Development of microconidia in *Fusarium* section Sporotrichiella

P. S. VAN WYK AND M. J. WINGFIELD

Department of Microbiology, University of the Orange Free State, P.O. Box 339, Bloemfontein 9300, South Africa

W. F. O. MARASAS

Medical Research Council, P.O. Box 70, Tygerberg 7505, South Africa

J. L. BOSMAN

Department of Plant Pathology, University of the Orange Free State, P.O. Box 339, Bloemfontein 9300, South Africa

In *Fusarium chlamydosporum* and *F. sporotrichioides* microconidia are produced from more than one locus per conidiogenous cell. In *F. chlamydosporum* each locus is plugged after a single conidium is produced holoblastically. Production of all subsequent conidia is preceded by enteroblastic sympodial proliferation. In *F. sporotrichioides* the first conidium is produced holoblastically and percurrent proliferation of the conidiogenous locus precedes production of subsequent conidia from the same locus. Enteroblastic sympodial proliferation of the conidiogenous cell precedes production of a new conidiogenous locus. No periclinal thickening results from proliferation as it occurs concurrently with the early stages of conidium development. In *Fusarium poae* and *F. tricinctum* microconidia are produced from a single locus per conidiogenous cell. In both, the first microconidium is produced holoblastically. The production of subsequent conidia is preceded by proliferation which results in periclinal thickening and eventually percurrent proliferation of the conidiogenous cell.

Ultrastructure of wall orientation during the development of macroconidia in several *Fusarium* spp. has been described and illustrated (Marchant, 1975; Schneider & Seaman, 1982; Van Wyk *et al.*, 1987). However, many *Fusarium* spp. produce an additional conidial state commonly referred to as microconidia (Nelson *et al.*, 1983). Subramanian (1971) stated that macro- and microconidia in *Fusarium* develop in the same way, although only macroconidia were illustrated. With the exception of some recent work on the Section Liseola (Tiedt *et al.*, 1986; Tiedt & Jooste, 1988*a*, *b*), ultrastructural aspects of microconidial development in *Fusarium* have not received attention.

Fusarium spp. included in sections Sporotrichiella and Liseola are presently considered to be the most important producers of mycotoxins (Gams, 1984; Marasas *et al.*, 1984). Species within these sections are separated solely on the morphology of microconidia and microconidiophores (Nelson *et al.*, 1983). Within the section Sporotrichiella four species, i.e. *F. poae* (Peck) Wollenw., *F. tricinctum* (Corda) Sacc., *F. sporotrichioides* Sherb. and *F. chlamydosporum* Wollenw. & Reinking, are recognized (Nelson *et al.*, 1983).

This paper reports on the ultrastructure of microconidial development in *Fusarium* section Sporotrichiella as interpreted using the terminology of Minter *et al.* (1982, 1983).

MATERIALS AND METHODS

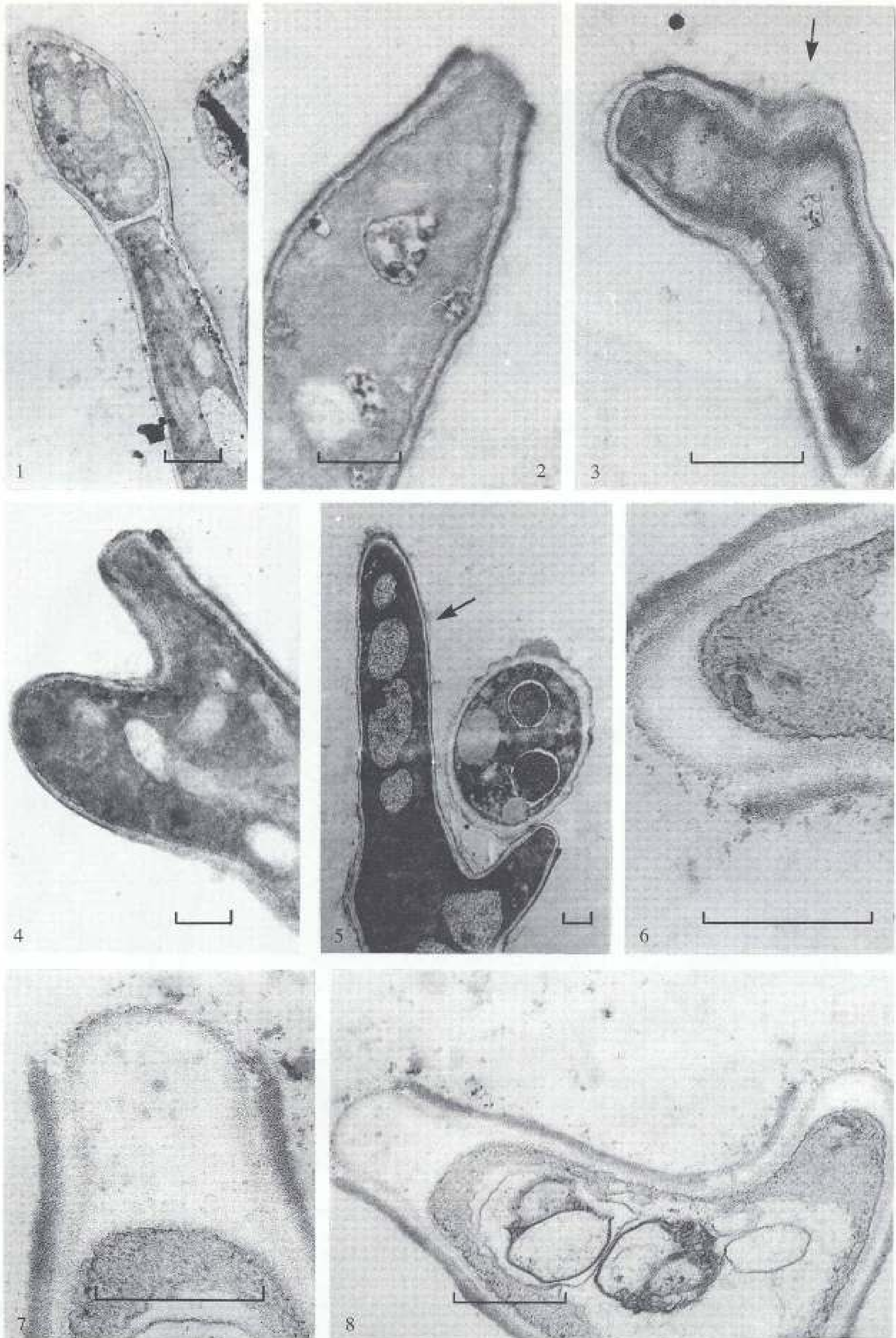
The following cultures from the collection of the South African Medical Research Council (MRC) were examined: *F. poae* (MRC 3225); *F. tricinctum* (MRC 1400); *F. sporotrichioides* (MRC 43, MRC 2184) and *F. chlamydosporum* (MRC 1798, MRC 3280).

Material for transmission electron microscopy (TEM) and scanning electron microscopy (SEM) was prepared as previously described (Van Wyk *et al.*, 1987; Wingfield *et al.*, 1987).

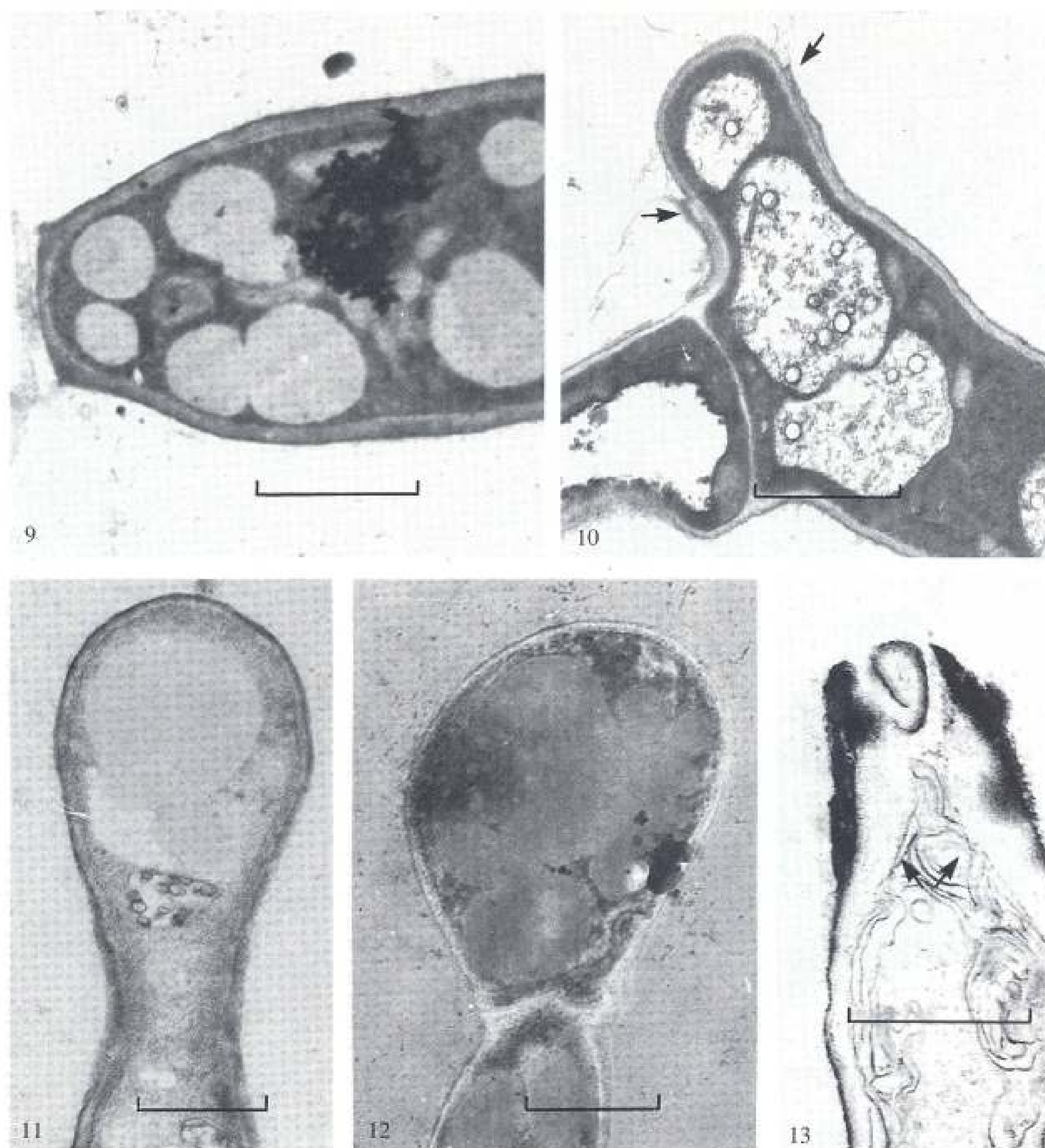
RESULTS

The first microconidium in *F. chlamydosporum* is produced holoblastically and is delimited by a septum (Fig. 1). After secession of the first conidium, outer wall remnants of the conidiogenous cell are visible as a minute collarette (Fig. 2) which is not detectable with a light microscope. At this stage enteroblastic sympodial proliferation of the conidiogenous cell is initiated (Fig. 3) and holoblastic development of the second conidium proceeds (Figs 4, 5). A single conidium is produced from each conidiogenous locus and, following secession, the conidiogenous locus is plugged with wall material laid down continuously with the inner wall layer of the conidiogenous cell (Figs 6–8). Production of all subsequent conidia is preceded by enteroblastic sympodial proliferation of conidiogenous cells.

The first microconidium in *F. sporotrichioides* is also produced holoblastically and secession results in a truncate based conidium (Fig. 9). The outer wall remnants are indistinct and



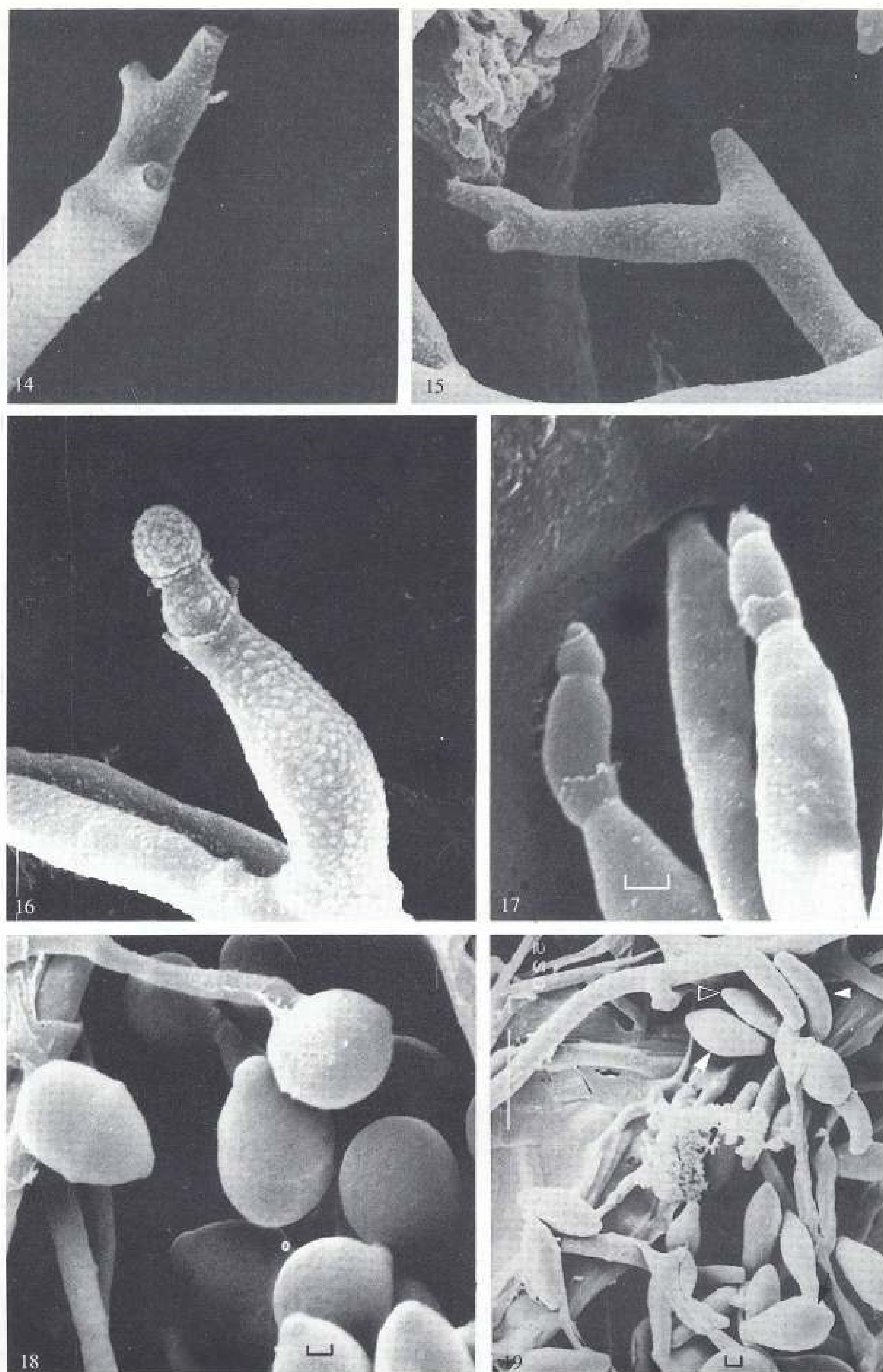
Figs 1–8. Development of microconidia in *Fusarium chlamydosporum* (TEM, bar = 1·0 µm). **Fig. 1.** First microconidium is produced holoblastically (diffuse wall-building) and delimited by a septum. **Fig. 2.** Condiogenous cell after secession of the first conidium. **Fig. 3.** Commencement of enteroblastic (arrows) sympodial proliferation of the conidiogenous cell. **Fig. 4.** Completed proliferation. **Fig. 5.** Second conidium (arrow) following holoblastic development and prior to delimitation. **Figs 6, 7.** Plugged conidiogenous loci with wall material laid down continuously with the inner wall layer of the conidiogenous cell. **Fig. 8.** Plugged conidiogenous cells.



Figs 9–13. Development of microconidia in *Fusarium sporotrichioides* and *F. poae* (TEM, bar = 1·0 μm). **Fig. 9.** Truncate base of holoblastically formed microconidium in *F. sporotrichioides*. **Fig. 10.** Developing second microconidium in *F. sporotrichioides*. The collarette is minute (arrows) and periclinal thickening absent. **Fig. 11.** Holoblastic production of first microconidium in *F. poae*. **Fig. 12.** Delimitation of first microconidium in *F. poae*. **Fig. 13.** Periclinal thickening (arrows) at the neck of the conidiogenous cell resulting from an accumulation of proliferation layers after production of several microconidia from the same locus in *F. poae*.

the small collarette (Fig. 10) is not visible using light microscopy. At this stage, however, production of subsequent conidia from this locus is not terminated (Booth, 1971; Gams, 1973) as in *F. chlamydosporum*. Following enteroblastic percurrent proliferation of the conidiogenous locus, subsequent microconidia are produced from the same locus (Fig. 10). The conidiogenous cell can also proliferate as in *F. chlamydosporum* to produce new loci from which conidia will be produced in the same way as those from the first locus. This finally results in a conidiogenous cell with more than one locus (Fig. 15). A SEM view of conidiophores of *F. chlamydosporum* and *F. sporotrichioides* suggests that they have similar conidiogenous cells (Figs 14, 15). However, what appear to be conidium initials in the case of *F. chlamydosporum* are in fact the plugged openings of the conidiogenous loci.

Development of the first microconidium in *F. poae* is holoblastic (Fig. 11) and delimitation (Fig. 12) is followed by secession. Repeated production of microconidia from the same locus results in periclinal thickening due to the build-up of proliferation layers in the neck of the conidiogenous cell (Fig. 13). Microconidia in *F. tricinctum* develop in exactly the same way and the conidiogenous cell is revitalized (Van Wyk *et al.*,



Figs 14–19. Conidiogenous cells and microconidia in *Fusarium* spp. (SEM, bar = 1·0 µm). **Fig. 14.** *F. chlamydosporum*, 'polyphialide'. **Fig. 15.** *F. sporotrichioides*, 'polyphialide'. **Fig. 16.** *F. poae*, percurrent proliferation of the 'monophialide'. **Fig. 17.** *F. tricinctum*, percurrent proliferation of the 'monophialide'. **Fig. 18.** Subglobose microconidia of *F. poae*. **Fig. 19.** Lemon-shaped (arrow) and spindle-shaped (arrow head) microconidia of *F. tricinctum*.

1988) by means of percurrent proliferation (Figs 16, 17). Production of microconidia is then resumed at a higher level in both species. Although microconidial development in *F. poae* and *F. tricinctum* is identical, *F. poae* produces only subglobose microconidia (Fig. 18) whereas *F. tricinctum* produces lemon-shaped as well as spindle-shaped microconidia (Fig. 19).

DISCUSSION

The four *Fusarium* spp. in the section Sporotrichiella can be divided into two groups on the basis of production of microconidia. In *F. poae* and *F. tricinctum* microconidia are produced from a single locus per conidiogenous cell (monophialide). In contrast, microconidia are produced from more than one locus on a conidiogenous cell (polyphialide) in *F. chlamydosporum* and *F. sporotrichioides*. Within both groups, species can be separated on the basis of the production of only one or more than one type of microconidium (Nelson *et al.*, 1983).

Due to the development of periclinal thickening in species producing conidia from a single locus, production of conidia has to be terminated when the opening is finally blocked. Alternatively cells must be revitalized by means of percurrent proliferation of the conidiogenous cell. In this respect, the development of microconidia in *F. poae* and *F. tricinctum* is similar to that reported for macroconidia in *F. crookwellense* (Van Wyk *et al.*, 1987).

In *Fusarium* spp. where microconidia are produced from more than one locus per conidiogenous cell, i.e. *F. chlamydosporum* and *F. sporotrichioides*, different types of proliferation preceding production of subsequent conidia were observed. In *F. chlamydosporum*, proliferation following production of the first conidium is enteroblastic and sympodial (Fig. 20). Multiple loci are, therefore, the result of sympodial proliferation of the conidiogenous cell (Cole, 1971). In contrast, production of a series of conidia (Booth, 1971; Gams, 1973) from the same locus results from enteroblastic percurrent proliferation of the condiogenous locus. Multiple loci, however, result from enteroblastic sympodial proliferation of the conidiogenous cell in *F. sporotrichioides*.

Although Cole (1971) defines typical sympodial development to be characterized by a single conidium which 'terminates each new growing point of the sympodially proliferating conidiogenous cell', we believe that this term should rather refer to the way in which the conidiogenous cell proliferates to form new conidiogenous loci. Development of the conidiogenous cell in *F. chalamydosporum* and *F. sporotrichioides* is similar and results in what are generally

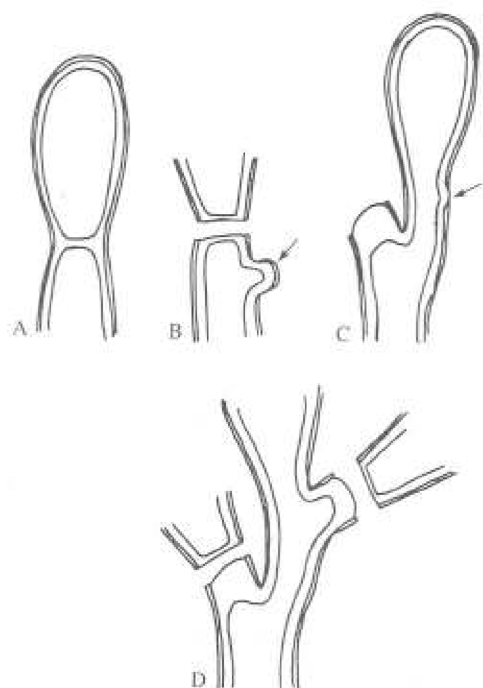


Fig. 20. Diagrammatic illustration of microconidial development in *Fusarium chlamydosporum*. A, First conidium has been delimited and secession commences; B, plugging of the conidiogenous locus and enteroblastic sympodial proliferation (arrow); C, second conidium is produced holoblastically and proliferation commences (arrow); D, third conidium to be delimited.

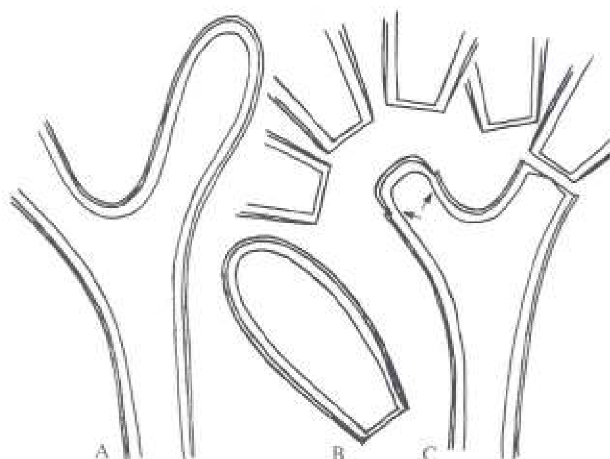


Fig. 21. Diagrammatic illustration of microconidial development in *Fusarium sporotrichioides*. A, Holoblastic development of a conidium; B, truncate based conidium as a result of schizolytic splitting of the septum; C, production of multiple microconidia from the same locus. Note absence of periclinal thickening (arrows).

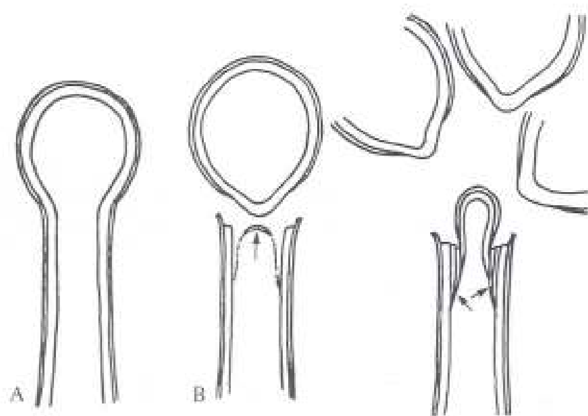


Fig. 22. Diagrammatic illustration of microconidial development in *Fusarium poae*. A, First microconidium produced holoblastically by means of diffuse wall-building; B, early stages in the development of a second microconidium (arrows); C, build-up of proliferation layers in the neck of the microconidiophore (periclinal thickening) following the production of several microconidia.

referred to as polyblastic (Booth, 1971) or polyphialidic (Nelson *et al.*, 1973) conidiogenous cells.

Proliferation preceding microconidium production in *F. sporotrichioides* never leads to periclinal thickening as seen in *F. poae* and *F. tricinctum*. It is, therefore, suggested that these differences are brought about by different forms of delimitation and secession (Van Wyk *et al.*, 1988). Proliferation layers, preceding conidium development in *F. poae* and *F. tricinctum*, remain part of the conidiogenous cell after conidium secession and function as a securing stage (as previously defined, Van Wyk *et al.*, 1988) prior to subsequent conidium development (apical wall-building, Fig. 22).

Booth (1971) considered the conidiogenous cells of *F. poae* and *F. tricinctum* as 'simple phialides'. Those of *F. chlamydosporum* (= *F. fusarioides* (Frag. & Cif.) Booth) were considered to be 'polyblastic conidiogenous cells' which produce 'blastospores'. It is possible that this conclusion was based on the clearly visible collarettes and periclinal thickening in the monophialides of *F. poae* and *F. tricinctum* and their absence in the polyphialides of *F. chlamydosporum* and *F. sporotrichioides*. These supposed differences prompted Booth (1971) to transfer the latter two species with 'polyblastic' conidiogenous cells from the Section Sporotrichiella to Arthrosporiella. Results of the present study indicate that microconidial development of the four *Fusarium* spp. presently accommodated in Section Sporotrichiella (Nelson *et al.*, 1983) is not fundamentally different and that they should be retained here. However, a detailed study of conidial development in Section Arthrosporiella is necessary finally to resolve this matter.

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