both *F. proliferatum* and *F. verticillioides*, which both produce microconidia in chains. The lack of chlamydospore production by *F. subglutinans* is the major morphological character distinguishing it from *F. oxysporum*. Also, the presence of polyphialidic conidiogenous cells and its inability to produce acid in creatine sucrose medium distinguish it from *F. verticillioides*. *F. subglutinans* differs from the closely related species *F. anthophilum* by the absence of pyriform and globose microconidia produce by *F. anthophilum*. Moreover, *F. subglutinans* can grow on tannin-sucrose medium while *F. anthophilum* not grow. This species in the present work was recovered from soil, lentil and sesame seeds, rhizoplane of lentil plants and air. In Egypt, *F. subglutinans* has been recovered from some Egyptian cereals grains (Abdel-Hafez *et al*. 1987, Aziz *et al*. 2007). Also, Gherbawy *et al*. (2006) isolated *F. subglutinans* from wheat field.

F. subglutinans is more common in cooler areas where maize is grown and is associated with stalk rot and cob rot of maize (Edwards 1935, White 1999); also on heads and stalks of sorghum (Booth 1971). *F. subglutinans* can persist in maize debris either on the soil surface or buried in a field for at least 21 months (Cotton & Munkvold 1998). Other hosts for *F. subglutinans* include banana (Knight 1982, Jimenez *et al*. 1993), cowpea (Kritzinger *et al*. 2003), millet (Onyike *et al*. 1991), soybean (Schlub *et al*. 1981) and wild rice (Nyvall *et al*. 1999). *F. subglutinans* can cause endophthalmitis (Srdic *et al*. 1993) and is resistant to most clinical antifungal.

Feed contaminated with *F. subglutinans* was toxic to rats. Cultures of *F. subglutinans* often are toxic to ducklings due to the large amount of moniliformin that can be produced in these cultures. *F. subglutinans* produces little or no fumonisins, but can produce moniliformin, beauvericin, and high levels of fusaproliferin (refer to Leslie & Summerell 2006).

29. *Fusarium thapsinum* Klittich, Leslie, Nelson & Marasas 1997

See Plate 29.

Section: Liseola.

Teleomorph: *Gibberella thapsina* Klittich, Leslie, Nelson & Marasas 1997.

Isolates examined: 2 isolates, Isolates deposited: AUMC 1402, AUMC 5903.

i. Macroscopic features

On PSA plates after 4 days: Growth rate ranges from 5.45-5.65 cm diameter with a mean ± SD = 5.55 ± 0.14, aerial mycelium white to light yellow pigmentation (M. 3A5).

On PDA slants after 10 days: Growth rate ranges from 8.5-8.65 cm length with a mean ± SD = 8.58 ± 0.11, aerial mycelium white to deep yellow pigmentation (M. 4A8).

ii. Microscopic features

Macroconidia: Often difficult to find, relatively slender, straight, thin walled, 3-5 septate, 25-55 x 2.5-3.5 µm with curved and tapering apical cell and poorly developed foot shaped basal cell.

Microconidia: Abundant, clavate with a fattened base, but occasionally napiforme, 0- septate, 10-15 x 1.5-2.5 µm, commonly in long chains, but false heads occur occasionally, on monophialidic conidiogenous cells.

Chlamydospores: Absent.

iii. Physiological features

The two isolates tested of *F. thapsinum* proved to be able to:

1- Grow on G25N medium with growth rate exceed 2 cm diameter, produce orange white aerial mycelium and grayish orange pigmentation.

2- Grow on mannitol medium with growth rate not exceed 5 cm diameter, produced pale red mycelium and brownish red pigmentation.

3- Grow on CZID medium and produced white aerial mycelium and pastel red pigmentation.

4- Produce acid on creatine sucrose agar.

5- Produce urease, peroxidase, phosphatase and pyrocatechol oxidase enzymes.

However, it was not capable of:

1- Growing on tannin-sucrose agar.

2- Producing acetylmethylcarbinol compound.

Fusarium thapsinum is characterized by the production of napiforme microconidia from monophialidic conidiogenous cells, however the production of this type of conidia differentiate it from *F. verticillioides* which produce only clavate shaped microconidia. It also is similar to *F. proliferatum*, but *F. thapsinum* produces both mono- and polyphilaidic conidiogenous cells. Additionally, *F. thapsinum* could be distinguished from both *F. proliferatum* and *F. verticillioides* by inability to grow on tannin-sucrose medium. Growth rate on DCPA (< 5 cm diameter) and on mannitol media (< 4 cm diameter) are also diagnostic for these species. *F. thapsinum* has been recovered in the present work from sorghum grains. *F. thapsinum* was first described by Klittich *et al*. (1997) prior to that it was recognized as *F. moniliforme*. The splitting of *F. thapsinum* was made because of the recognition of the teleomorph (G. thapsina) as a separate mating population (Klittich & Leslie 1992) and a number of physiological characteristics including host preference and toxin production.

F. thapsinum causes stalk rot and grain mold of sorghum (refer to Leslie & Summerell 2006) and is very pathogenic towards sorghum seedlings in an in vitro assay system (Leslie *et al*. 2005). The degree of pathogenicity is dependent on growth stage (Tarekegn *et al*. 2004) and genetic background of the host (Tesso *et al*. 2004). *F. thapsinum* also is associated with grain mold of sorghum (Bandyopadhyay & Mughogho 1988, Rodriguez *et al*. 2000), bananas, maize and peanuts (Klittich *et al*. 1997, Leslie & Plattner 1991). *F. thapsinum* is toxic to ducklings and can produce high levels of moniliformin, but little more than trace amounts of fumonisins. It also can produce fusaric acid (refer to Leslie & Summerell 2006).

30. *Fusarium trichothecioides* Wollenweber 1912

See Plate 30.

Section: Discolor

Synonyms: *Fusarium sambucinum* Fuckel var. *trithecioides* (Wollenweber) Bilai 1955

Teleomorph: Not known.

Isolates examined: 7 isolates, Isolates deposited: MH 208, MH 209, MH 210, MH 211, MH 212, MH 213.

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 5.75-6.5 cm diameter with a mean ± SD = 6.09 ± 0.28, aerial mycelium floccose, white to greyish orange (M. 5B4), pigmentation light brown (M. 6D6).

On PDA slants after 10 days: Growth rate varies from 8.5-9.45 cm length with a mean ± SD = 8.89 ± 0.34, aerial mycelium white with brownish orange (M. 5C5) and pigmentation brown (M. 7D8).

ii. Microscopic features

Macroconidia: Stout, curved, short and with a short beaked apical cell; and a short foot-shaped (with a well-marked heel) basal cell, they are 3-5 septate, 14-27 x 5-6.5 µm.

Microconidia: Absent.

Chlamydospores: Formed sparsely, in chains or clumps, smooth walled and globose.

iii. Physiological features

The six isolates tested of *F. trichothecioides* proved to be able to:

1- Grow on G25N medium with growth rate exceed 2 cm diameter, produce orange aerial mycelium, and golden yellow or brownish yellow pigmentation.

2- Grow on mannitol medium and produce yellow or yellowish white mycelium and reddish yellow or yellowish orange or yellow pigmentation.

3- Grow on CZID medium and produce white or yellow aerial mycelium and yellow or yellowish brown or grayish yellow pigmentation.

4- Produce acid on creatine sucrose agar.

5- Produce peroxidase and phosphatase enzymes.

However, it was not capable of:

1- Growing on tannin-sucrose agar.

2- Producing urease enzyme.

Moreover, different isolates gave variable responses towards the production of:

1- Acetylmethylcarbinol compound.

2- Pyrocatechol oxidase enzyme.

This species was included together with *F. sulphureum* within *F. sambucinum sensu stricto* (Nirenberg 1995). However it was considered as a separate species by Booth (1971). *F. trichothecioides* is characterized by stout, short (up to 27 µm long) and curved macroconidia with a short beaked apical cell and a short foot-shaped basal cell. Also, it was characterized by the absence of microconidia and sparse production of chlamydospores. Strains of *F. trichothecioides* morphological are near to strains of *F. camptoceras*,

F. sambucinum, *F. semitectum* and *F. chlamydosporum*. However, it could be distinguished by there short and curved macroconidia. It could be also distinguished from the other 4 species recorded within section discolor (*F. culmorum*, *F. graminearum*, *F. sambucinum* and *F. heterosporum*) by its ability to produce acid on creatine-sucrose medium. Moreover, it could be distinguished from *F. sambucinum* [include *F. trichothecioides* as synonym name (Nirenberg 1995)] by its inability to produce urease enzyme, its faster growth and colony colour on G25N medium and its distinct macroconidia morphology (up to 27 mm versus 55 mm long). In the present work it has been isolated from soil. *F. trichothecioides* occurs widely but its economic importance is principally as a storage rot, chiefly of potatoes (white powdery dry rot) (Booth 1971).

31. *Fusarium tricinctum* (Corda) Saccardo 1886

See Plate 31.

Section: Sporotrichiella.

Synonyms: *Selenosporium tricinctum* Corda 1838

F. sporotrichioides Sherb. var. *tricinctum* (Corda) Raillo 1950

Teleomorph: *Gibberella tricincta* El-Gholl, McRitchie, Schoulties & Ridings 1978

Isolates examined: 21 isolates, Isolates deposited: MH 172, MH 173, MH 174, MH 175, CBS 253.50 (=AUMC 1269).

i. Macroscopic features

On PSA in plates after 4 days: Growth rate ranges from 4.85-5.5 cm diameter, with a mean ± SD = 4.69 ± 1.56, with floccose, reddish white (M. 11A2) aerial mycelium and red pigmentation (M. 11C8).

On PDA in slants after 10 days: Growth rate ranges from 8-9.35 cm length, with a mean ± SD = 8.56 ± 1.06, floccose, pastel pink (M. 11A4) aerial mycelium and dark red pigmentation (M. 10C8).

ii. Microscopic features

Macroconidia: Falcate, or more strongly curved, 3-5 septate, 25-55 x 3-4.5 µm, with curved and tapering apical cell and well developed foot shaped basal cell.

Microconidia: Abundant, napiform, oval, pyriform, 0-1 septate, 7-20 x 4.5-7.5 µm, on false heads like a bunch of grapes, from monophialidic conidiogenous cells.

Chlamydospores: Sparse, singly or in chains, globose with smooth wall.

iii. Physiological features

The five isolates tested of *F. tricinctum* proved to be able to:

1- Grow on G25N medium with growth rate more than 2 cm diameter, produce white or pale red aerial mycelium and orange or greyish red pigmentation.

2- Grow on mannitol medium with growth rate less than 4 cm diameter, produce pale yellow or gryish yellow mycelium and reddish yellow or orange yellow or yellow pigmentation.

3- Grow on CZID medium and produce reddish aerial mycelium and pigmentation.

4- Grow on tannin-sucrose agar.

5- Produce peroxidase and phosphatase enzymes.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Acetylmethylcarbinol compound.

3- Urease enzyme.

Also, these isolates gave variable results with production of pyrocatechol oxidase enzyme. *F. tricinctum* cultures on PDA or PSA can be confused with *F. poae*, *F. sporotrichioides* and *F. fusarioides*. *F. tricinctum* could be differentiated from these species by the micrconidial shape. Also, *F. tricinctum* could be distinguished from these species by its incapability of producing urease enzyme. In the present work this species has been reported from soil, rhizosphere, rhizoplane, monthly fluctuated soil and air. In Egypt, it was isolated by Depasquale *et al*. (1990). Also, it was isolated from fish feeds by Abdelhamid (2007).

F. tricinctum is usually occurs as a saprophyte or a weak parasite in temperate regions. This species generally is not regarded as a plant pathogen and has not been associated with any human or animal toxicoses. It produces the toxins fusarin C, enniatins and moniliformin, and the secondary metabolites acuminatopyrone, fosfonochlori and visoltricin (refer to Leslie & Summerell 2006).

32. *Fusarium udum* Butler 1915

See Plate 32.

Section: Lateritium

Synonyms: *F. oxysporum* Schlecht. emend. Snyd & Hans. f. sp. *udum* (Butler) Snyd. & Hans. 1940

Teleomorph: *Gibberella indica* B. Rai & R. S. Upadhyay 1982

Isolates examined: 42 isolates, Isolates deposited: MH 231, MH 232, MH 233, MH 234, MH 235 (Table 4).

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 4.7-5.85 cm diameter with a mean ± SD = 5.36 ± 0.31. Ten isolates produced white or little aerial mycelium with grayish violet pigmentation (M.17D5), but the remaining isolates (32) do not produced aerial mycelium and be nearly covered by a sheet of conidia. The pigmentation for all isolates tested were deep purple (M. 14F5).

On PDA slants after 10 days: Growth rate varies from 8.15-9.4 cm length with a mean ± SD = 8.56 ± 0.32. Ten isolates produce deep purple (M. 14F5) discoloration of agar, and aerial mycelium white felted with deep Magenta (M. 14D8). The other 32 isolates not produced aerial mycelium, but produce deep purple pigmentation (M. 14F5).

ii. Microscopic features

Macroconidia: Straight to falcate, thin walled, 1-5 septate, but predominantly 3-septate; 15-30(-46) x 2.5-3.5 µm with curved to almost hooked apical cell and foot-shaped basal cell.

Microconidia: Fusiform to reniform or oval and 0- to 1-septate, 6-11 x 2-3 µm, produced in false heads on monophialidic conidiogenous cells.

Chlamydospores: Usually abundant, commonly intercalary in hyphae, in pairs, chains and clusters, globose and smooth walled.

iii. Physiological features

The five isolates tested of *F. udum* proved to be able to:

1- Grow on G25N medium and produce orange aerial mycelia and brown pigmentation.

2- Grow on mannitol medium and produce white or pale red mycelium and pale red to brownish red pigmentation.

3- Grow on tannin-sucrose agar.

4- Produce phosphatase enzyme.

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Acetylmethylcarbinol compound.

3- Urease and pyrocatechol oxidase enzymes.

Fusarium udum bears some similarities to *F. oxysporum* and consequently some authorities placed it in section Elegans while others place it in section Lateritium. Aerial mycelium of *F. udum* is almost absent or felted. Isolates of *F. udum* (5) could not produce urease enzyme while those of *F. oxysporum* (9) could. Also, it could be distinguished along with *F. stilboides* from the other two species within section Lateritium (*F. lateritium* and

F. xylarioides) by their incapability of producing urease enzyme. Moreover, *F. udum* along with *F. xylarioides* were pyrocatechol oxidase non-producers, while *F. lateritum* and *F. stilboides* were producers. In the present work *F. udum* has been recovered from soil, maize and sorghum grains, lentil and sesame seeds and rhizoplane of lentil. In Egypt it has been recovered from cotton seeds by Abdel-Satar *et al*. (2003).

F. udum causes a serious wilt disease of pigeon pea (Kannaiyan *et al*. 1984) that was initially reported from India but has been recovered in a number of other countries where this crop is grown. Strains pathogenic to cotton also have been reported. Disease symptoms are those of a vascular wilt in which infected plants suddenly wilt and dry followed by yellowing of the leaves and then their loss (Leslie & Summerell 2006). *F. udum* has been reported to produce fusaric acid and some derivatives. It also is pathogenic to some freshwater fish and has some mycoparasitic activity (refer to Leslie & Summerell 2006).

33. *Fusarium verticillioides* (Saccardo) Nirenberg 1976

See Plate 33.

Section: Liseola.

Synonyms: *F. fujikuroi* Nirenberg 1935

F. moniliforme Sheldon 1904

Teleomorph: *Gibberella moniliformis* Wineland 1924

Gibberella fujikuroi (Sawada) Ito 1931

Isolates examined: 80 isolates, Isolates deposited: MH 138, MH 139, MH 140, MH 141, MH 142, MH 143, MH 144, MH 145, AUMC 2399.

i. Macroscopic features

On PSA plates after 4 days: Growth rate varies from 4.5-5.75 cm diameter with a mean ± SD = 5.09 ± 0.34. Thirty three isolates (out of 80 isolates) produced white to light lilac (M.14A3) aerial mycelium and deep violet pigmentation (M. 16D8), while 21 isolates produced white to pale violet (M. 15A3) and purple (M. 15B7) pigmentation and 21 isolates produced grayish magenta (M. 14D5) mycelium and dull violet pigmentation (M. 16D4). Culture of 5 isolates had white mycelium and no pigments.

On PDA slants after 10 days: Growth rate ranged from 8-9.55 cm length with a mean ± SD = 8.45 ± 0.33. Thirty six isolates produced pale violet (M. 16A3) aerial mycelium and deep magenta (M. 14D8) pigmentation, while 23 isolates produced white to pale violet (M. 16A3) mycelium and dull violet (M.16E4) pigmentation. On the other hand, 16 isolates produced reddish lilac (M. 14B4) aerial mycelium and grayish violet (M. 15D5)

pigmentation while 5 isolates (the same as on PSA) produced white mycelium and no pigments. Sporodochia may be tan or orange, in colour.

ii. Microscopic features

Macroconidia: Difficult to find, however if present, long and slender, slightly falcate or straight, thin walled 3-7 septate, 25-60 x 2.5-4 µm, with apical cell curved and often tapered to a point and basal cell notched or foot shaped.

Microconidia: Abundant, oval to clavate shaped with a flattened base and usually 0-septate, 5-12 x 1.5-2.5 µm, in long chains on monophialidic conidiogenous cells, but small aggregates of a few spores may also occur.

Chlamydospores: Chlamydospores are not produced, although some isolates may produce swollen cells in hyphae.

iii. Physiological features

The nine isolates tested of *F. verticillioides* proved to be able to:

1- Grow on mannitol medium and produce white or pale red mycelium and red to brownish red pigmentation.

2- Grow on tannin-sucrose agar

3- Produce acid on creatine sucrose agar.

4- Produce urease and phosphatase enzymes.

However, these isolates gave variable results with production:

1- Acetylmethylcarbinol compound.

2- Peroxidase and pyrocatechol oxidase enzymes.

F. verticillioides is morphologically identical to most species of section Liseola. *F. verticillioides* is similar to *F. proliferatum*, but the latter is distinguished by its ability to form chains of microconidia from polyphialidic conidiogenous cells. Also, *F. verticillioides* is similar in some respects to *F. nygamai*. However, *F. nygamai* forms microconidia in short chains from mono- and polyphialidic conidiogenous cells and chlamydospores in the aerial hyphae in older culture. Moreover, *F. thapsinum* produces 0-septate napiform microconidia in addition to clavate microconidia identical to those of *F. verticillioides*. However, *F. verticillioides* could grow on tannin-sucrose agar while *F. thapsinum* could not. Also, all isolates tested of *F. verticillioides* could produce urease enzyme while those of *F. nygamai* not. In the present work *F. verticillioides* has been reported from all sources of isolation.

In Egypt, it was isolated from different types of soil, rhizosphere, rhizoplane, phyllosphere and phylloplane of broad bean, barley grains, shells, soil baited with human hair, wheat and broad bean straw composts (refer to Moubasher 1993). Also, *F. verticillioides*

isolated by Abde-Hafez *et al*. (1989, 1995, 2000), Gherbawy *et al*. (2006) and Aziz *et al*. (2007) from different substrates.

F. verticillioides is widely distributed throughout the world. *F. verticillioides* is the causal agent of kernel and ear rot of maize. This destructive disease occurs virtually everywhere that maize is grown worldwide. In years with high temperatures, drought, and heavy insect damage, the disease can significantly diminish crop quality. *F. verticillioides* also may recover from finger millet, and native North American tallgrass prairie grasses and desert soils. It may be recovered from and cause disease on sorghum (refer to Leslie & Summerell 2006).

The most common human health problem associated with *F. verticillioides* is skin lesions, but it also can infect through wounds and has been associated with keratitis (de Hoog *et al*. 2000, Al-Hussainy *et al*. 2010). *F. verticillioides* is resistant to most clinical antifungals (refer to Leslie & Summerell 2006). The most significant economic impact of *F. verticillioides* is its ability to produce fumonisin mycotoxins. Various diseases caused by fumonisins have been reported in animals, such as liver and kidney cancer as well as neural tube defects in rodents (Howard *et al*. 2001, Seefelder *et al*. 2003), leukoencephalomalacia in equines (Wilson *et al*. 1992), and pulmonary edema in pigs (Kriek *et al*. 1981). More importantly, epidemiological correlations have been established between human esophageal cancer and the consumption of fumonisin-contaminated maize in some regions of the world where maize is a dietary staple.

34. *Fusarium xylarioides* Steyaert 1948

See Plate 34.

Section: Lateritium

Synonyms: *F. oxysporum* Schlecht. ex Fr. *f. xylarioides* (Steyaert) Delassus 1954.

F. lateitium f. sp. *xylarioides* (Steyaert) Gordon 1965

Telemorph: *Gibberella xylarioides* Heim & Saccas 1950

Isolates examined: 10 isolates, Isolates deposited: MH 236, 237, 238, 239, 240, 241, 242, CBS 258.52 (= AUMC 1270).

i. Macroscopic features

On PSA plates after 4 days: Growth rate ranges from 4.3-5.5 cm diameter, with a mean ± SD = 5.05 ± 0.4, with floccose, aerial mycelium violet white (M. 15A2) with pigmentation dull violet (M. 16D3-4).

On PDA slants after 10 days: Growth rate varies from 7.8-8.57 cm length, with a mean ± SD = 8.25 ± 0.31, aerial mycelium pale violet (M. 15A3) and pigmentation grayish violet (M. 15E4-7).

ii. Microscopic features

Macroconidia: Curved, cylindrical, 3-5 septate, common 3 septate, 26-55 x 3.5-4.5 µm, with beaked apical cell and notched or foot-shaped basal cell.

Microconidia: Strongly curved, allantoid, 0-1 septate, 6-10 x 2.5-3.5 µm, produce singly, or in false heads from monophialidic conidiogenous cells.

Chlamydospores: Absent.

iii. Physiological features

The eight isolates tested of *F. xylarioides* proved to be able to:

1- Grow on G25N medium and produce white or yellowish white aerial mycelium and yellowish pigmentation.

2- Grow on mannitol medium with growth rate more than 4 cm diameter; produce reddish white mycelium and red pigmentation.

3- Grow on CZID medium with growth rate less than 5 cm diameter, produced white or pinkish white aerial mycelium and brownish gray or purplish grey pigmentation.

4- Grow on DCPA medium and growth rate less than 5 cm diameter.

5- Grow on tannin-sucrose agar.

6- Produce urease and phosphatase enzymes

However, it was not capable of producing:

1- Acid on creatine sucrose agar.

2- Acetylmethylcarbinol compound.

3- Pyrocatechol oxidase enzyme.

Also, different isolates gave variable response towards peroxidase enzyme production. *F. xylarioides* could be differentiated from the other 3 species recorded within section Lateritium by the strongly curved 0-1 septate microconidia. *F. xylarioides* and *F. udum* have morphological similarities on PSA and PDA media where, they produce violet pigmentation but *F. xylarioides* produce abundant aerial mycelium while *F. udum* produce felted or absent mycelia. *F. xylarioides* and *F. udum* could be differentiated from the other 2 species (*F. lateritium* and *F. stilboides*) by incapability of producing pyrocatechol oxidase enzyme. In addition, urease-producing ability, growth rate on mannitol agar, and colony pigmentation on G25N. In the present work, *F. xylarioides* has been isolated from soil, lentil and sesame seeds and monthly fluctuations of air.

F. xylarioides has been reported on *Coffea canephora* and *C. liberica*, causing a disease referred to as tracheomycosis or carbuncullariosis (Booth 1971). In 1965 Abrego referred to its occurrence in El Salvador as a stem-pitting disease with longitudinal cracks in the bark extending from the collar to the crown and with necrosis of the underlying wood.

Plates

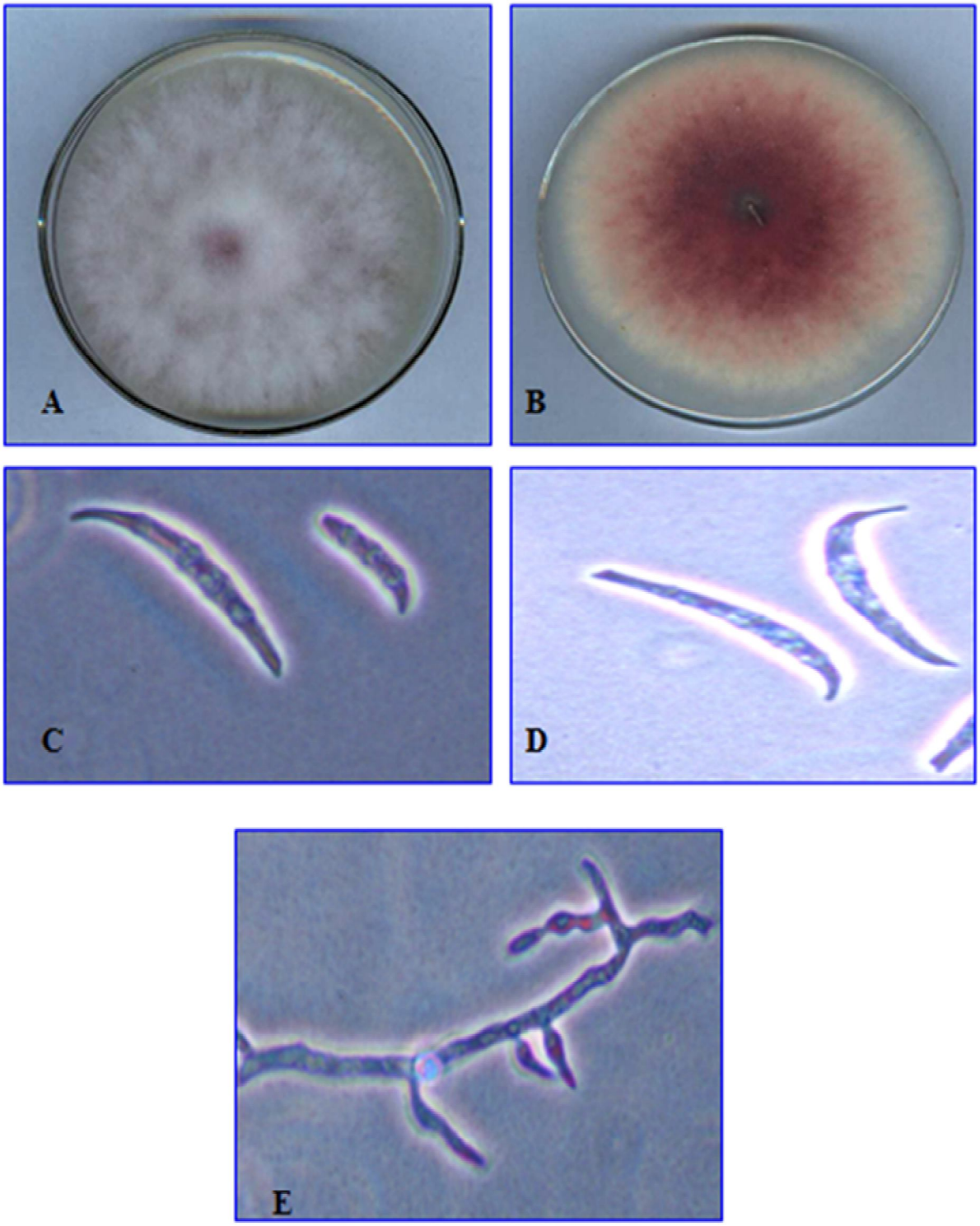

Plate 1: *Fusarium acuminatum* Ellis & Everhart
A, B: Colour of colony and reverse; A-E: Photographs; C-D: Macroconidia, E: Monophilaidic conidiogenous cells.

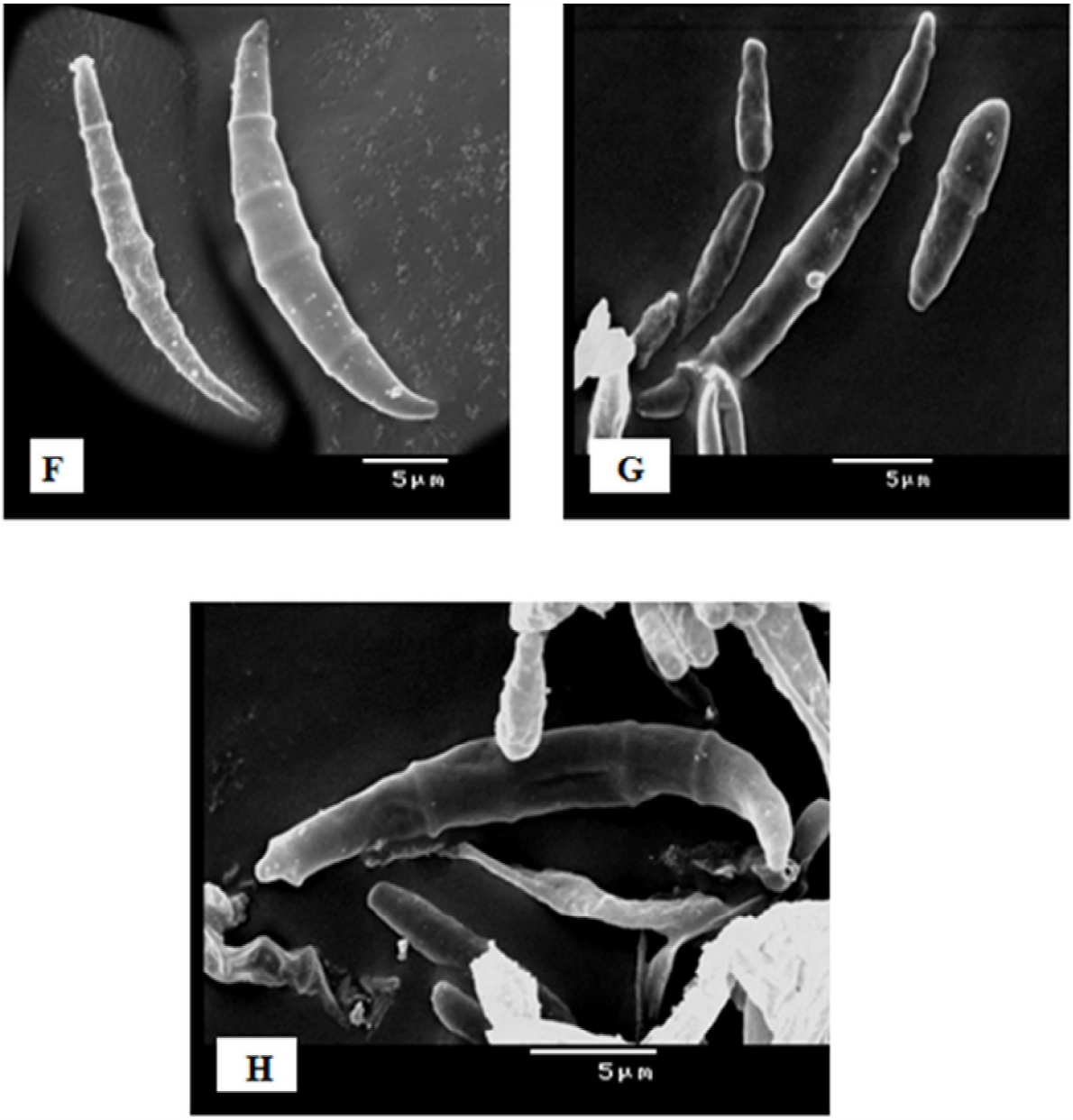

Plate 1 (continued): ***Fusarium acuminatum*** **Ellis & Everhart**
F-H: S.E.M.; F-H: Macroconidia; G: Microconidia.

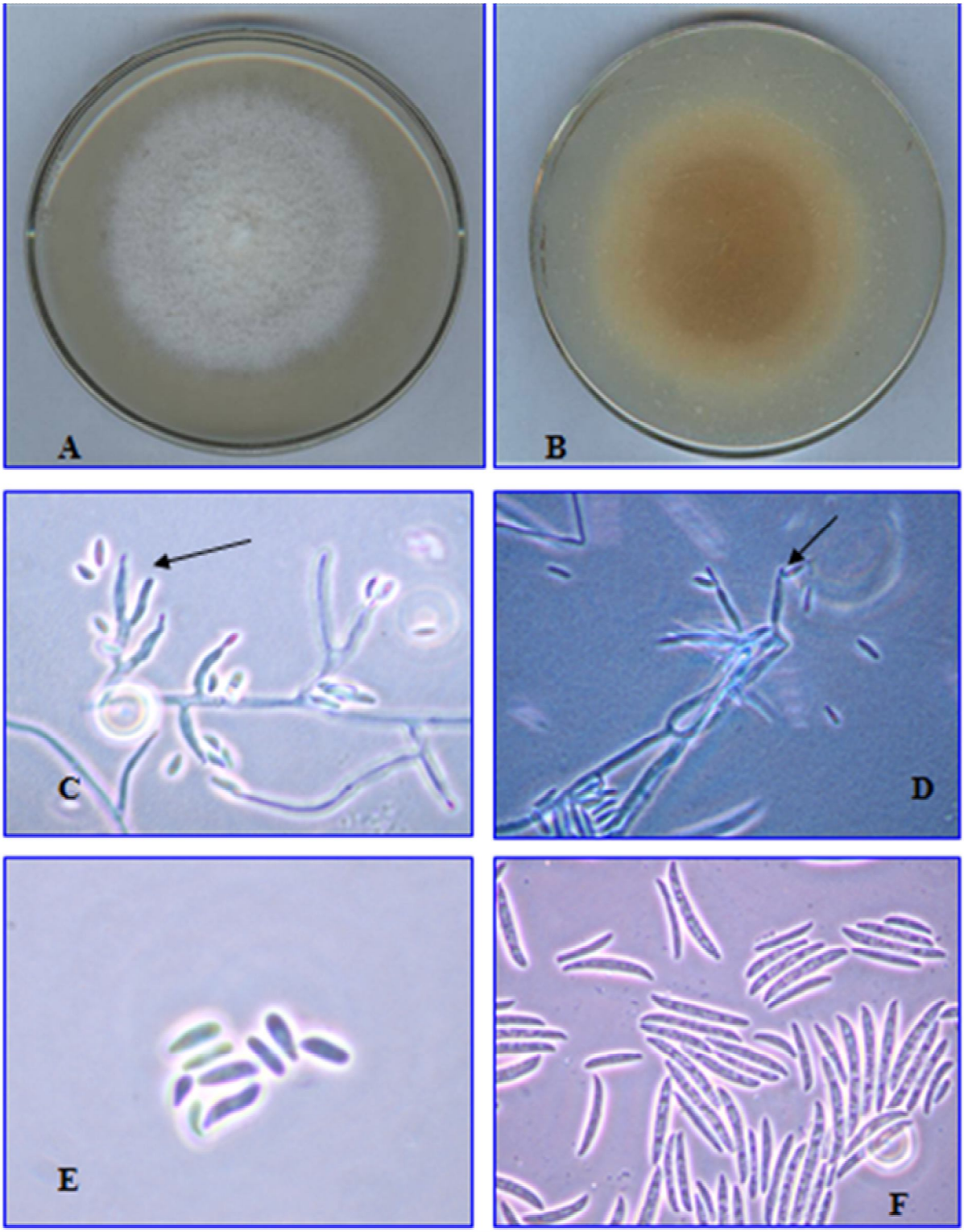

Plate 2: *Fusarium acutatum* Nirenberg & O'Donnell

A, B: Colony colour and reverse on PSA; A-F: Photographs; C-D: Mono- and polyphialidic conidiogenous cells; E: Microconidia; F: Macroconidia.

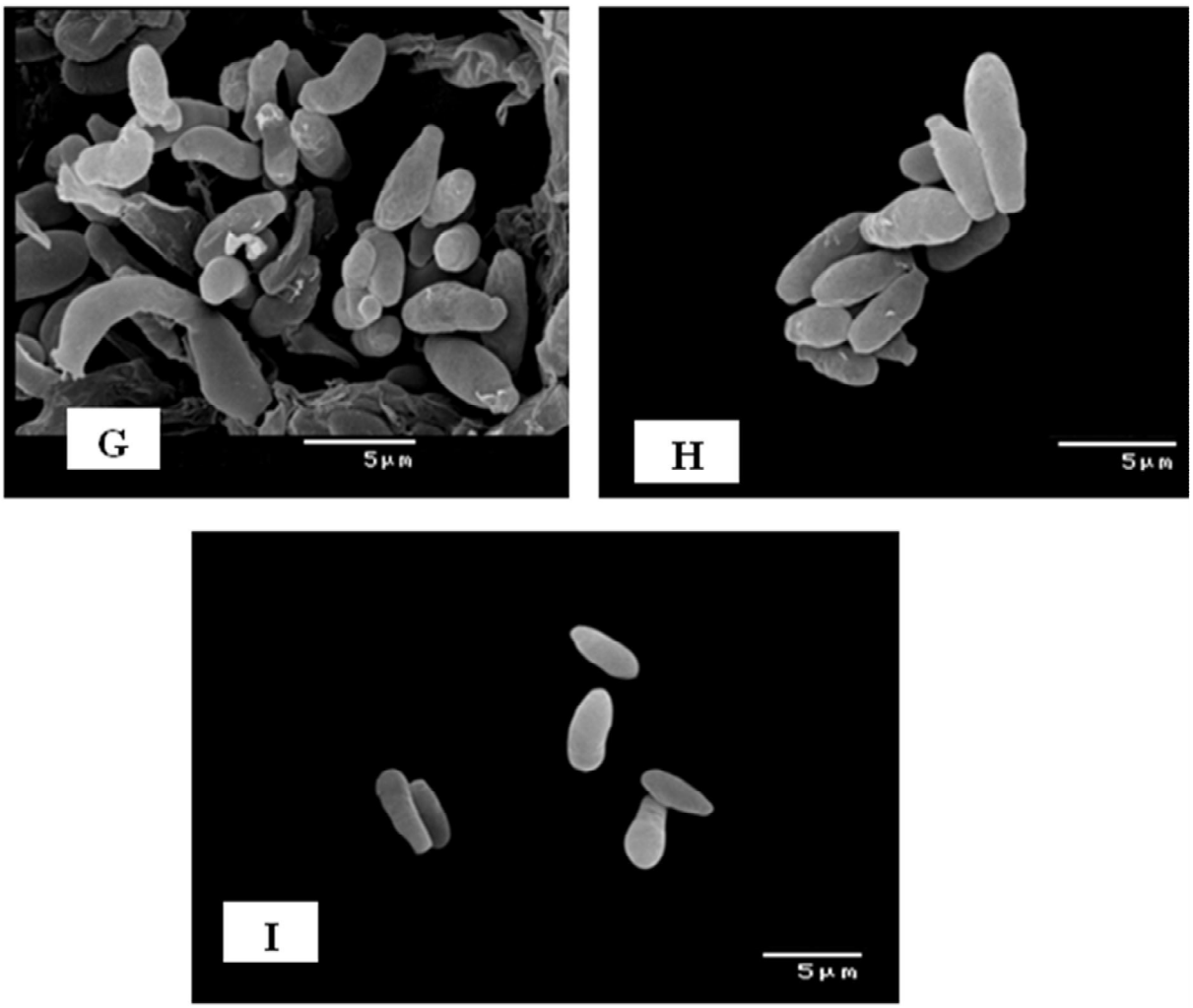

Plate 2 (continued): ***Fusarium acutatum*** **Nirenberg & O'Donnell**
G-I: Microconidia (Scanning selectron micrographs).

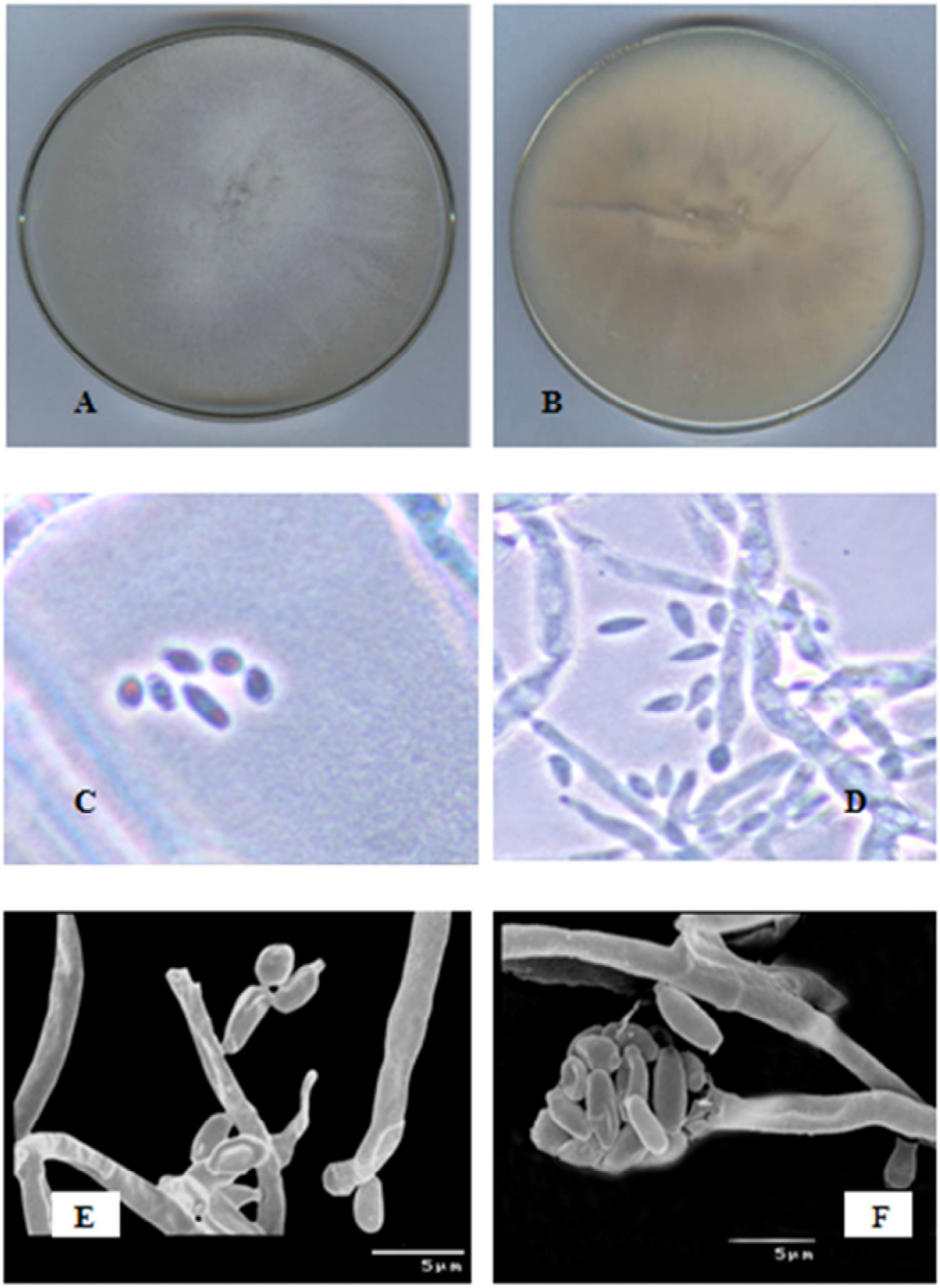

Plate 3: ***Fusarium anthophilum*** **(A. Braun) Wollenweber**

A, B: Colony colour and reverse on PSA; C-D: Photographs; E-F: S.E.M.; C-F: Microconidia (globose and ovoid); E-F: Mono- and polyphialidic conidiogenous cells; F: False heads.

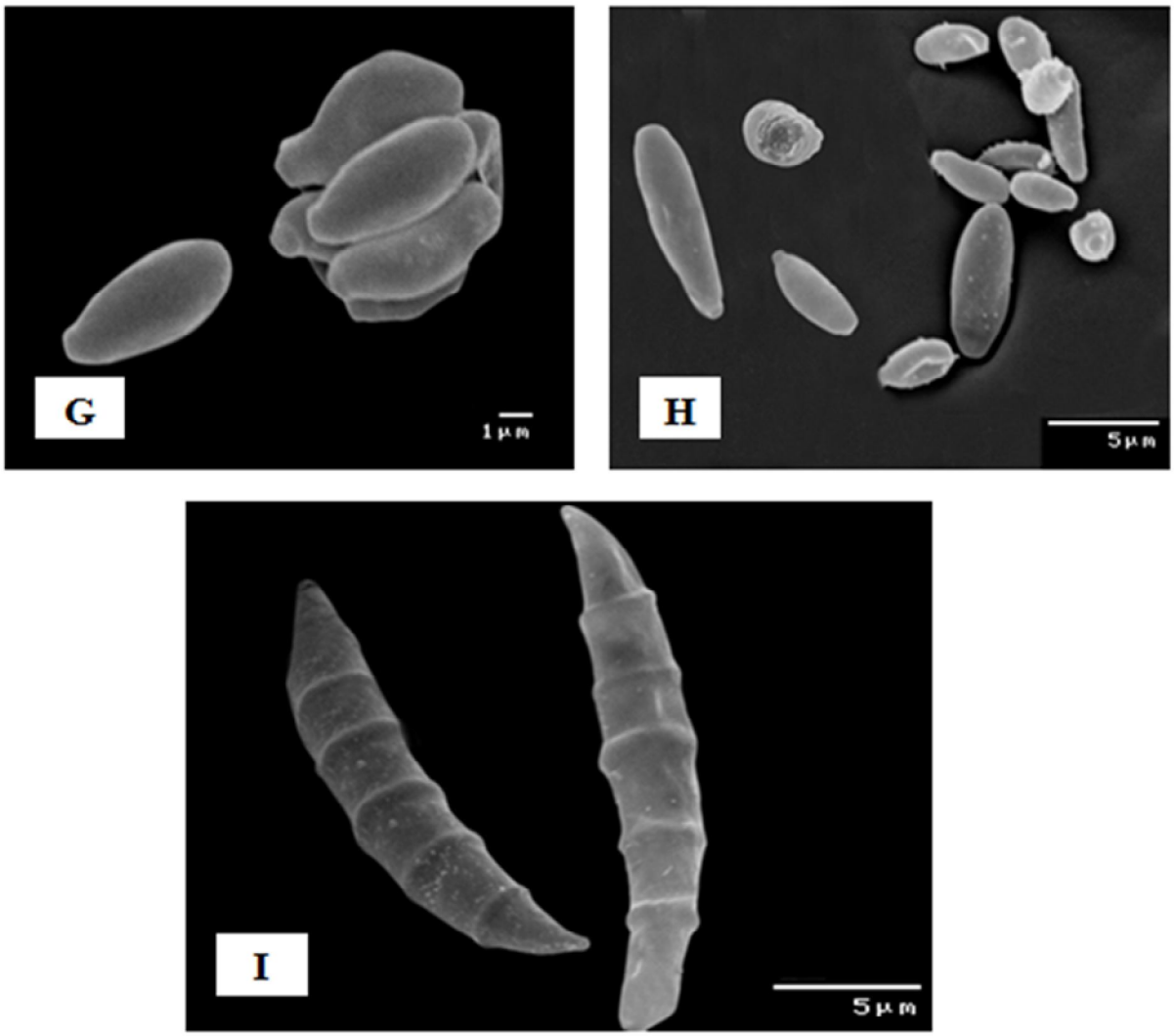

Plate 3 (continued): ***Fusarium anthophilum*** **(A. Braun) Wollenweber**
G-H: S.E.M.; G, H: Microconidia (globose and ovoid); I: Macroconidia.

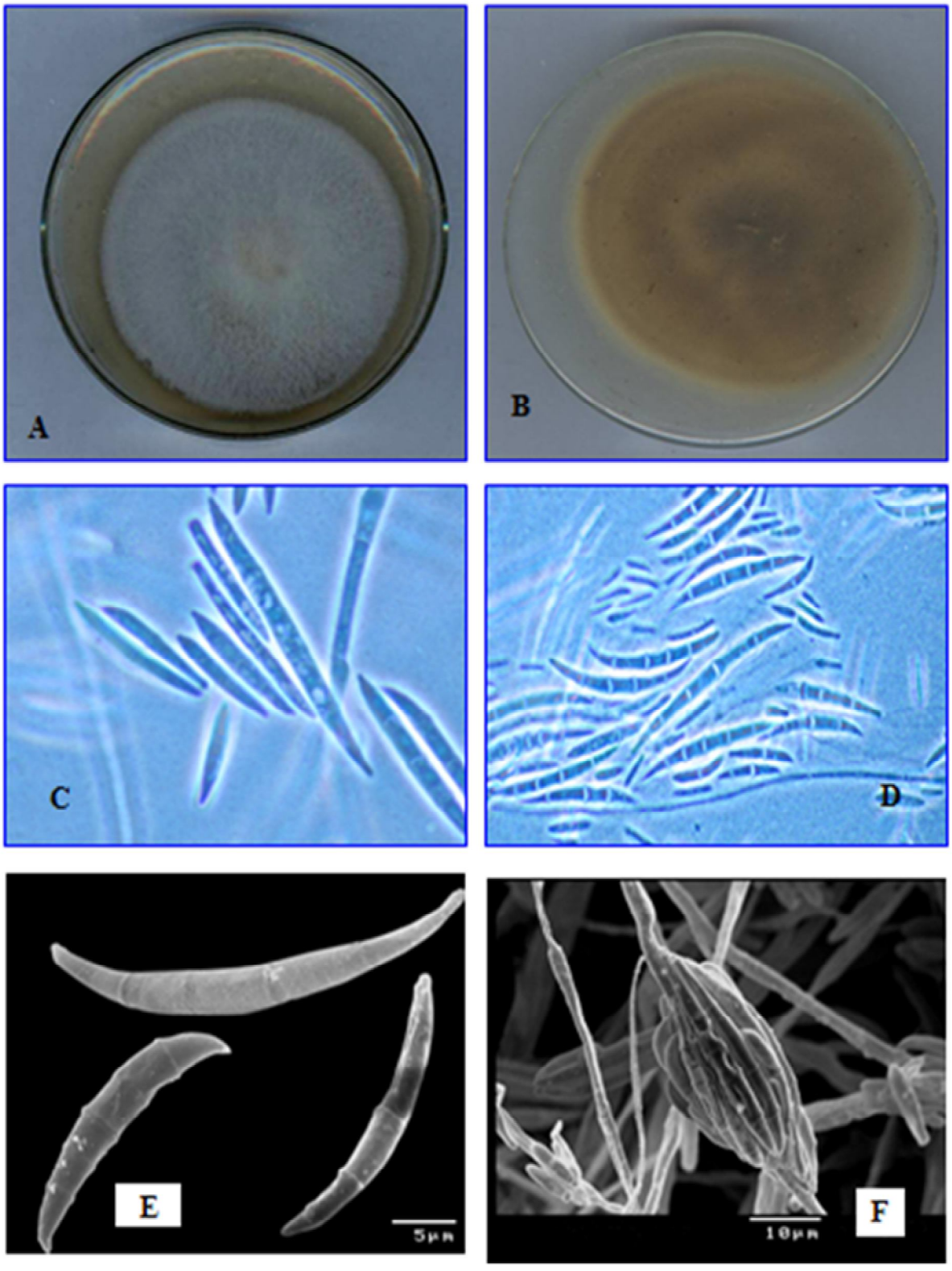

Plate 4: *Fusarium avenaceum* (Fries) Saccardo
A, B: Colony colour and reverse on PSA; C-D: Photographs;
E-F: S.E.M.; C-F: Macroconidia; D: Microconidia.

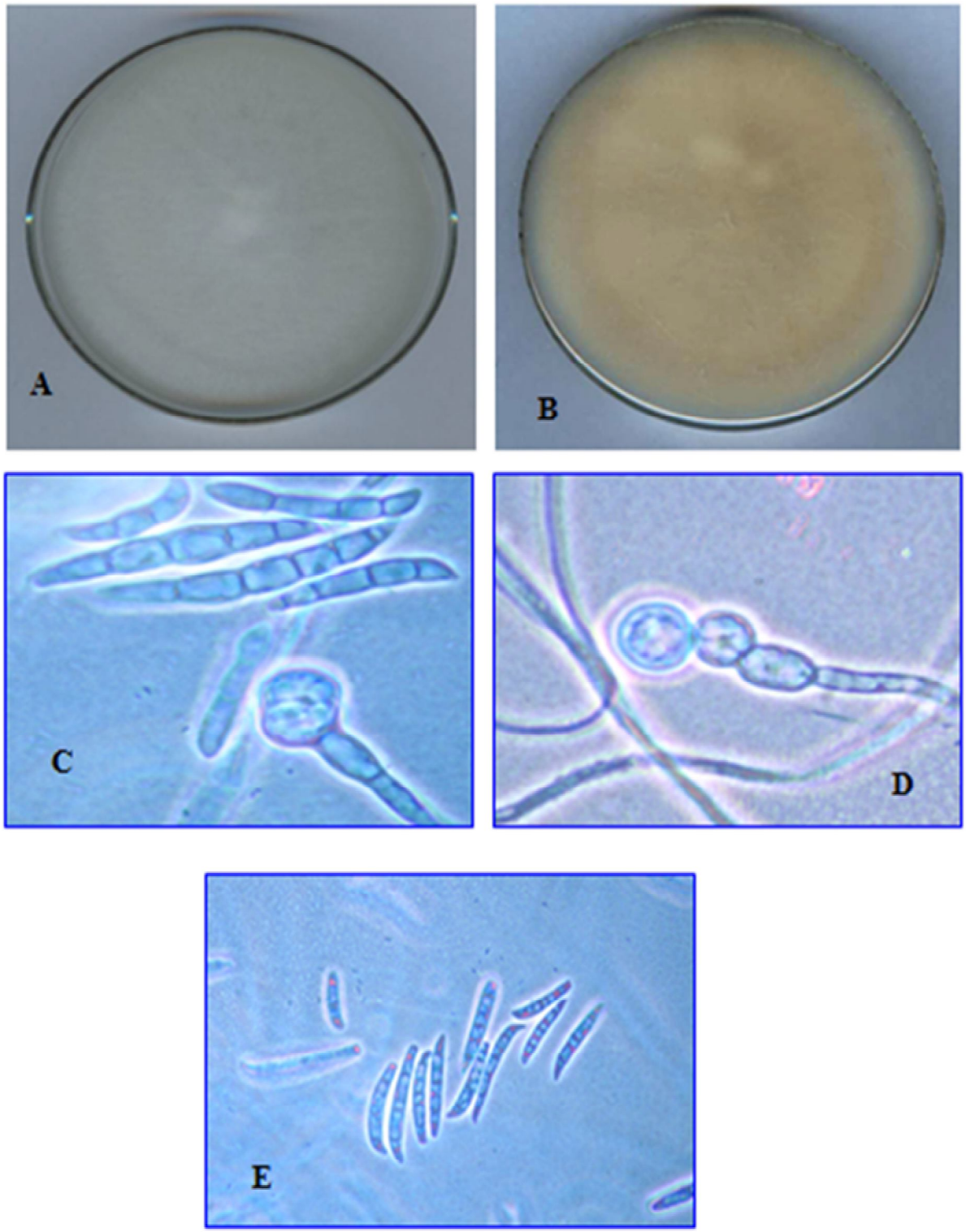

Plate 5: *Fusarium camptoceras* Wollenweber & Reinking emend. Marasas & Logrieco
A, B: Colony colour and reverse on PSA; C-D: Photographs;
C, D: Chlamydospores; C, E: Macroconidia.

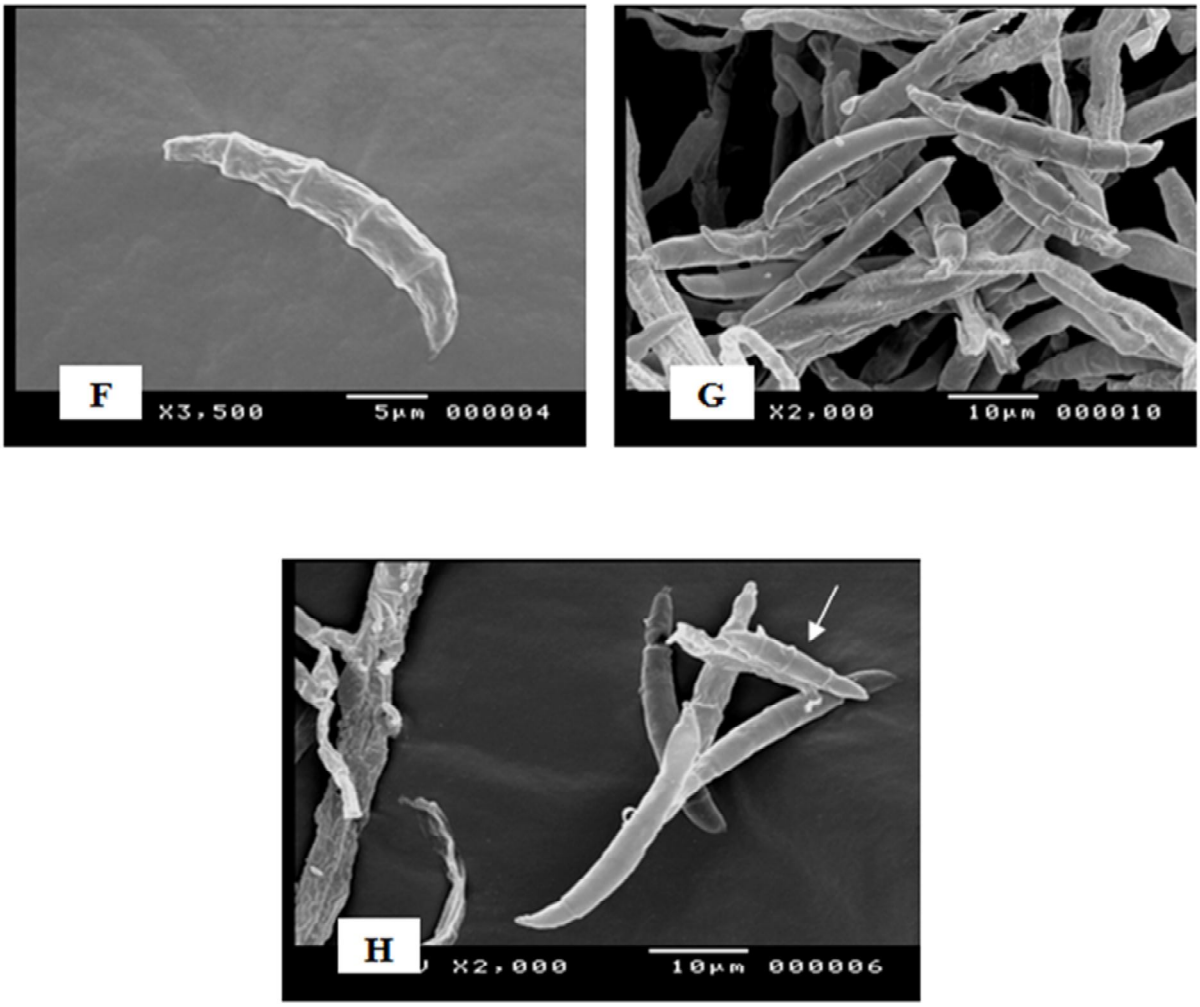

Plate 5 (continued): ***Fusarium camptoceras*** **Wollenweber & Reinking emend. Marasas & Logrieco**

F-H: S.E.M.; F-H: Macroconidia; H: Mesoconidia.

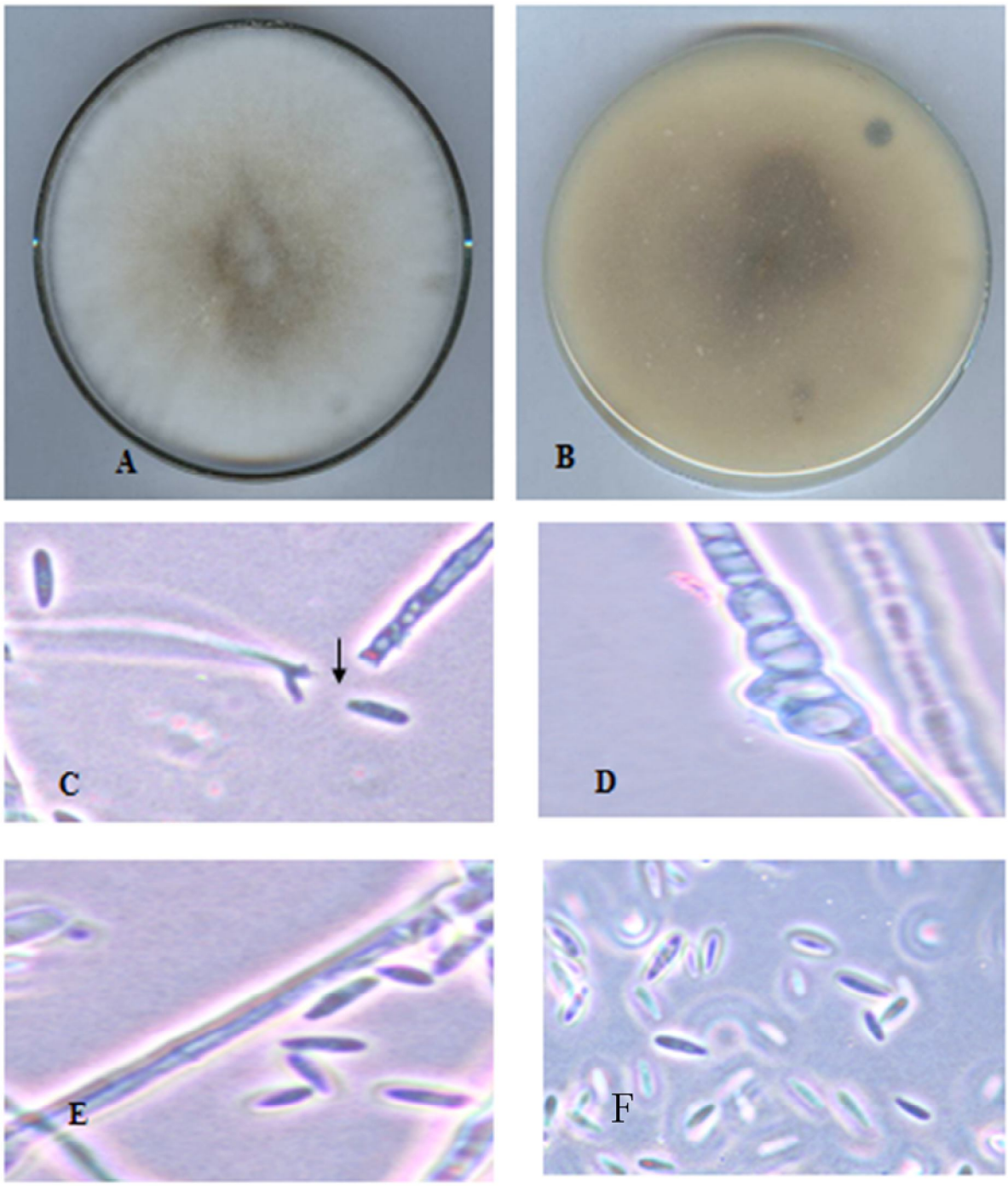

Plate 6: *Fusarium chlamydosporum* Wollenweber & Reinking
A, B: Colony colour and reverse; A-F: Photographs; C: Polyphialidic conidiogenous cells; D: Chlamydospores; E, F: Microconidia.

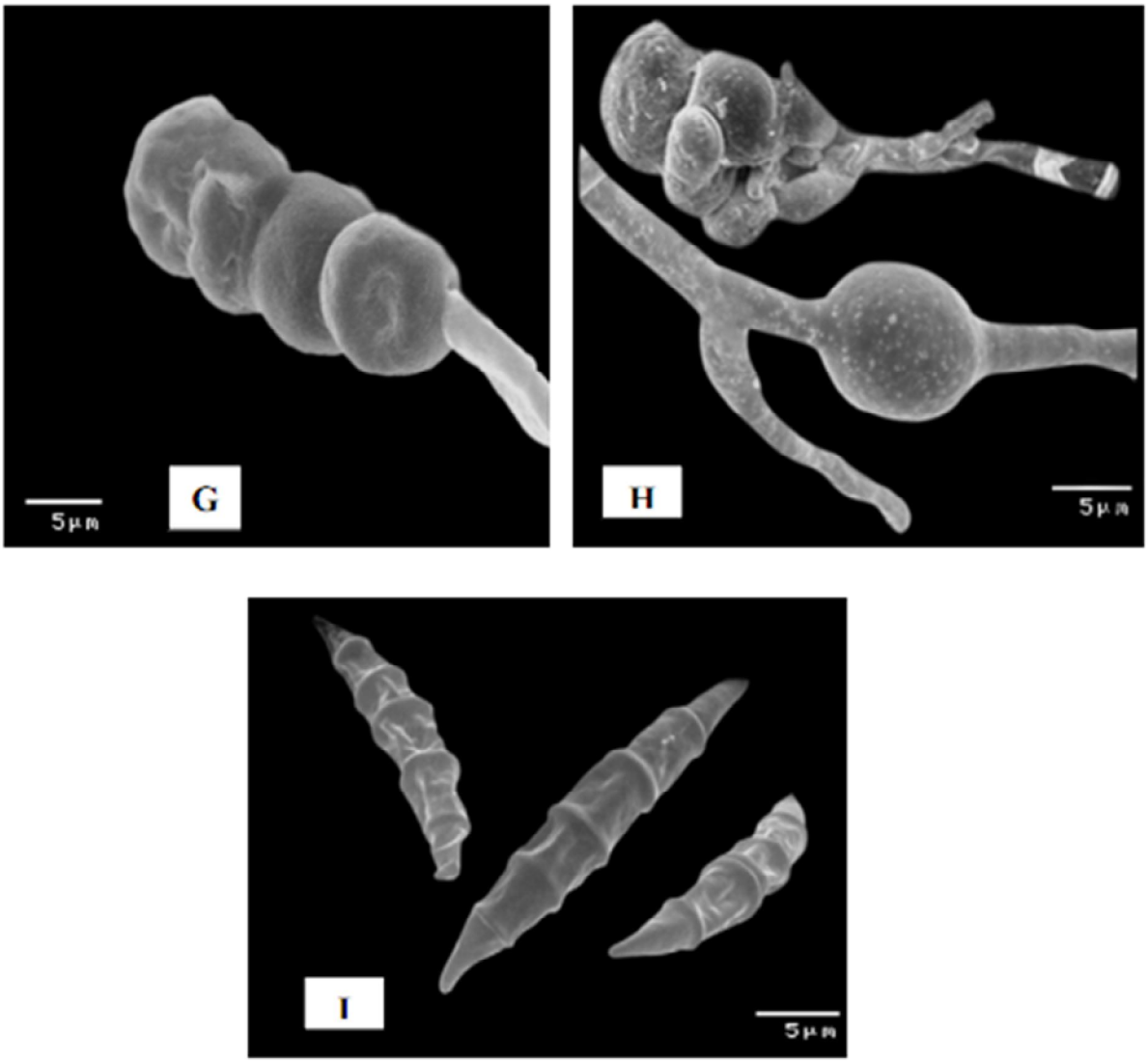

Plate 6 (continued): ***Fusarium chlamydosporum*** **Wollenweber & Renking**
G-I: S.E.M.; G, H: Chlamydospores; I: Macroconidia.

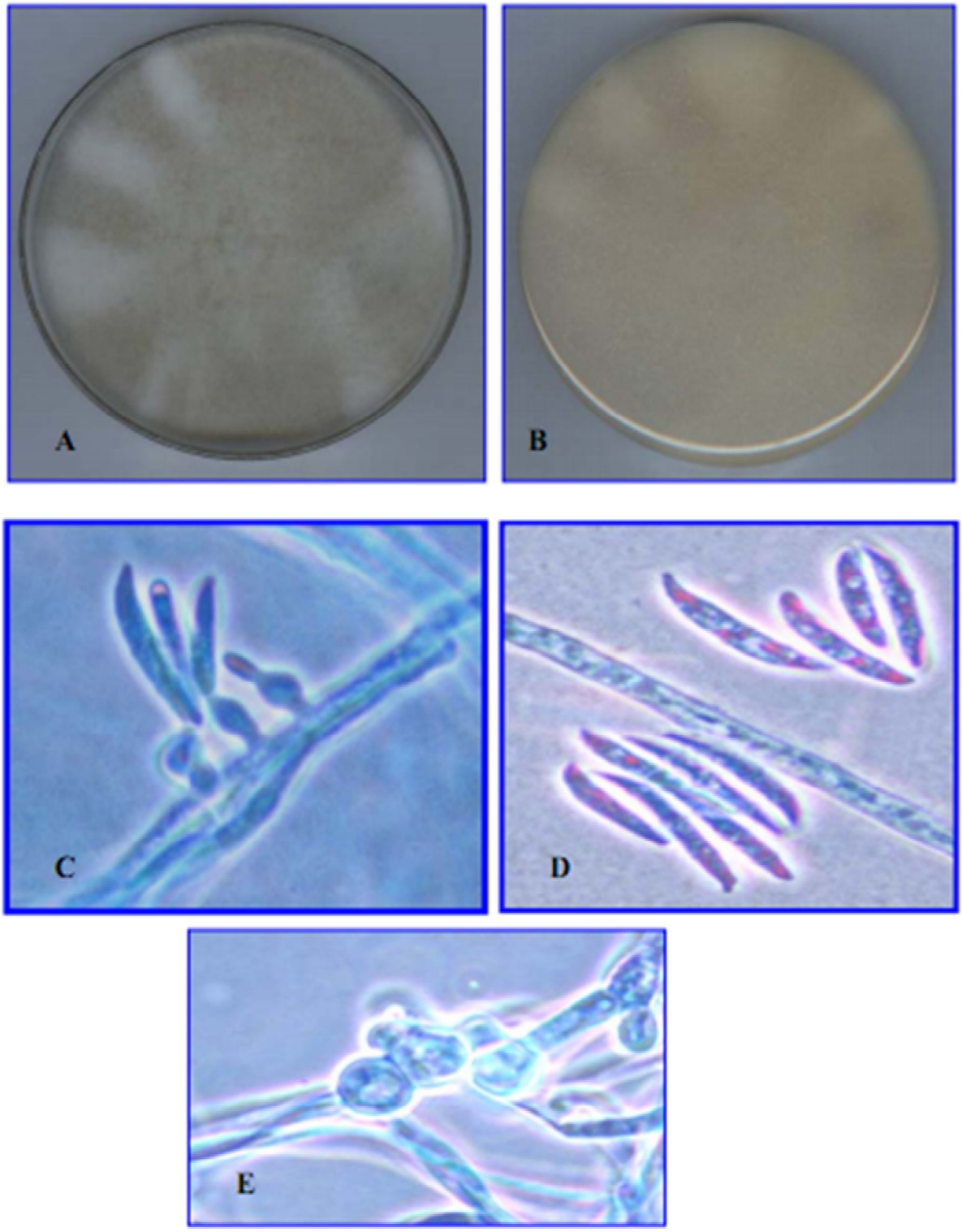

Plate 7: *Fusarium concolor* Reinking
A, B: Colony colour and reverse on PSA; A-E: Photographs;
C, D: Macroconidia; E: Chlamydospores.

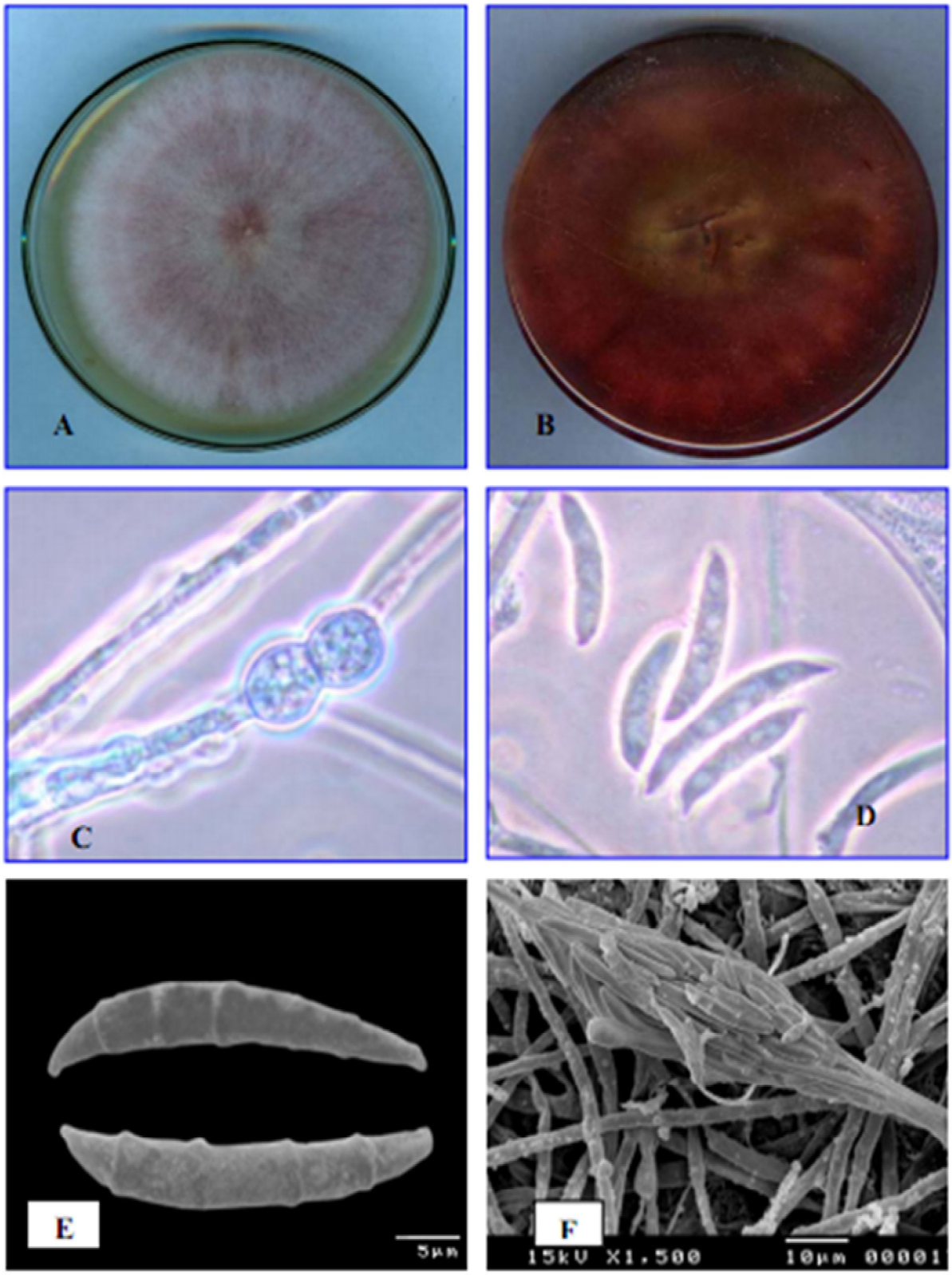

Plate 8: ***Fusarium culmorum*** **(W. G. Smith) Saccardo**

A, B: Colony colour and reverse on PSA; A-D: Photographs;
E-F: S.E.M; C: Chlamydospores; D, E: Macroconidia; F: Sporodochia.

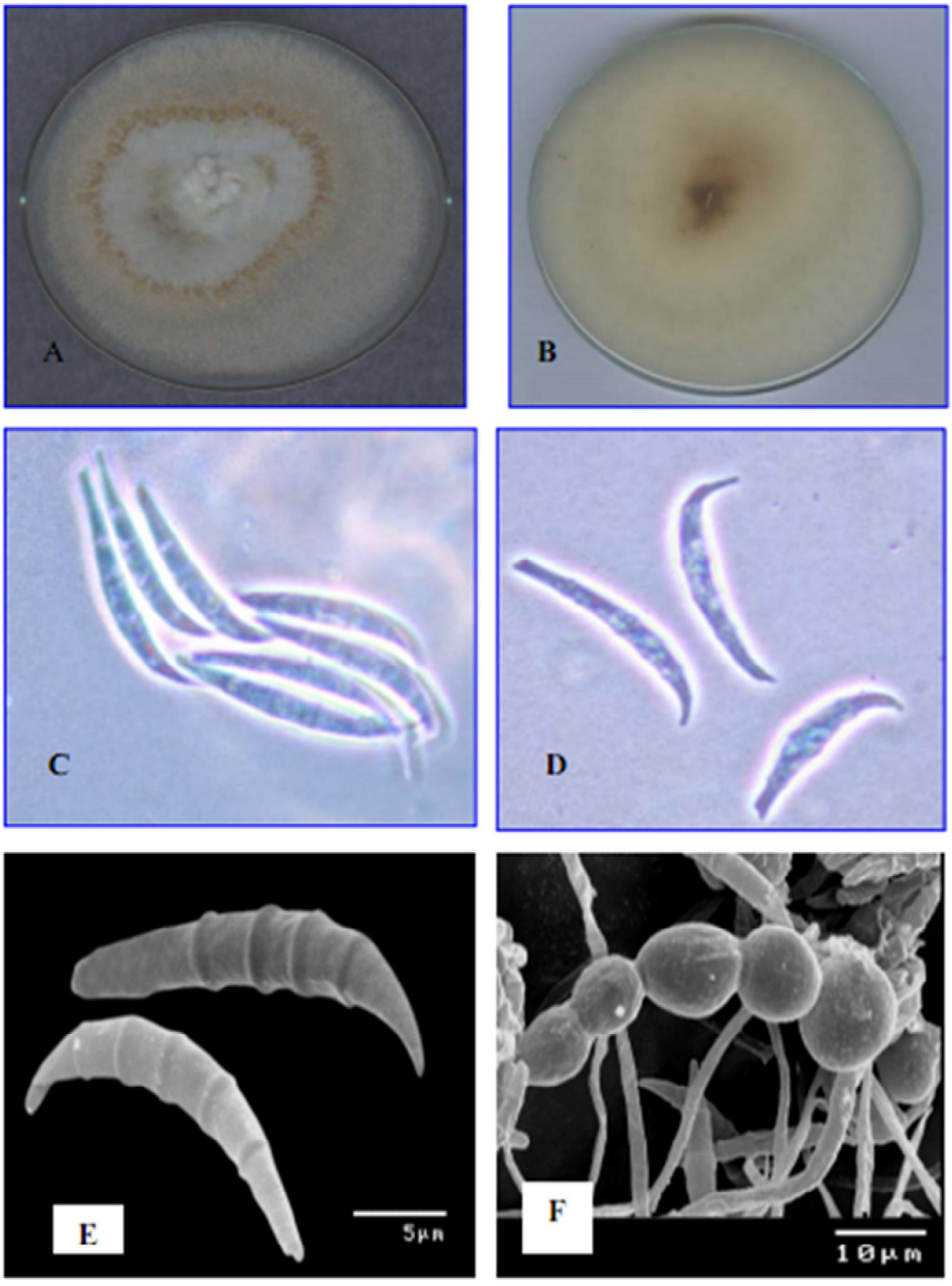

Plate 9: ***Fusarium equiseti*** **(Corda) Saccardo**
A, B: Colony colour and reverse on PSA; A-D: Photographs;
E-F: S.E.M.; C-E: Macroconidia; F: Chlamydospores.

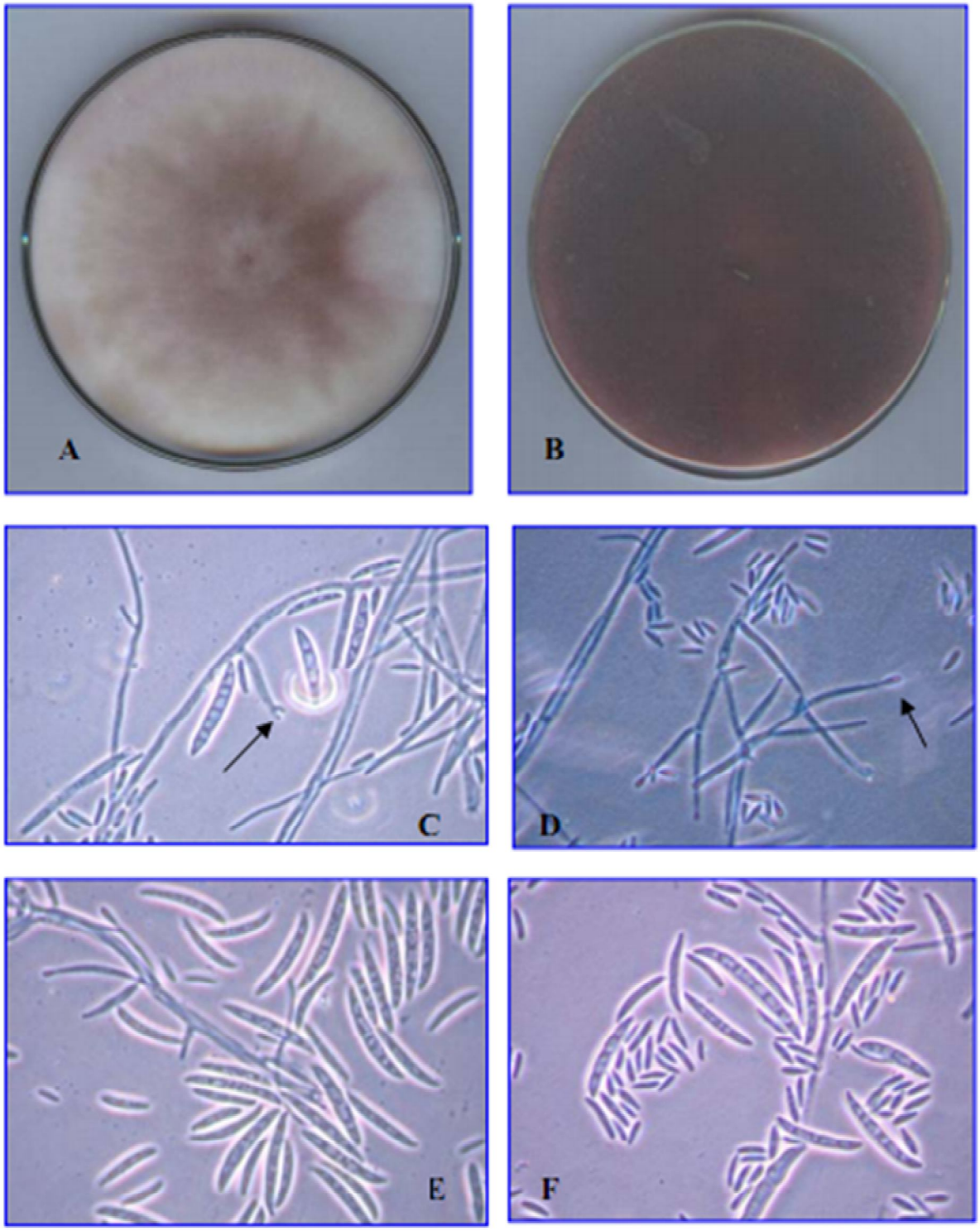

Plate 10: *Fusarium fusarioides* (Fragoso & Ciferri) Booth
A, B: Colony colour and reverse on PSA; A-E: Photographs;
C, D: Mono- and polyphialidic conidiogenous cells;
E, F: Microconidia and macroconidia.

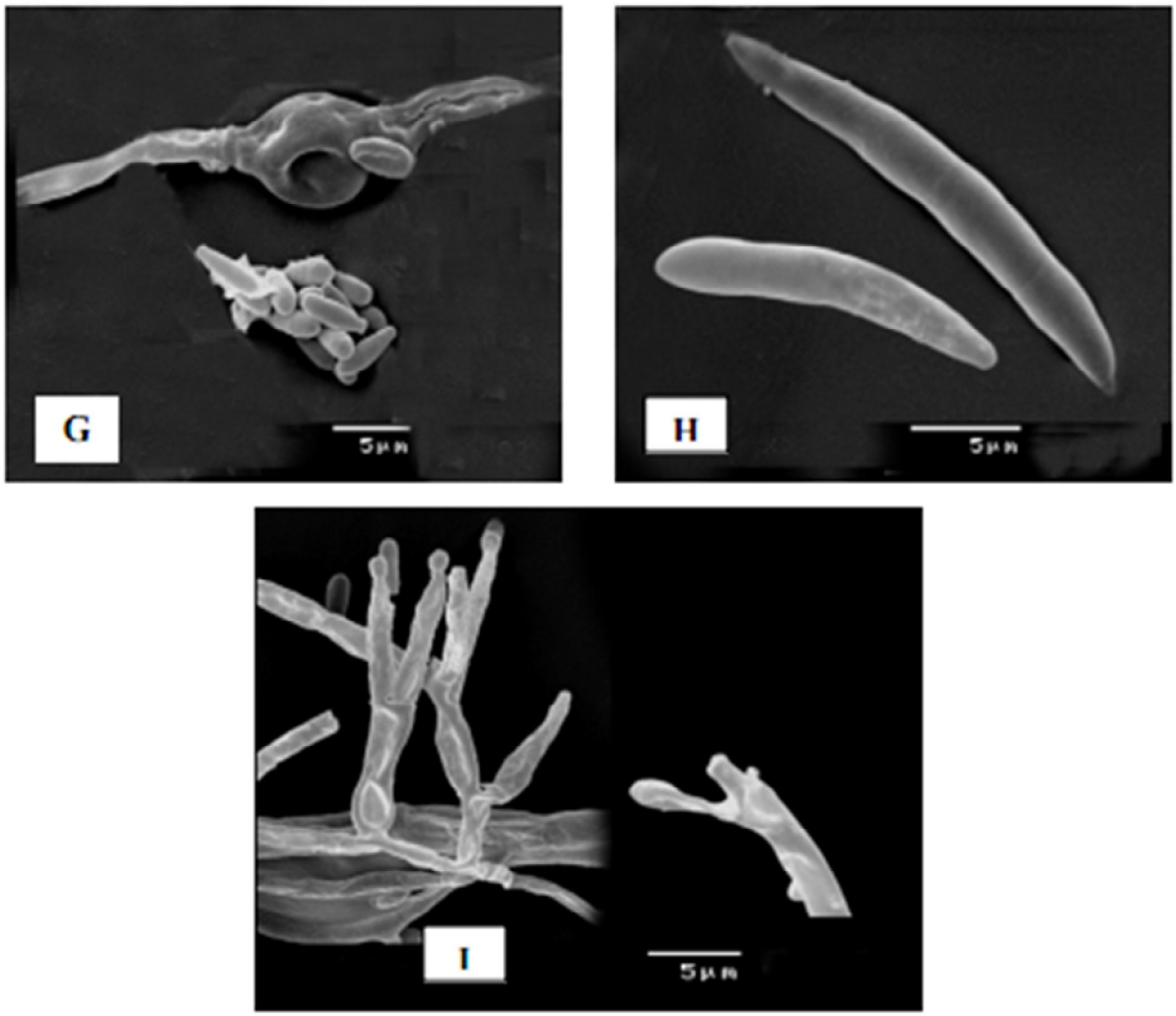

Plate 10 (continued): ***Fusarium fusarioides*** **(Fragoso & Ciferri) Booth**
G-I: S.E.M.; G: Chlamydospores, microconidia; H: Macroconidia;
I: Mono- and polyphialidic conidiogenous cells.

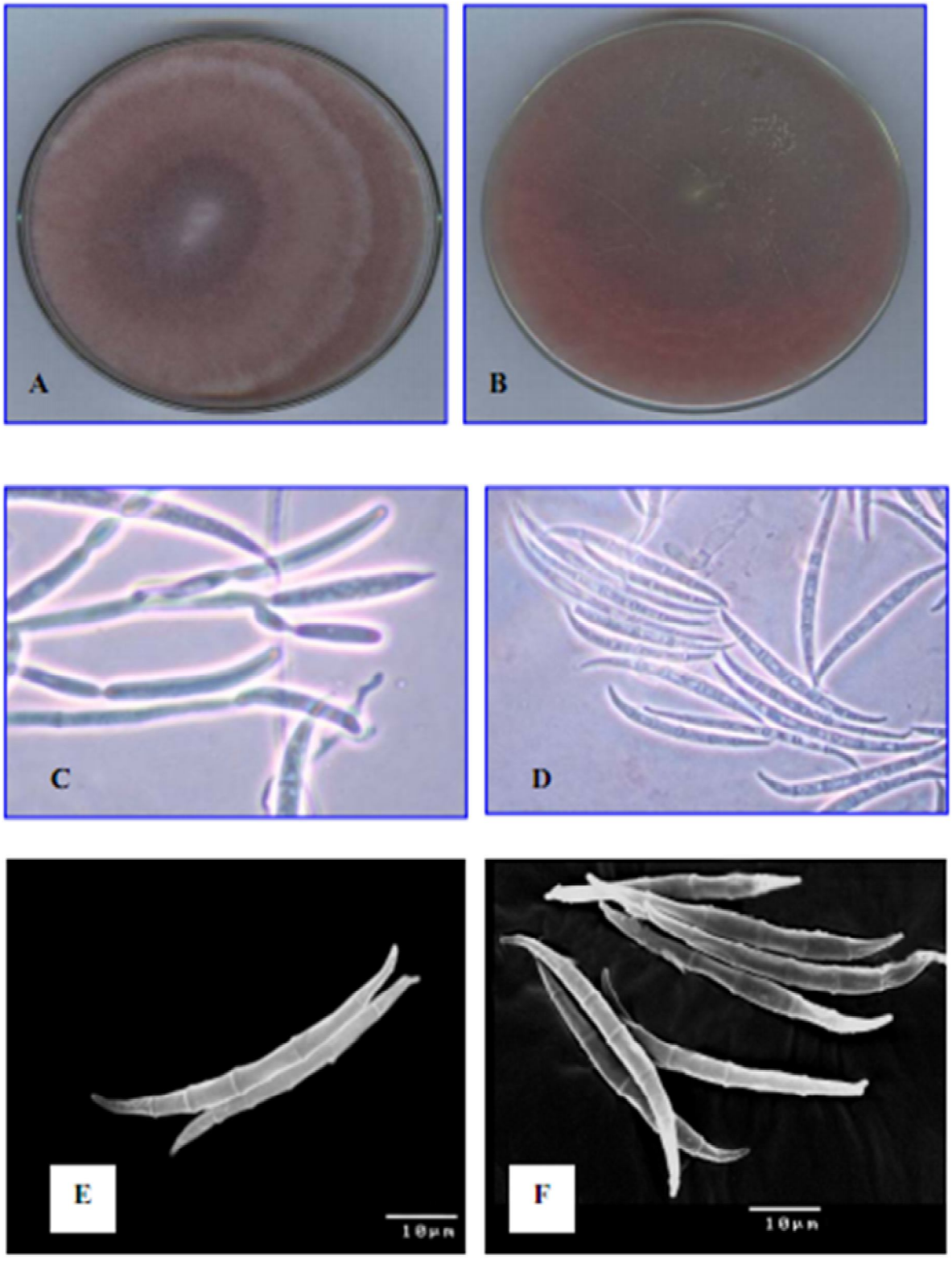

Plate 11: *Fusarium graminearum* Schwabe
A, B: Colony colour and reverse on PSA;
A-D: Photographs; E-F: S.E.M.; C-F: Macroconidia.

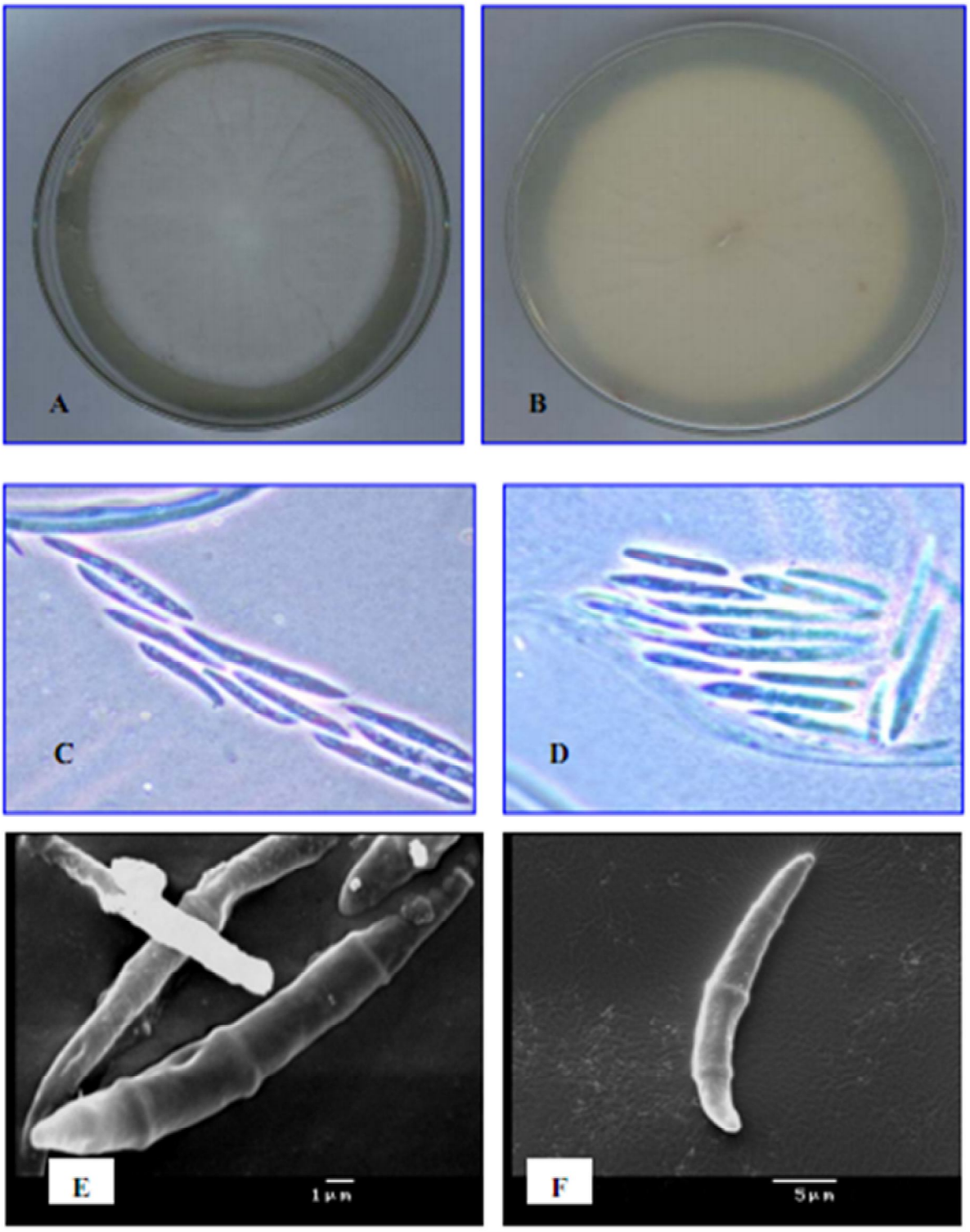

Plate 12: *Fusarium heterosporum* Nees ex Fries
A, B: Colony colour and reverse on PSA; A-D: Photographs;
E-F: S.E.M; C-F: Macroconidia.

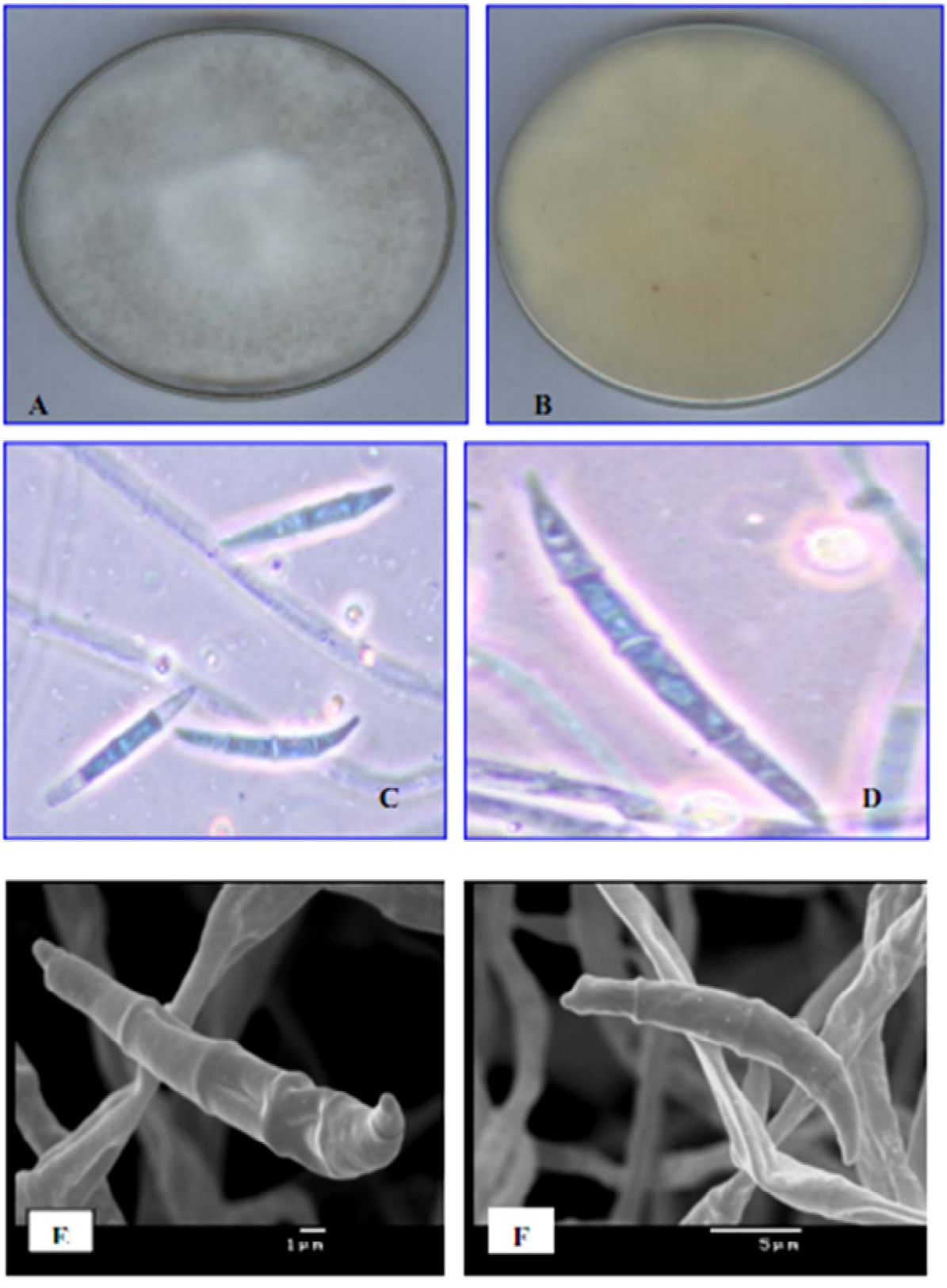

Plate 13: *Fusarium lateritium* Nees

A, B: Colony colour and reverse on PSA;

A-D: Photographs; E-F: S.E.M.; C-F: Macroconidia.

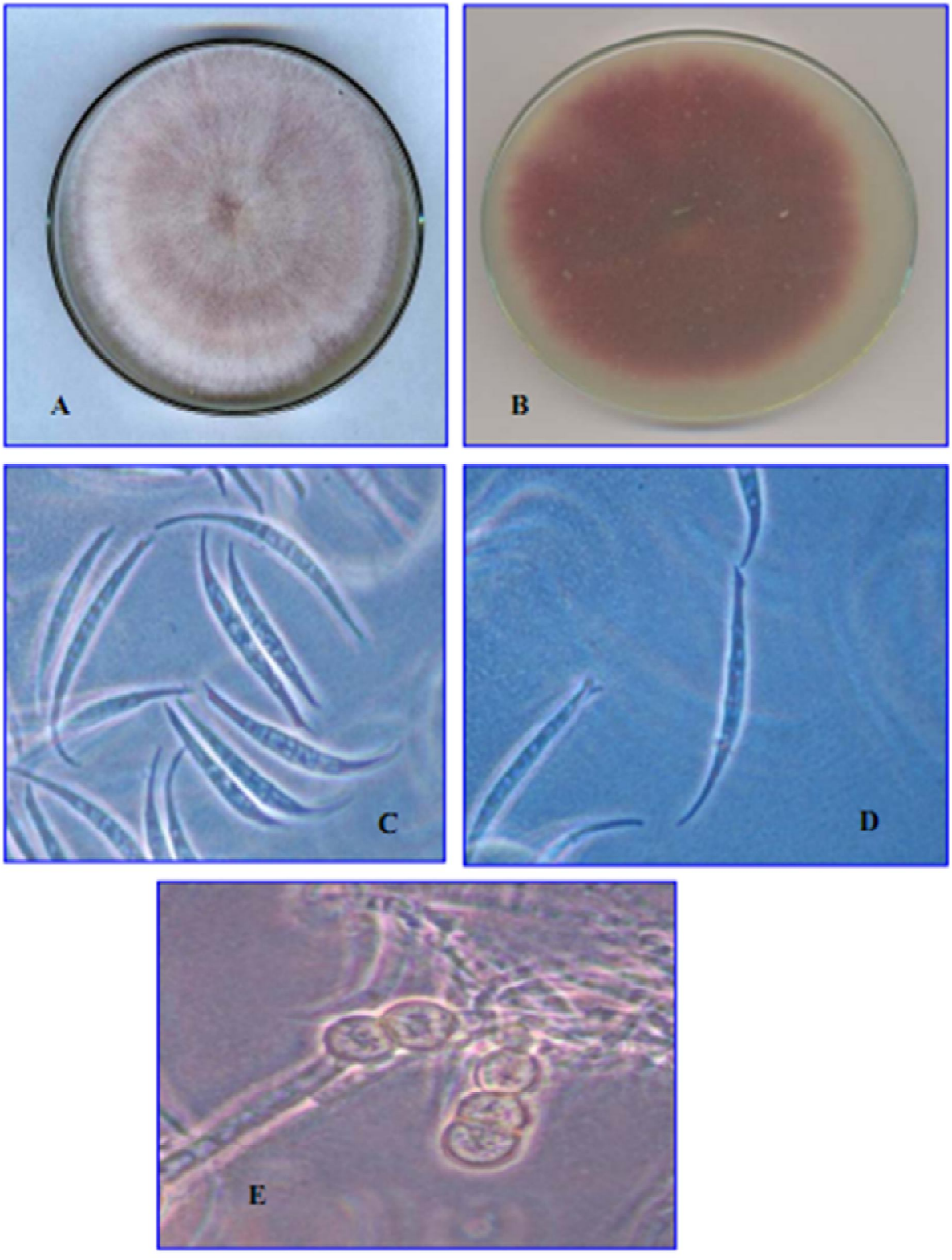

Plate 14: *Fusarium longipes* Wollenweber & Reinking
A, B: Colony colour and reverse on PSA; A-E: Photographs;
C, D: Macroconidia; E: Chlamydospores.

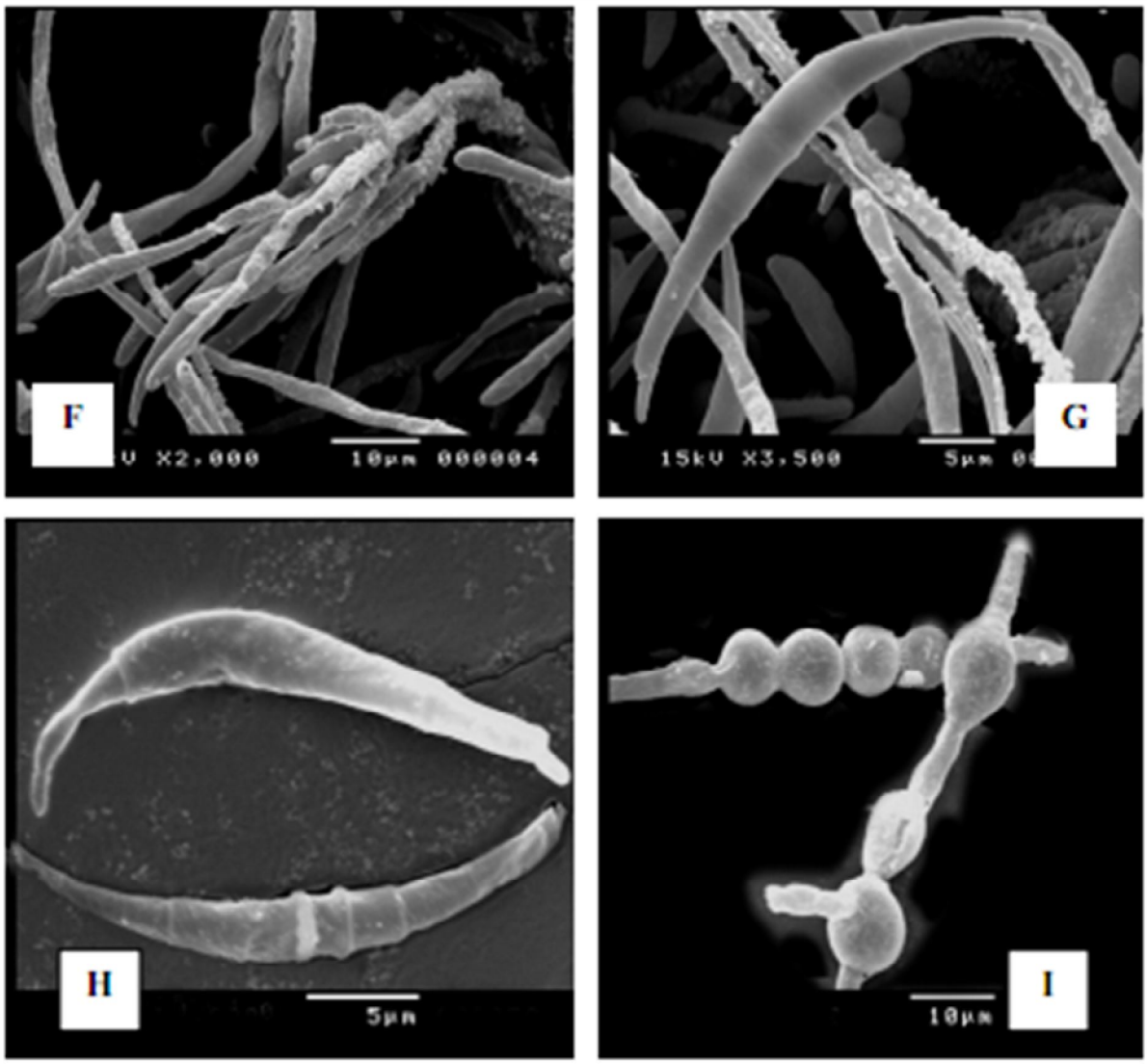

Plate 14 (continued): ***Fusarium longipes*** **Wollweber & Reinking**
F-I: S.E.M.: F: Sporodochia; G, H: Macroconidia;
I: Chlamydospores.

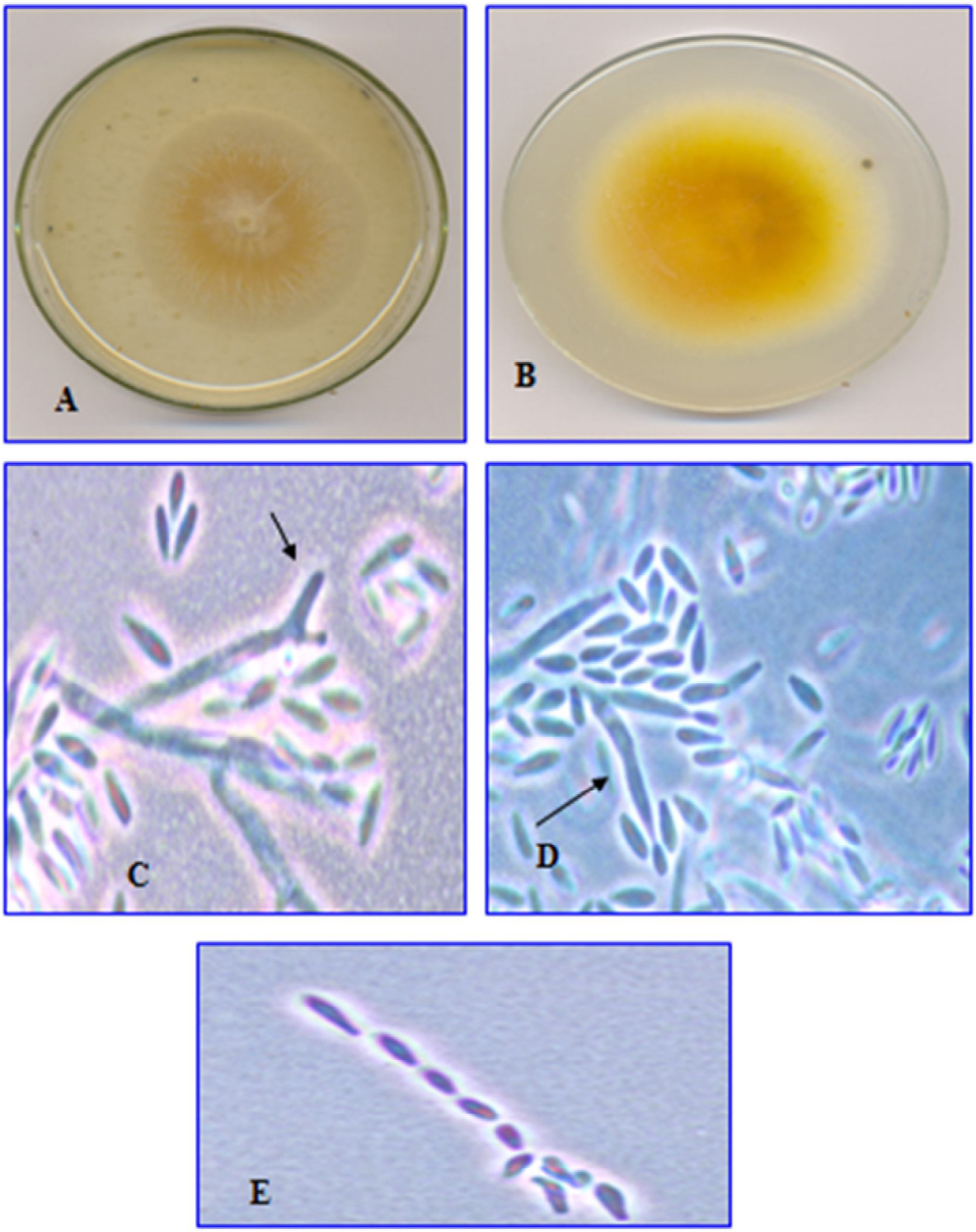

Plate 15: *Fusarium nisikadoi* T. Aoki & Nirenberg

A, B: Colony colour and reverse on PSA; A-E: Photographs:

C, D: Poly- and monophialidic conidiogenous cells; E: Microconidia in chains.

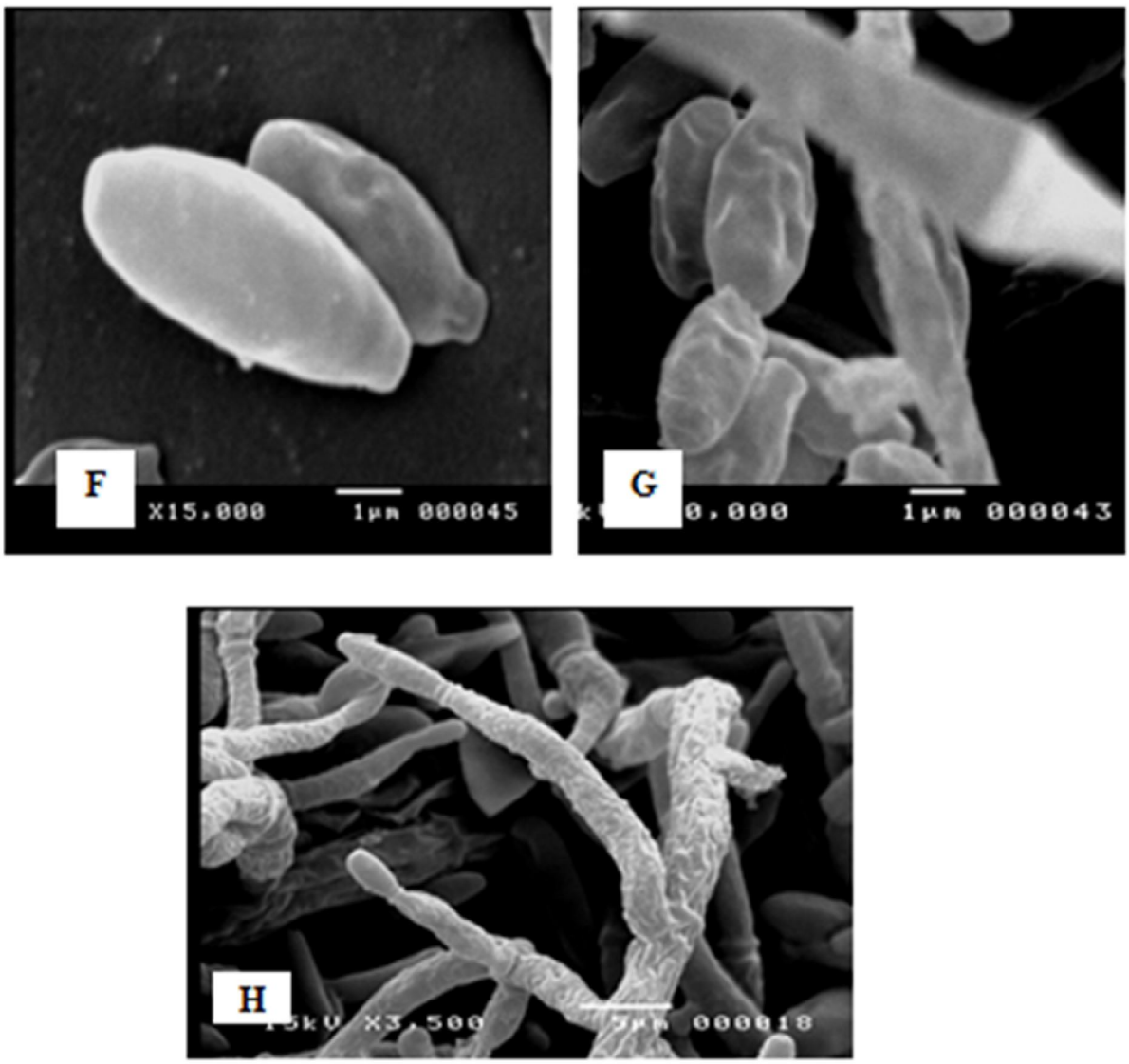

Plate 15 (continued): ***Fusarium nisikadoi*** **T. Aoki & Nirenberg**
F-H: S.E.M.; F, G: Microconidia; H: Monophialidic conidiogenous cells.

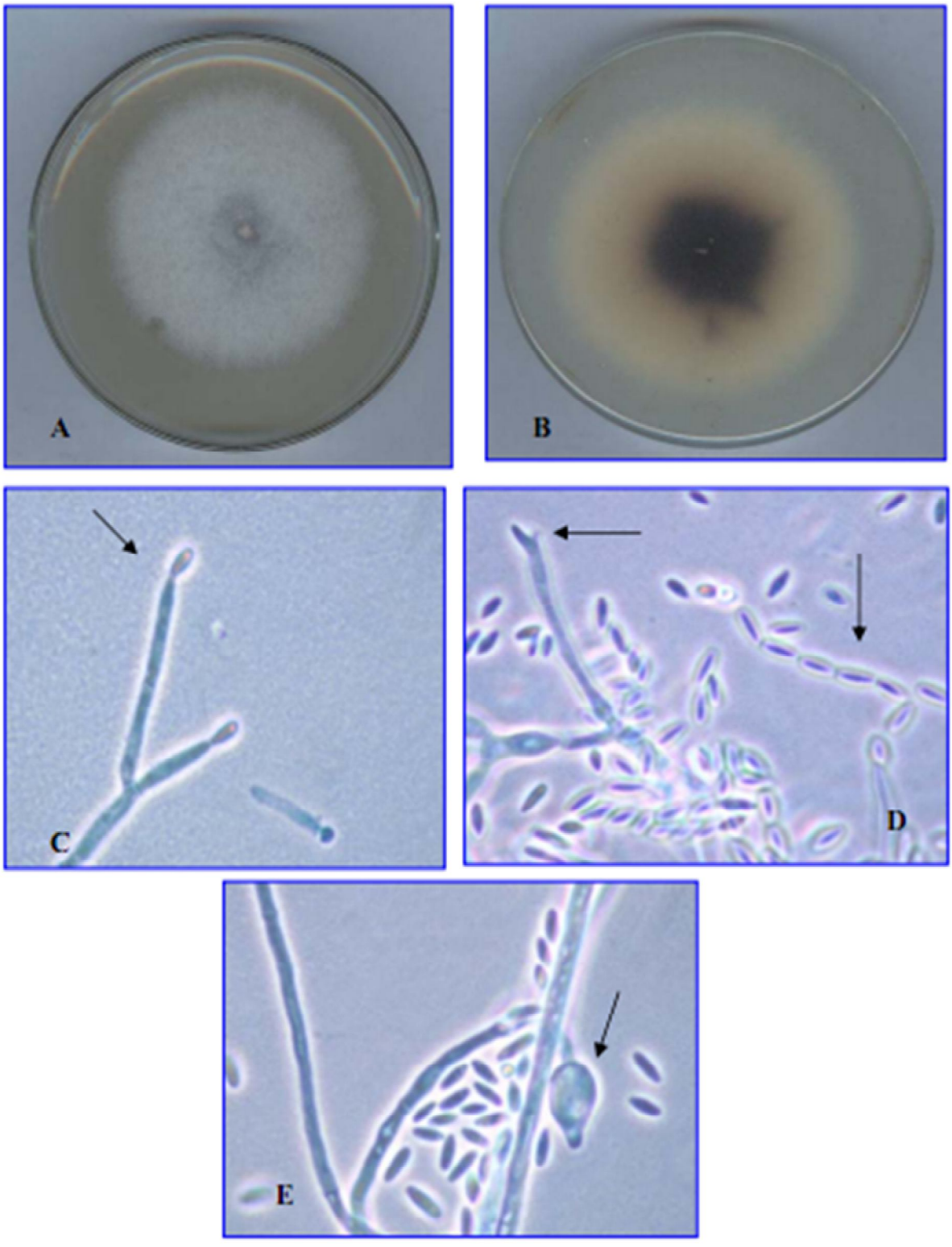

Plate 16: *Fusarium nygamai* Burgess & Trimoli

A, B: Colony colour and reverse on PSA; A-E: Photographs;
C, D: Mono- and polyphialidic conidiogenous cells;
D: Microconidia in chains; C: Chlamydospores.

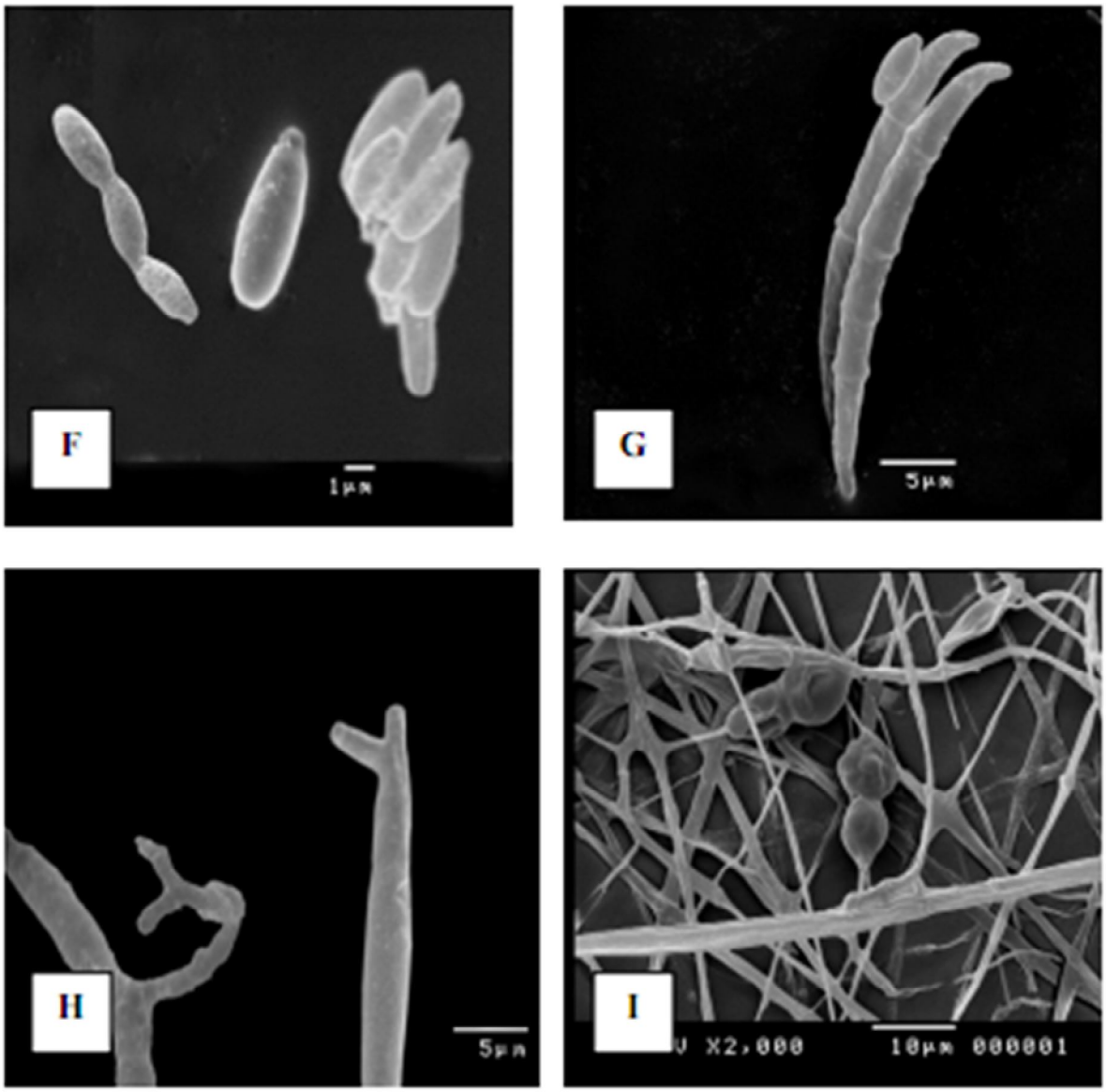

Plate 16 (continued): *Fusarium nygamai* Burgess & Trimboli
F-I: S.E.M.; F: Microconidia; G: Macroconidia;
H: Polyphialidic conidiogenous cells; I: Chlamydospores.

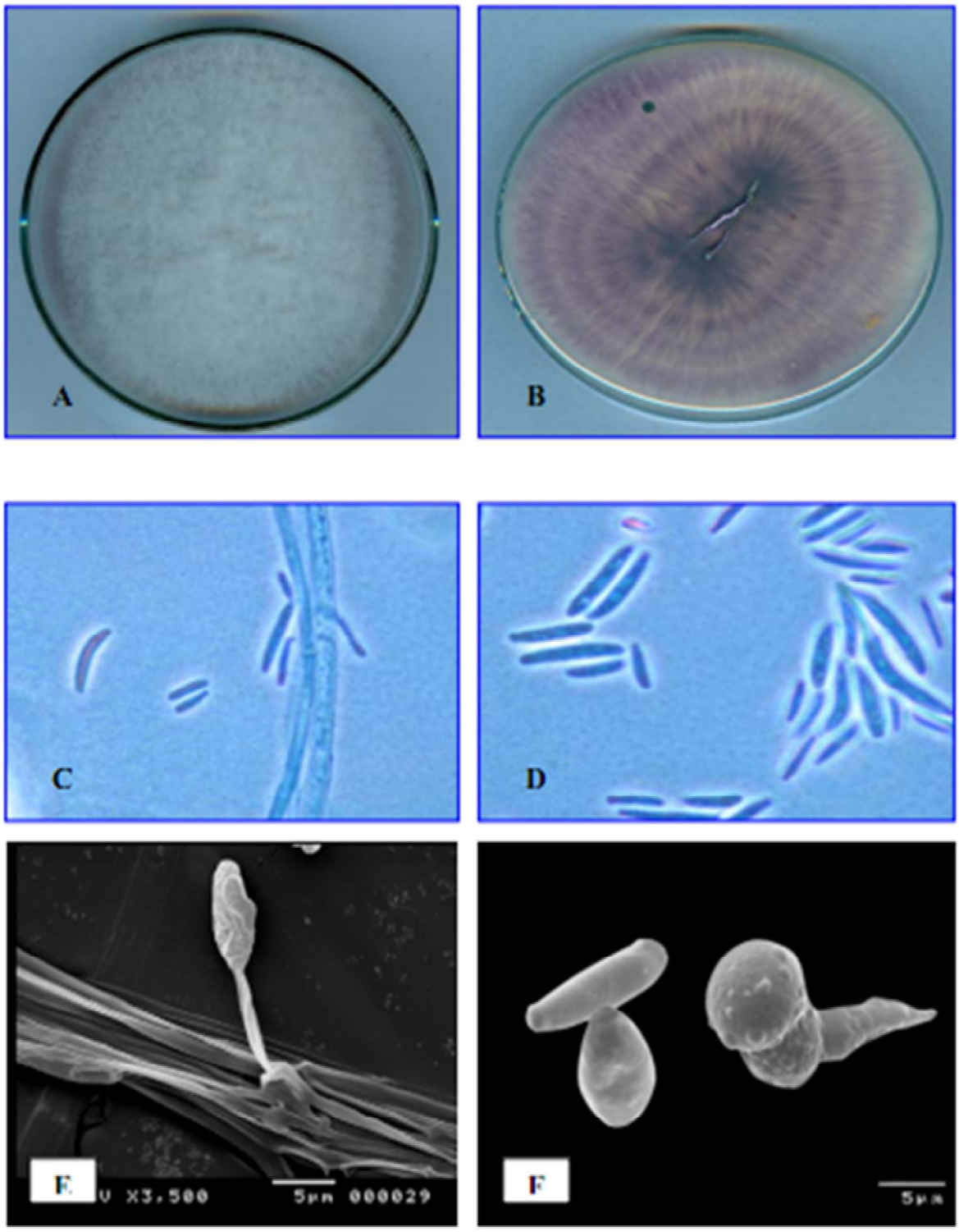

Plate 17: *Fusarium oxysporum* Schlechtendahl emend. Snyder & Hansen
A, B: Colony colour and reverse on PSA; A-D: Photographs; E-F: S.E.M.;
C: Monophialidic conidiogenous cell; D: Micro- and macroconidia;
E: False head; F: Chlamydospores.

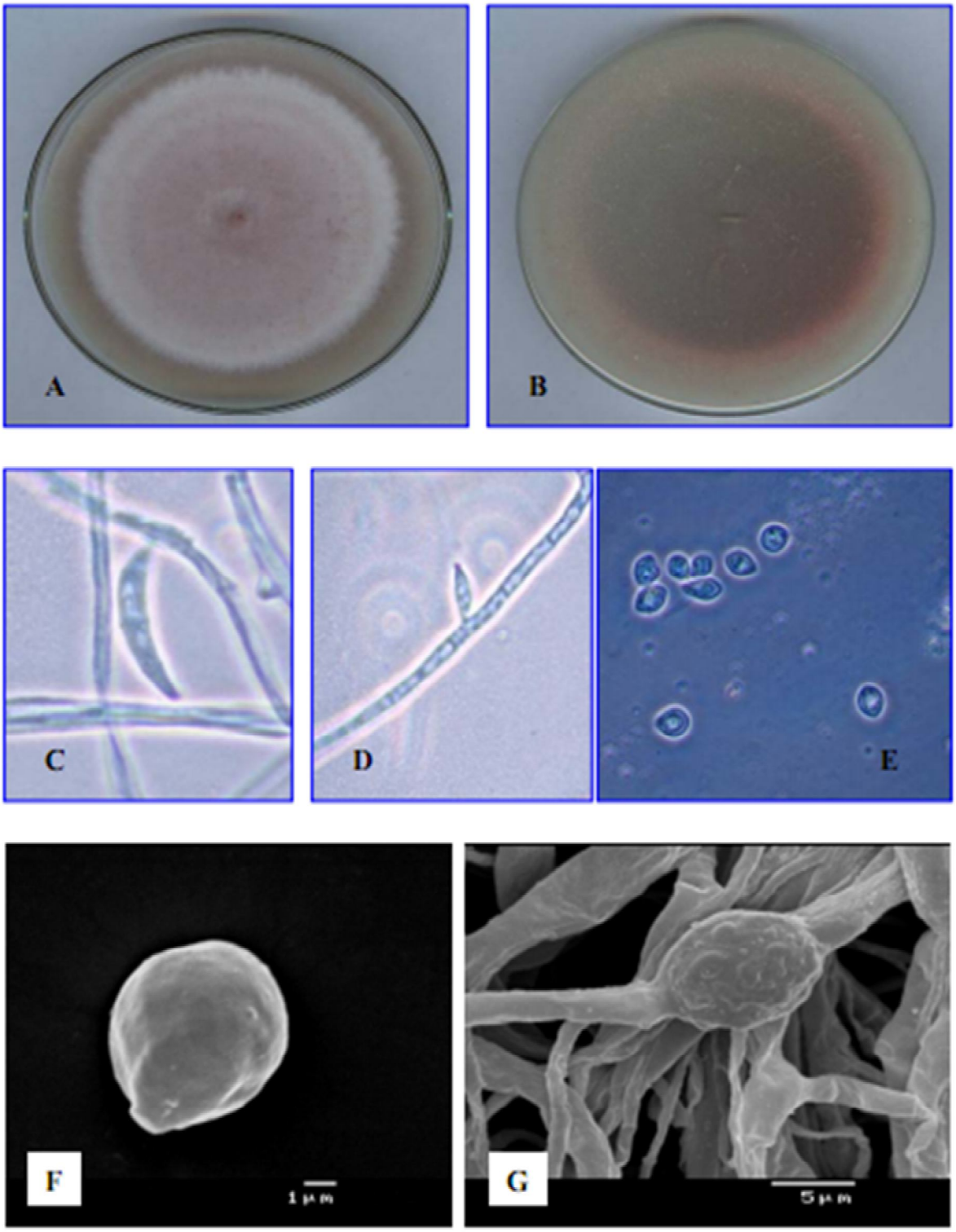

Plate 18: *Fusarium poae* (Peck) Wollenweber

A, B: Colony colour and reverse on PSA; A-E: Photographs; F-G: S.E.M.;
C: Macroconidia; D: Monophialidic conidiogenous cell;
E, F: Microconidia; G: Chlamydospores.

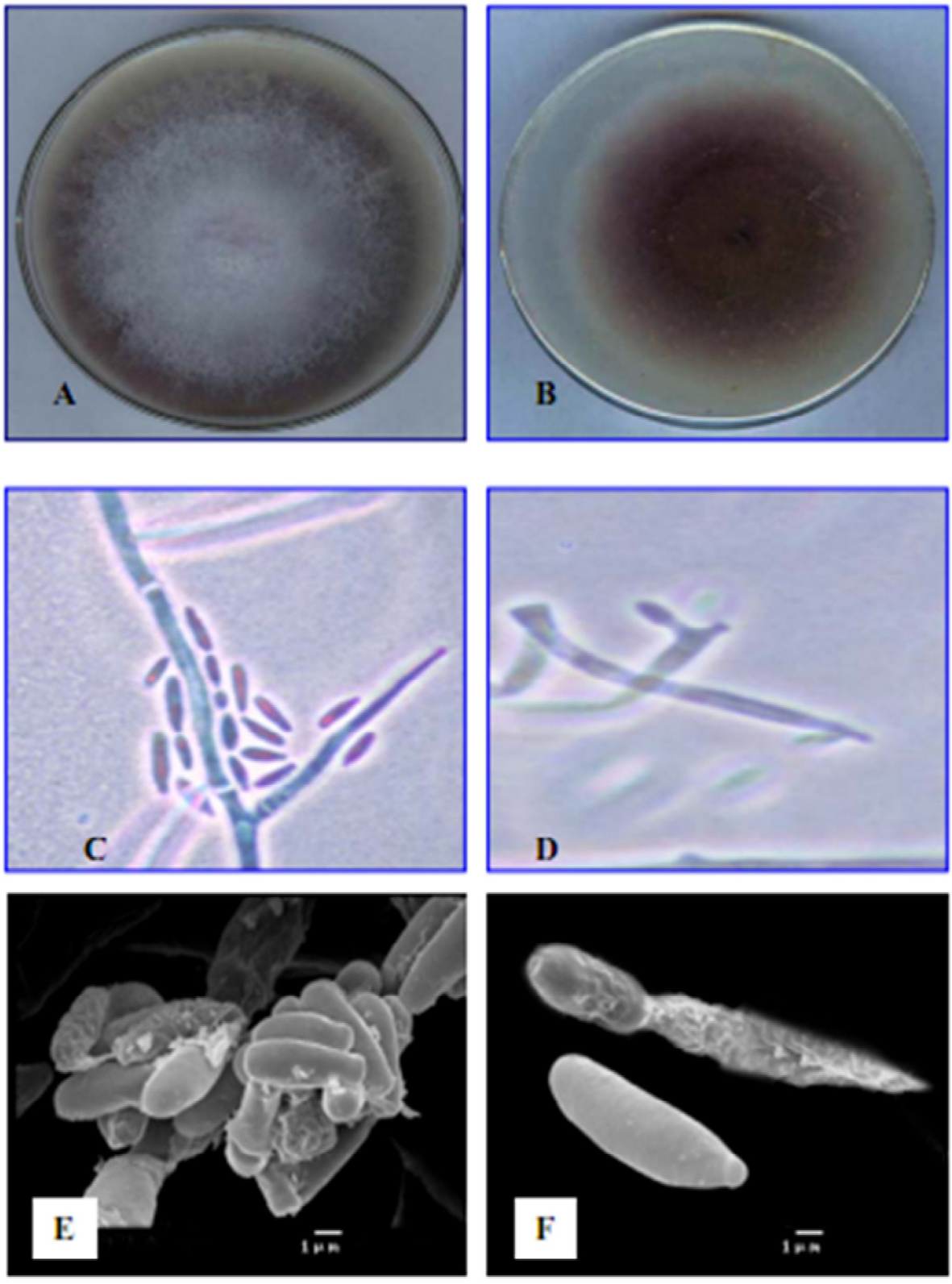

Plate 19: *Fusarium proliferatum* (Matsushima) Nirenberg

A, B: Colony colour and reverse on PSA; A-D: Photographs; E, F: S.E.M.;
C: Microconidia in chains; D: Polyphialidic conidiogenous cells;
E: Microconidia in false heads; F: Monophialidic conidiogenous cell.

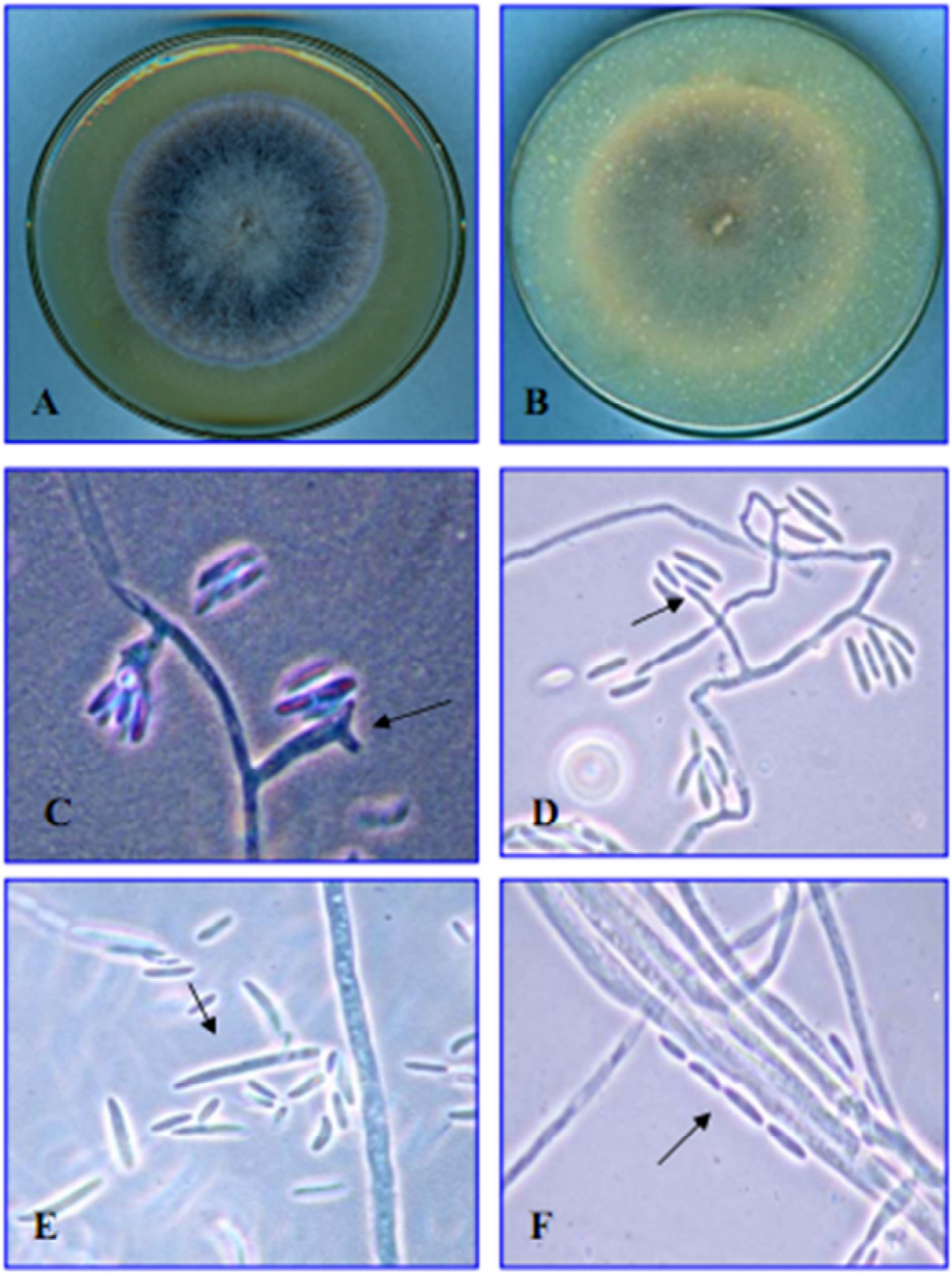

Plate 20: ***Fusarium pseudoanthophilum*** **Nirenberg & O'Donnell & Mubatanhema**
A, B: Colour of colony and reverse on PSA; A-F: Photographs;
C, D: Poly- and monophialidic conidiogenous cells;
E: Macroconidia; F: Microconidia in chain.

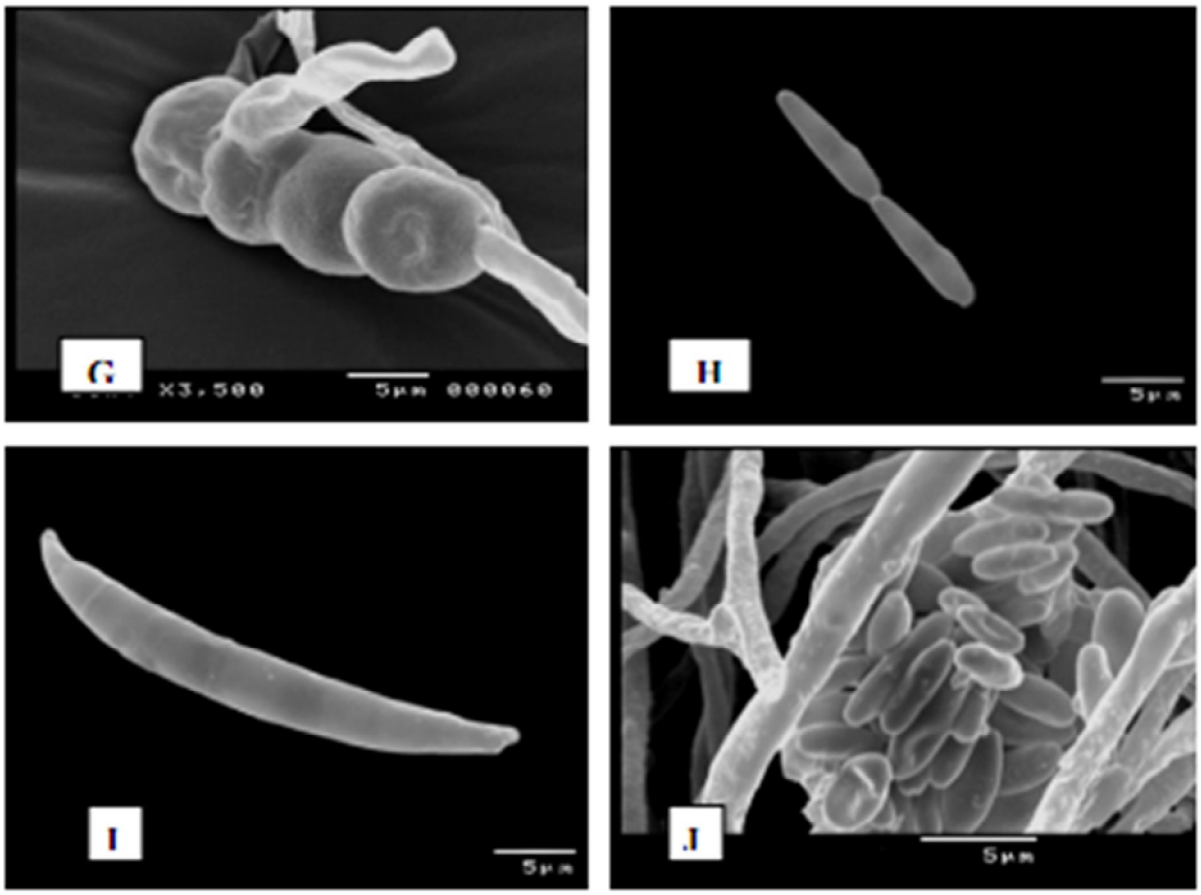

Plate 20 (continued): ***Fusarium pseudoanthophilum*** **Nirenberg & O'Donnell & Mubatanhema**

G-J: S.E.M.; G: Chlamydospores; H: Microconidia in chains;
I: Macroconidia; J: Microconidia.

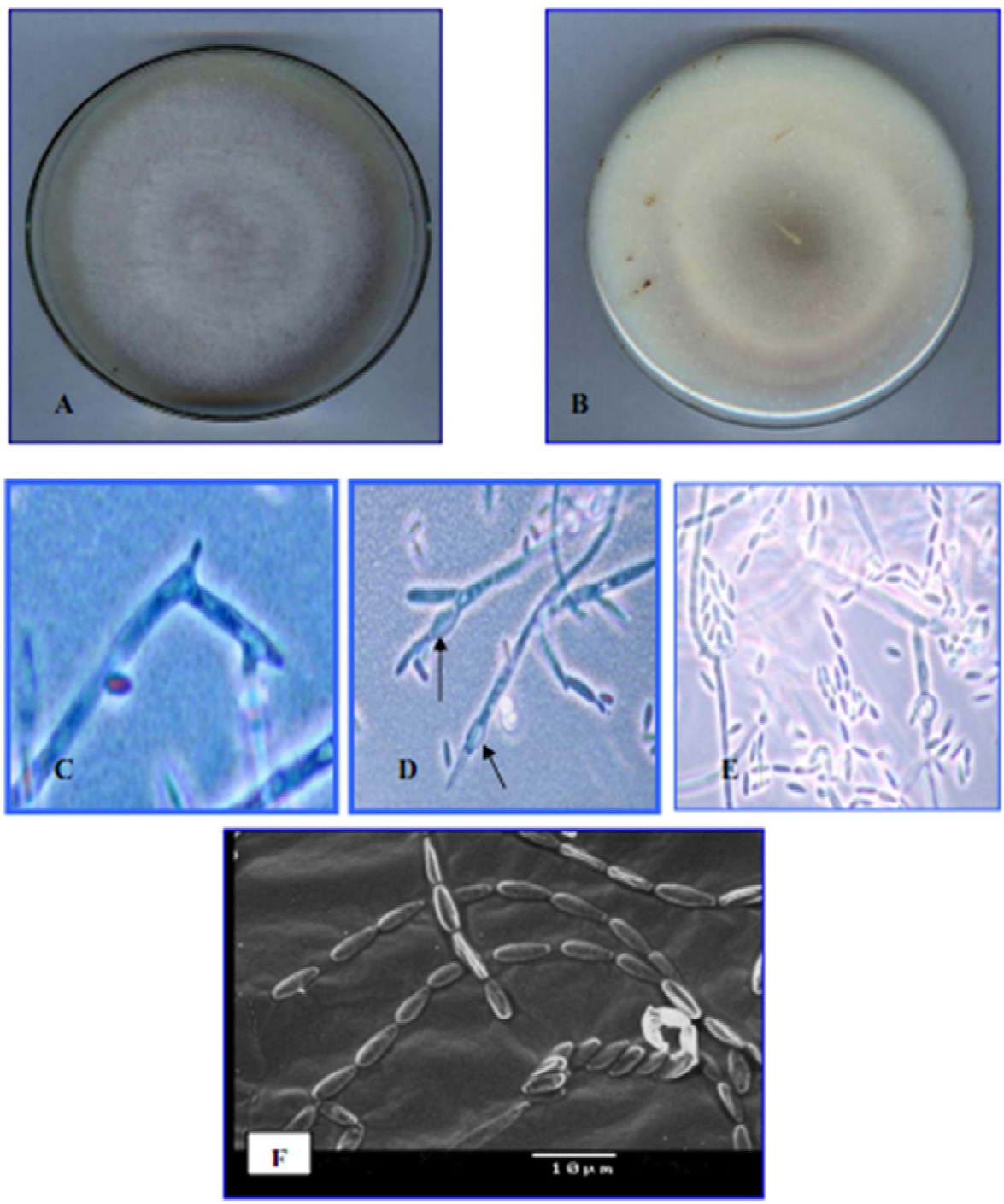

Plate 21: *Fusarium pseudonygamai* O'Donnell & Nirenberg

A, B: Colony colour and reverse on PAS; A-E: Photographs; F: S.E.M.; C: Polyphialidic conidiogenous cell; D: Hyphal swellings; E, F: Microconidia in chains.

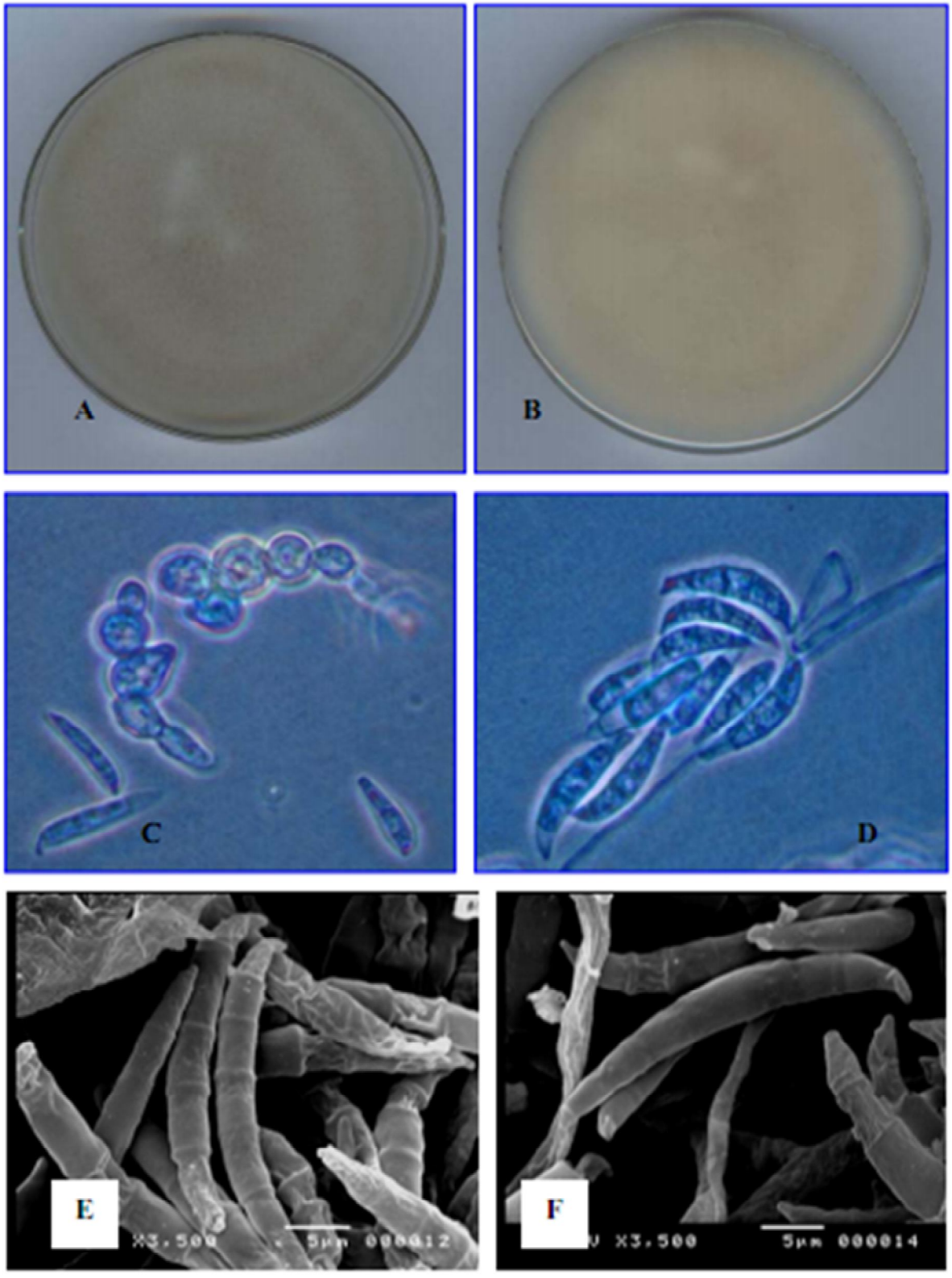

Plate 22: *Fusarium sambucinum* Fuckel

A, B: Colour of colony and reverse on PSA; A-D: Photographs;
E, F: S.E.M.; C: Chlamydospores; D-F: Macroconidia.

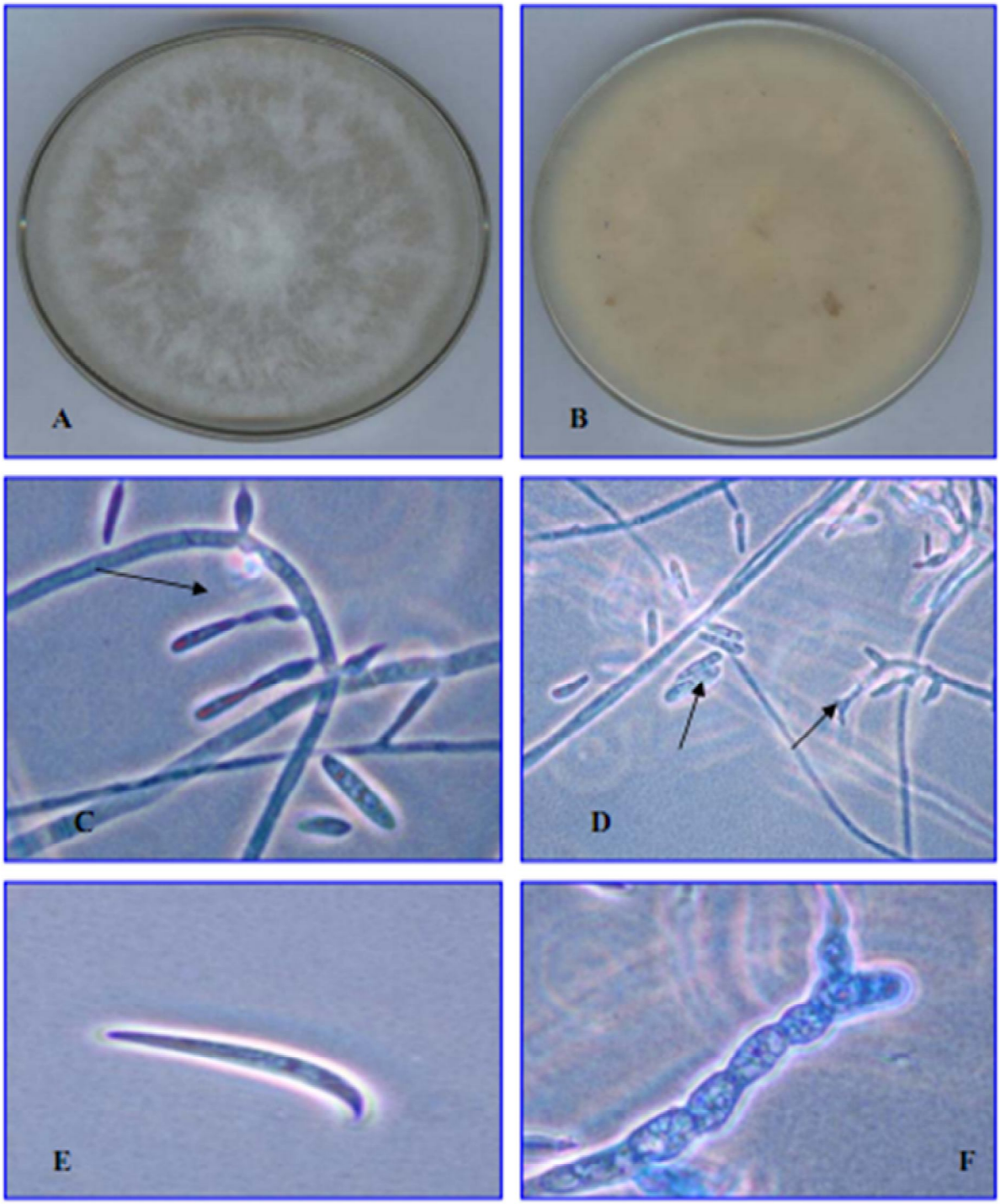

Plate 23: *Fusarium scirpi* Lambotte & Fautrey

A, B: Colony colour and reverse on PSA; A-F: Photographs;
C: Monophialidic conidiogenous cells; D: Polyphialidic conidiogenous cell and Microconidia; E: Macroconidia; F: Chlamydospores.

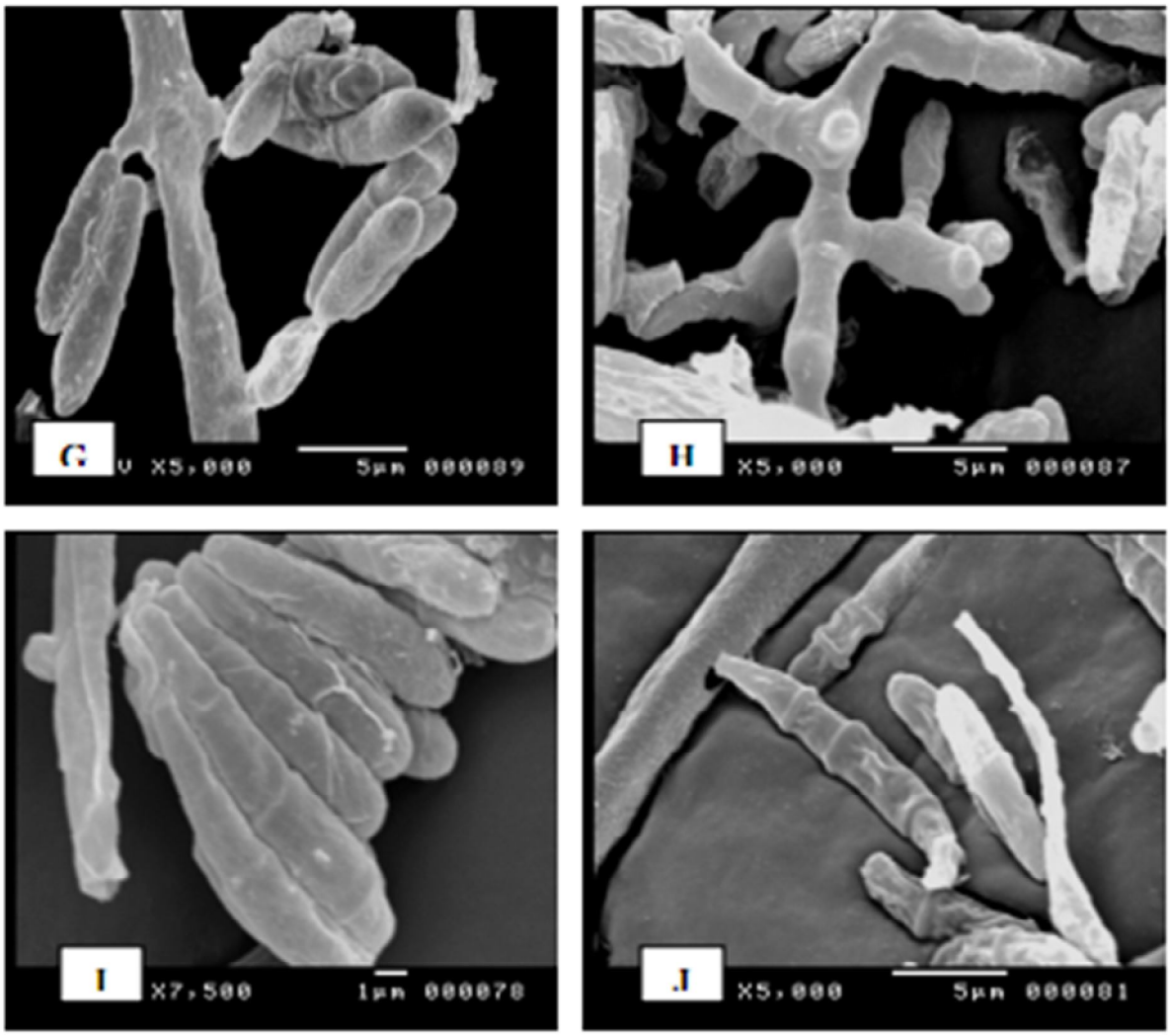

Plate 23 (continued): ***Fusarium scirpi*** **Lambotte & Fautrey**
G-J: S.E.M.; G, H: Mono-and polyphialidic conidiogenous cells;
I, J: Microconidia and Macroconidia.

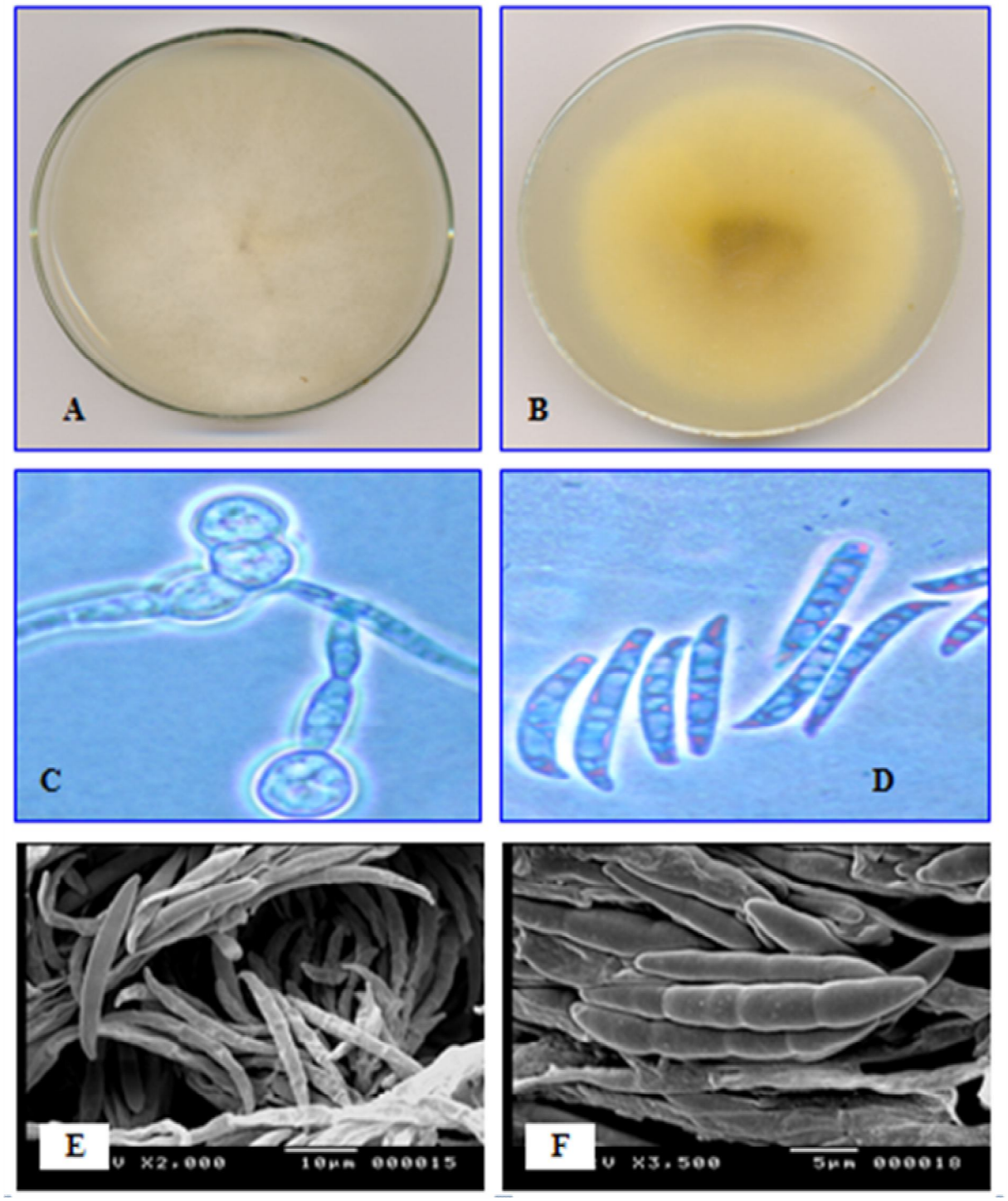

Plate 24: *Fusarium semitectum* Berkeley & Ravenel
A, B: Colony colour and reverse on PSA; A-D: Photographs; E, F: S.E.M.;
C: Chlamydospores; D, E: Macroconidia; F: Mesoconidia.

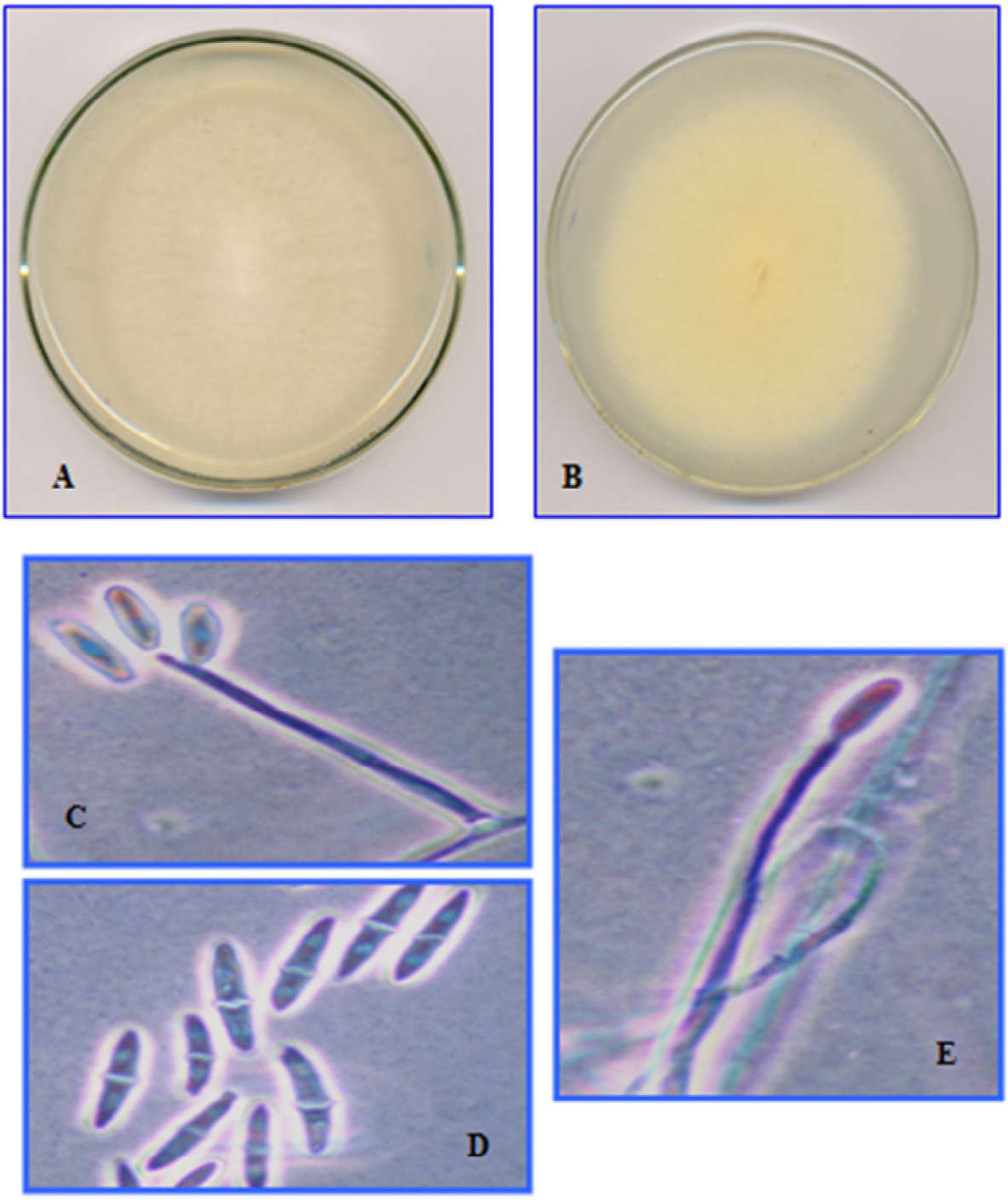

Plate 25: *Fusarium solani* (Martius) Appel & Wollenweber emend. Snyder & Hnsen
A, B: Colony colour and reverse on PSA; A-E: Photographs;
C, E: Long monophialidic conidiogenous cells; D: Microconidia.

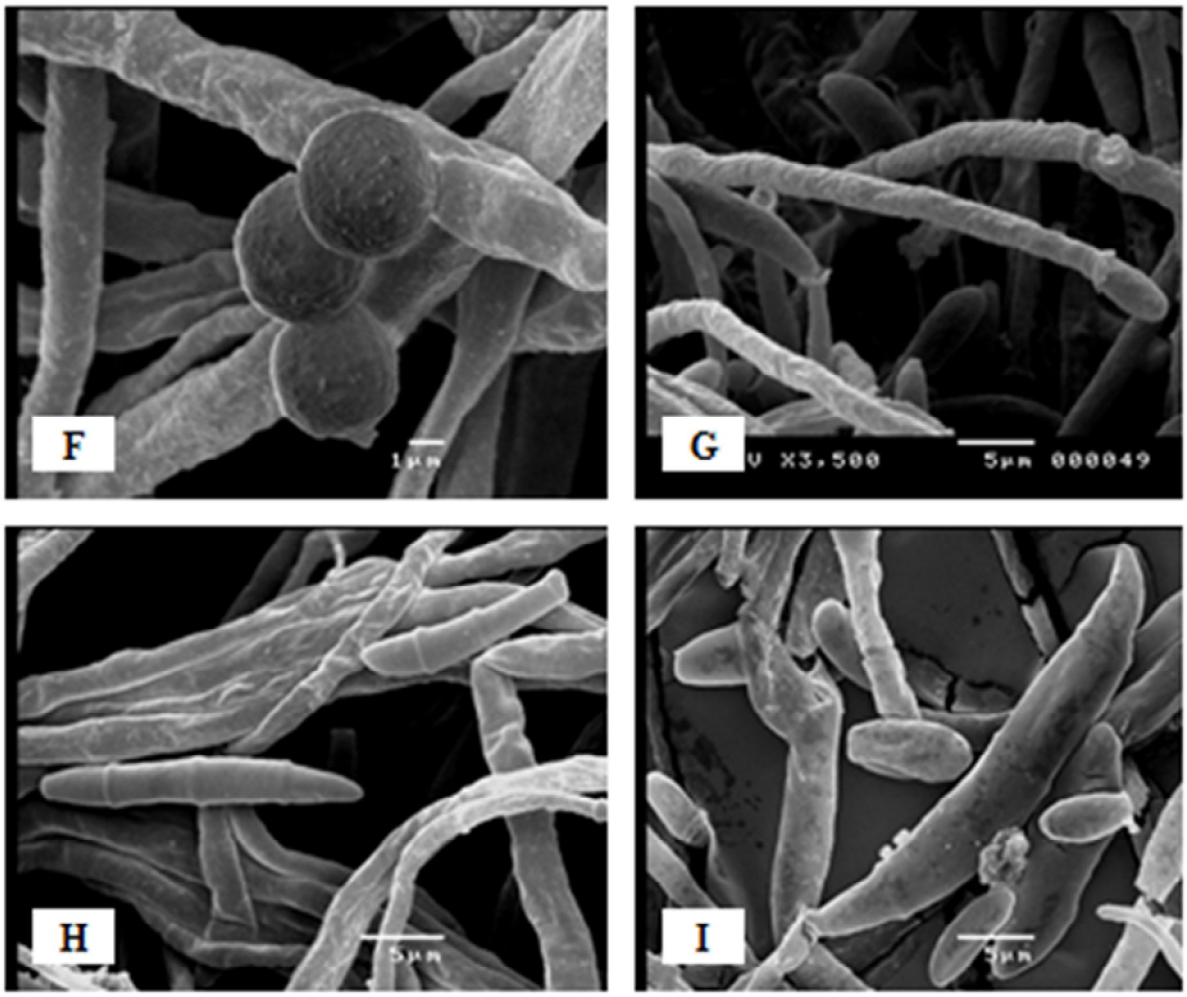

Plate 25 (continued): ***Fusarium solani*** **(Martius) Appel & Wollenweber emend. Snyder & Hnsen**

F-I: S.E.M.; F: chlamydospores; G: Long monophialidic conidiogenous cells; H, I: Macroconidia and microconidia.

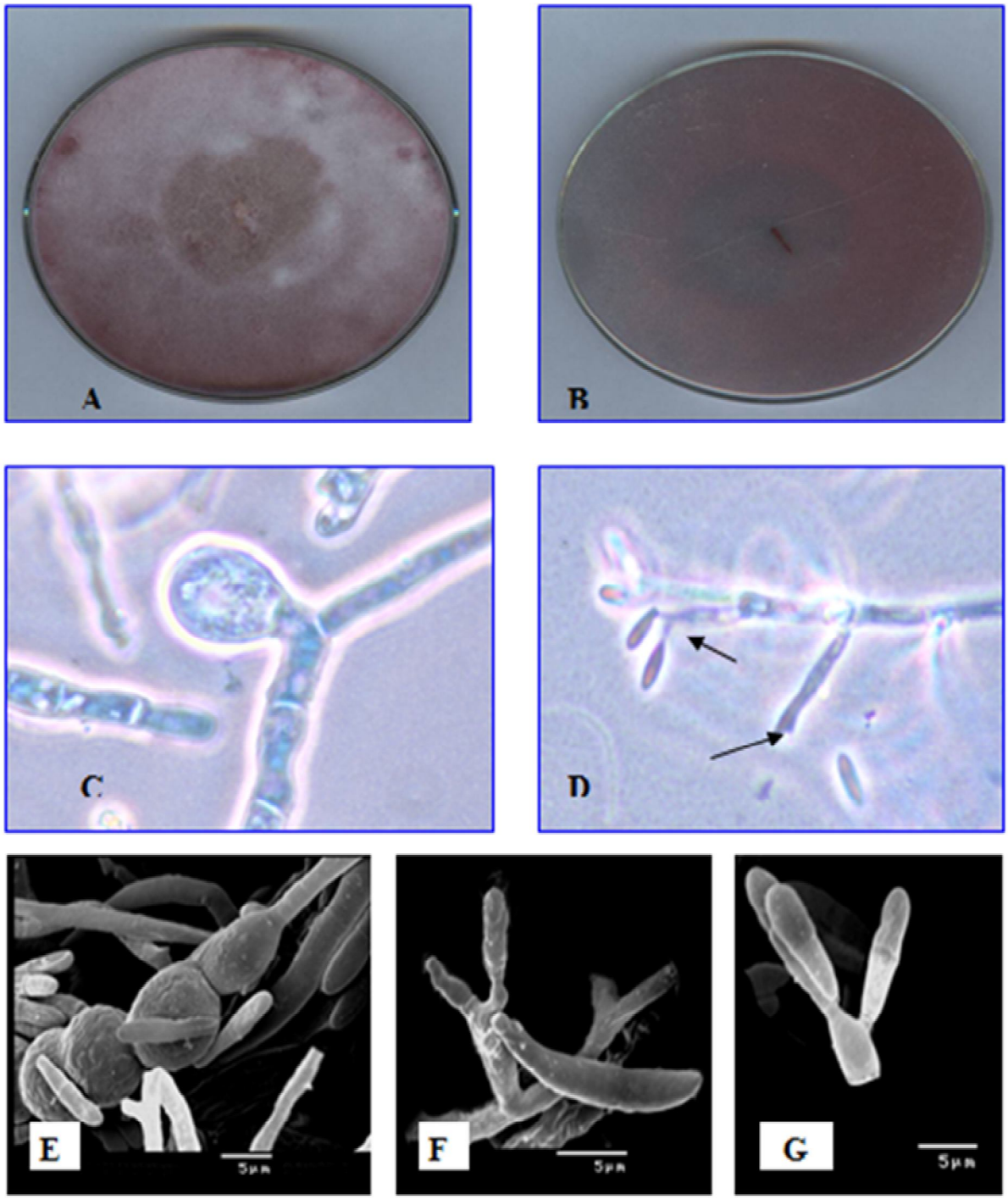

Plate 26: ***Fusarium sporotrichioides*** **Sherbakoff**
A, B: Colony colour and reverse on PSA; A-D: Photographs; E-G: S.E.M.;
C, E: Chlamydospores; D, F, G: Polyphialidic conidiogenous
cells and Microconidia; F: Macroconidia.

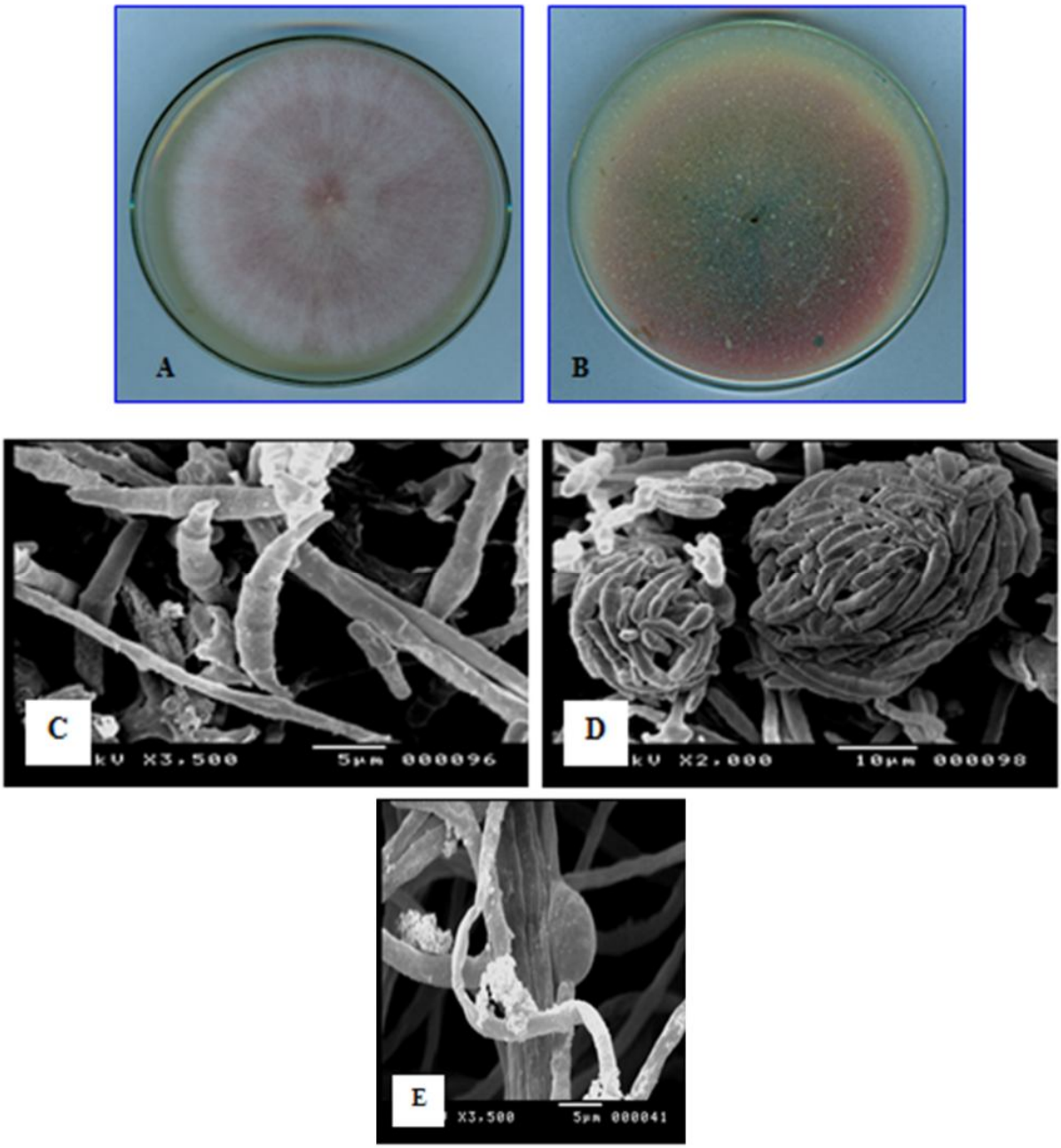

Plate 27: *Fusarium stilboides* Wollenweber

A, B: Colony colour and reverse on PSA; A, B: Photographs;
C-E: S.E.M.; C, D: Macroconidia; E: Chlamydospores.

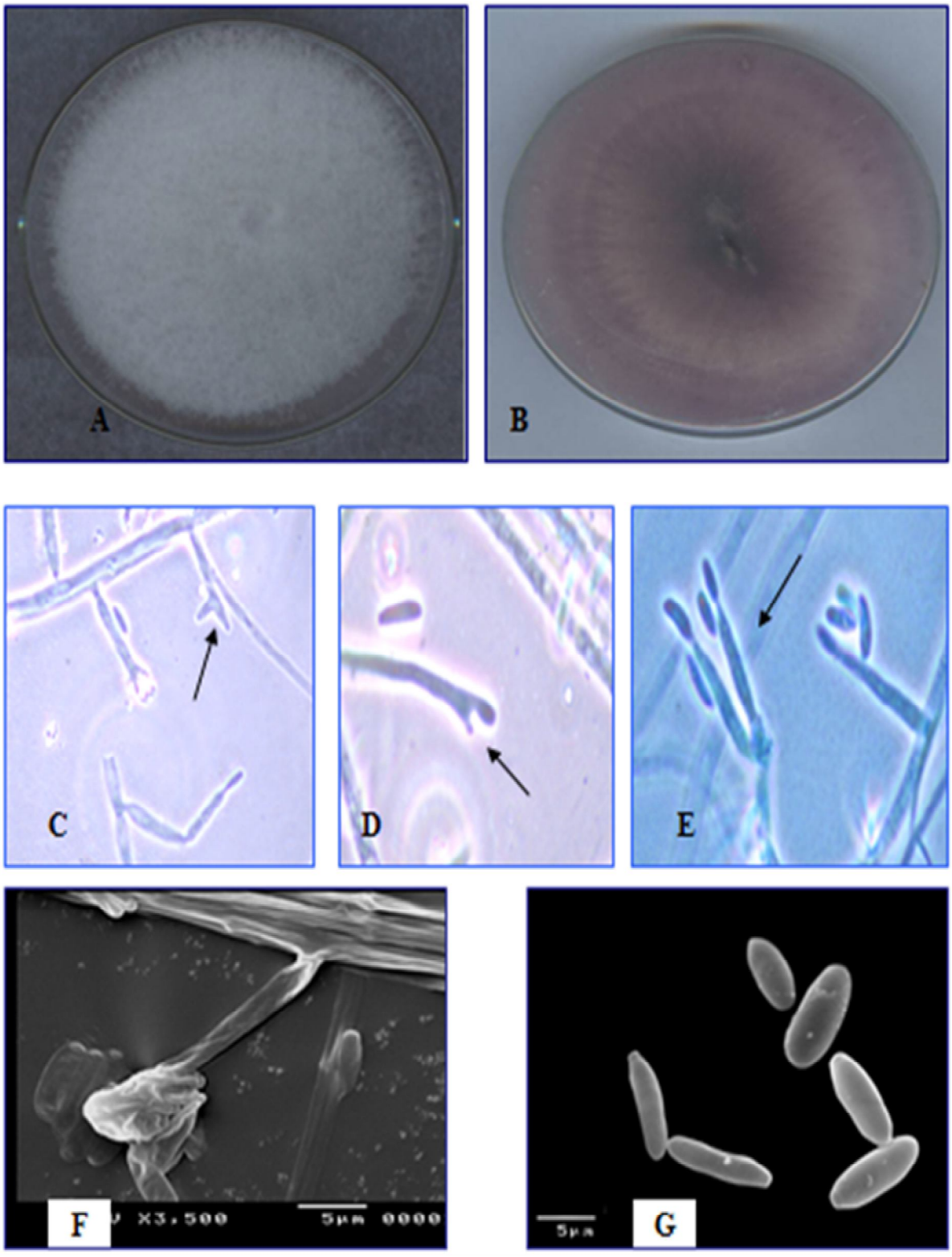

Plate 28: *Fusarium subglutinans* (Wollenweber & Reinking) Nelson, Toussoum & Marasas

A, B: Colony colour and reverse on PSA; A-E: Photographs; F, G: S.E.M.; C, D: Polyphaialidic conidiogenous cells; E: Monophialidic conidiogenous cells and Microconidia; F: False heads; G: Microconidia

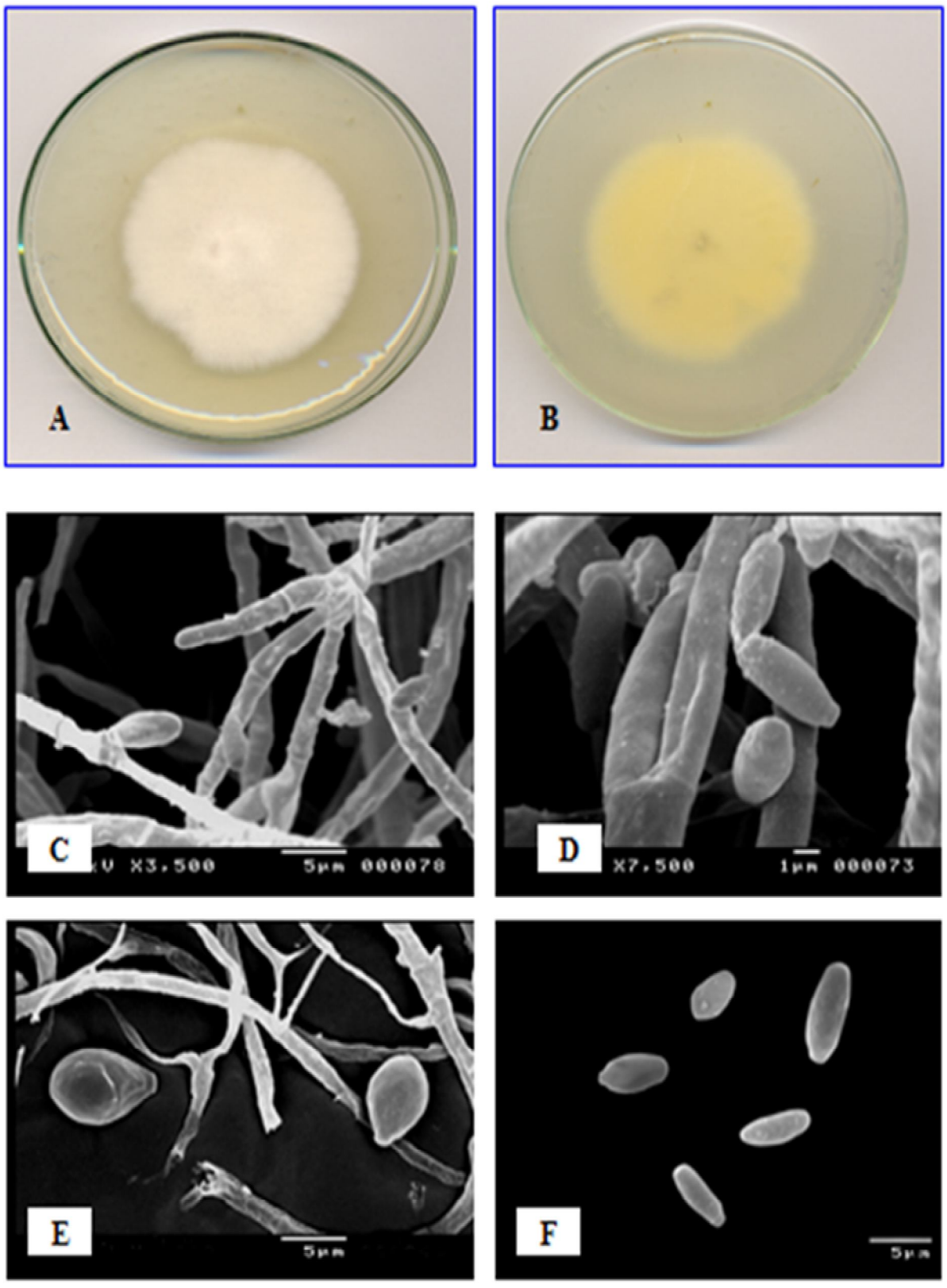

Plate 29: *Fusarium thapsinum* Klittich, Leslie, Nelson & Marasas
A, B: Colony colour and reverse on PSA; A, B: Photographs; C-F: S.E.M.;
C: Monophialidic conidiogenous cells; D, F: Microconidia (clavate);
E: Microconidia (napiforme).

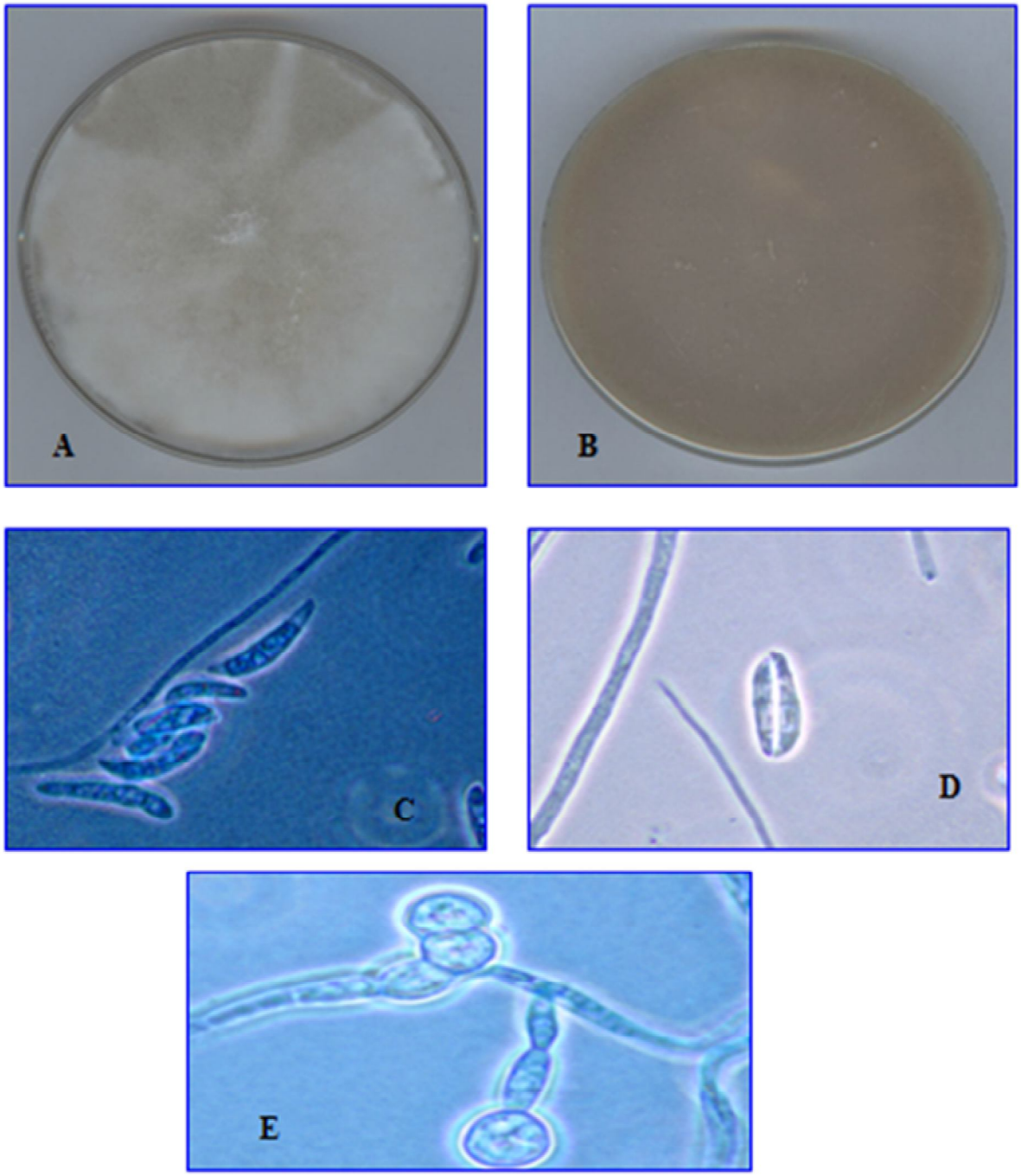

Plate 30: *Fusarium trichothecioides* Wollenweber
A, B: Colony colour and reverse on PSA; A-E: Photographs;
C, D: Macroconidia; E: chlamydospores.

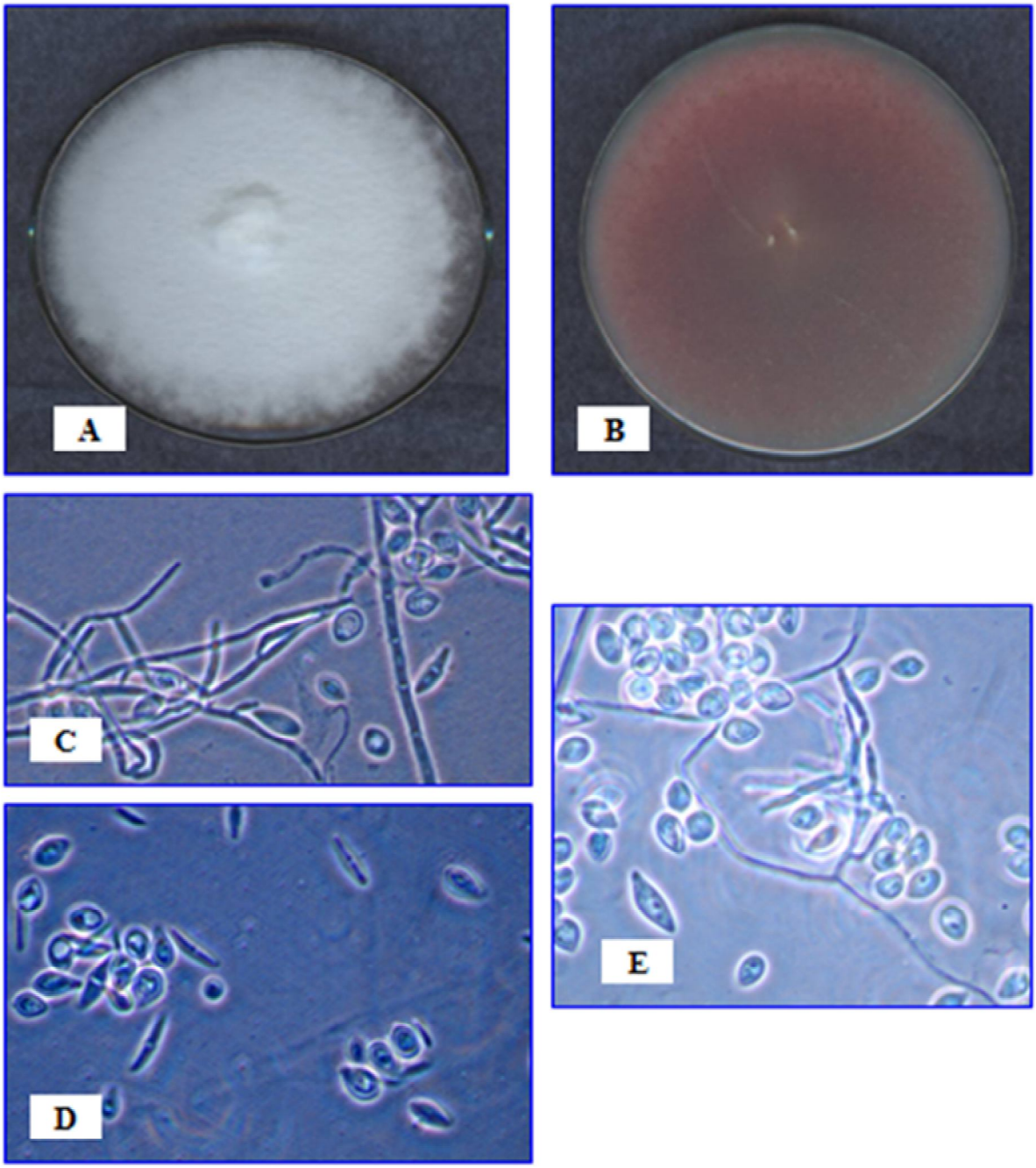

Plate 31: *Fusarium tricinctum* (Corda) Saccardo
A, B: Colony colour and reverse on PSA; A-E: Photographs;
C-E: Microconida (napiforme, oval, pyriforme).

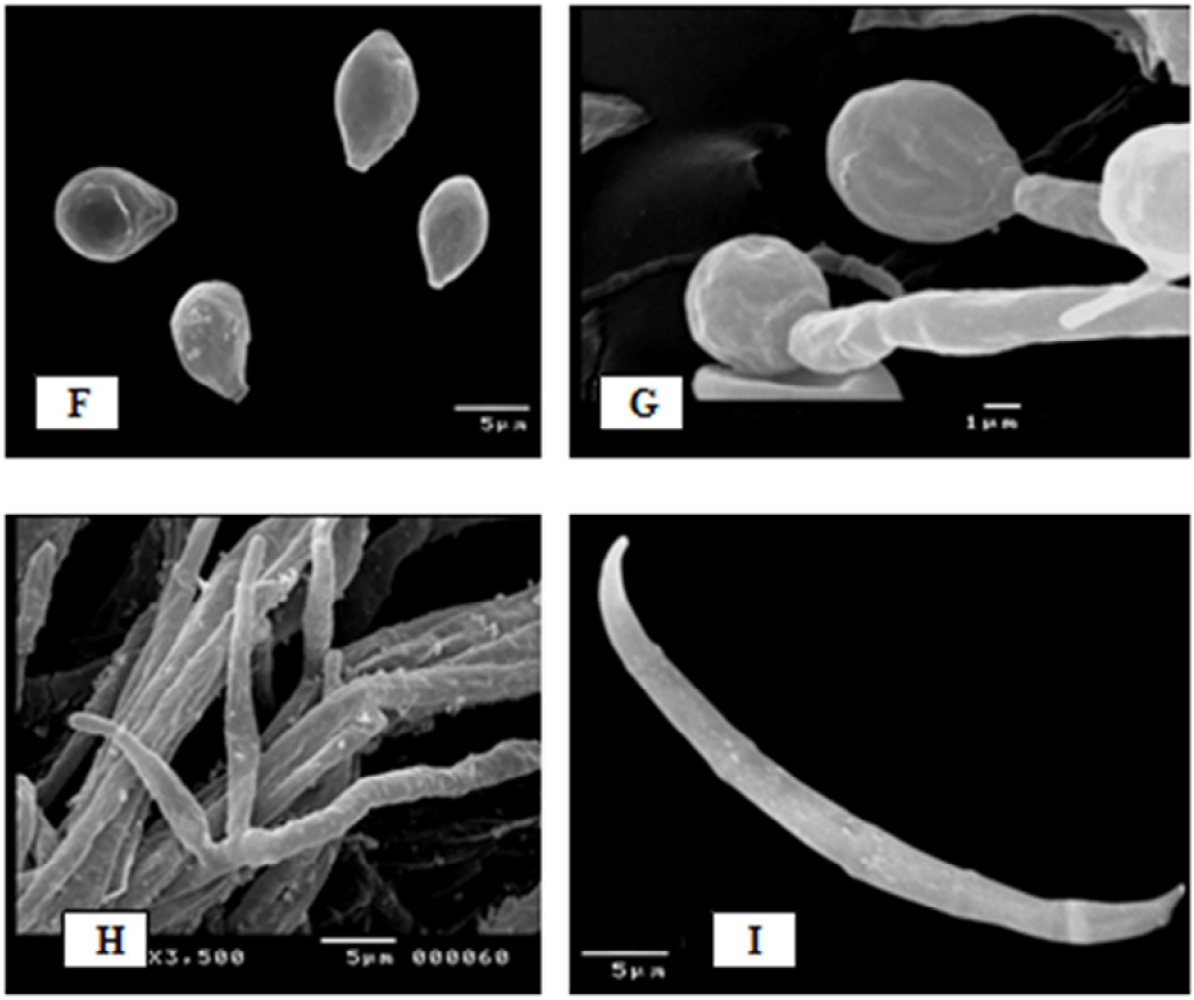

Plate 31 (continued): *Fusarium tricinctum* (Corda) Saccardo
F-I: S.E.M.; F, G: Napiforme microconidia; H: Monophialidic conidiogenous cells; I: Macroconidia.

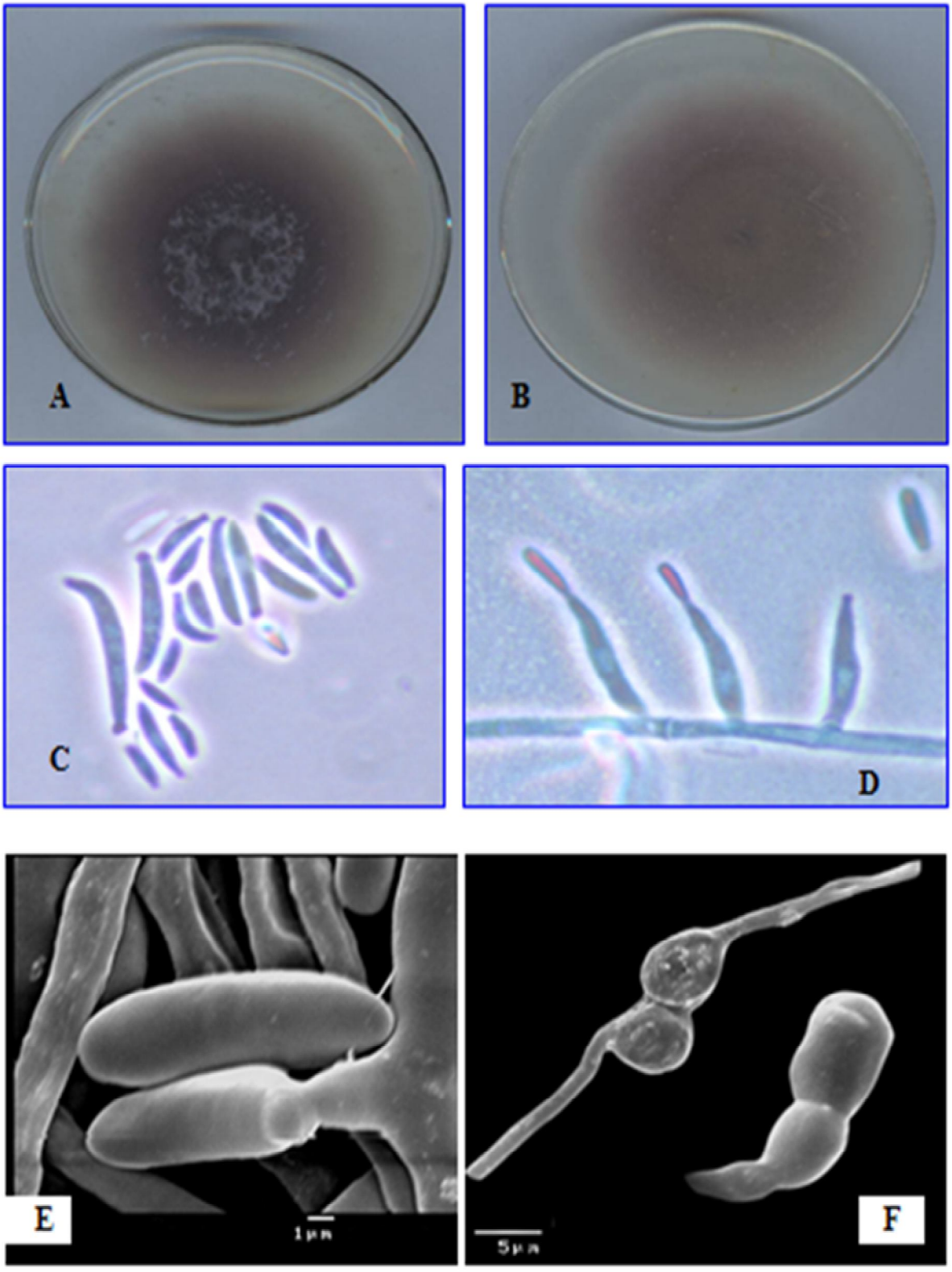

Plate 32: *Fusarium udum* Butler

A, B: Colony colour and reverse on PSA; A-D: Photographs; E-F: S.E.M;
C: Micro and macroconidia; D-E: Monophialidic conidiogenous cells,
F: Chlamydospores.

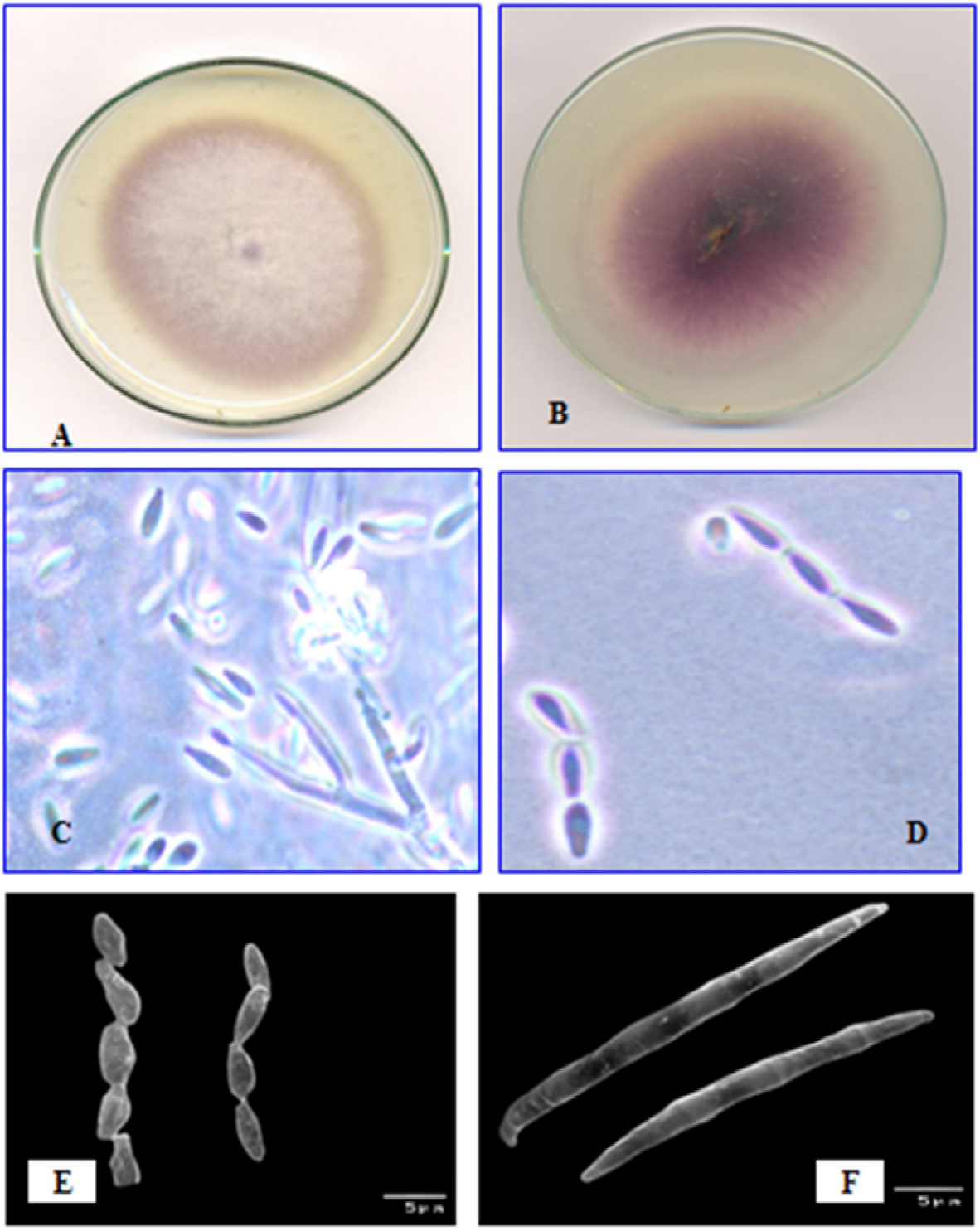

Plate 33: ***Fusarium verticillioides*** **(Saccardo) Nirenberg**

A, B: Colony colour and reverse on PSA; A-D: Photographs; E-F: S.E.M.;
C: Monophialidic conidiogenous cells; D-E: Microconidia in chains,
F: Macroconidia.

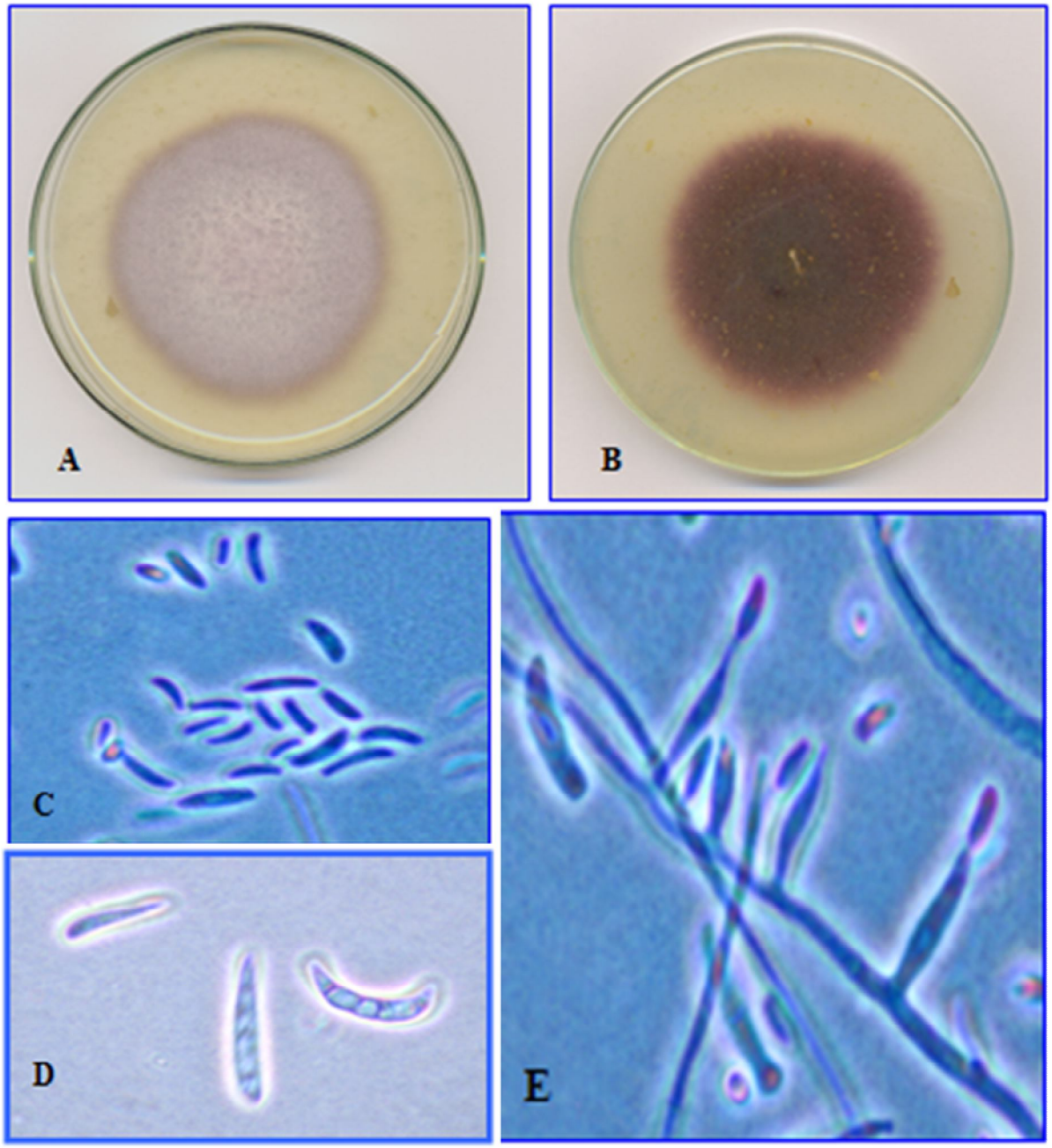

Plate 34: *Fusarium xylarioides* Steyaert

A, B: Colony colour and reverse on PSA; A-E; Photographs;

C-D: Micro- and Macroconidia, E: Monophialidic conidiogenous cells.

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