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Polish Endogonaceae 1. Acaulospora bireticulata, Entrophospora infrequens, Glomus caledonium, and Scutellospora pellucida

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BŁASZKOWSKI, J. 1989: Polish Endogonaceae 1. Acaulospora bireticulata, Entrophospora infrequens, Glomus caledonium, and Scutellospora pellucida. — Karstenia 29:1–10.

The occurrence and distribution of four species of the Endogonaceae in Poland are described and illustrated. *Entrophospora infrequens* (Hall) Ames & Schn., *Glomus caledonium* (Nicol. & Gerd) Trappe & Gerd., and *Scutellospora pellucida* (Nicol. & Schenck) Walker & Sanders probably occur in the whole of Poland, but in low frequencies, and *Acaulospora bireticulata* Rothw. & Trappe seems to be a very rare species, having been found in only 2 of the 141 soil samples studied. *G. caledonium* is new to Poland and the other species were found for the first time in Europe.

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Introduction

A wide range of plants form vesicular–arbuscular mycorrhizae (VAM) with fungi of the family Endogonaceae. Gerdemann (1968) recognized that these are possibly the most common of all soil fungi and that it would be easier to list families and genera of plants which do not enter into mycorrhizal connections with these fungi than those which do.

The VAM fungi are divided into six genera (*Acaulospora* Gerd. & Trappe, *Entrophospora* Ames & Schn., *Gigaspora* Gerd. & Trappe, *Glomus* Tul. & Tul., *Sclerocystis* Berk. & Br., *Scutellospora* Walker & Sanders) and are primarily differentiated by the spore morphology (Gerdemann & Trappe 1974, Walker & Sanders 1986).

The occurrence and distribution of VAM fungi are best known in the U.S. and Canada (Gerdemann & Trappe 1974, Nicolson & Schenck 1979, Schenck & Smith 1982, Berch & Fortin 1984, Miller et al. 1985), and in New Zealand and Australia (Mosse & Bowen 1968, Tandy 1975, Hall & Abbott 1984, McGee 1986). They have been found sporadically in Europe, viz. in France (Tulasne & Tulasne 1845), Denmark (Lange 1956), Great Britain (Godfrey 1957, Hawker 1974), Italy (Fassi 1965, Puppi & Riess 1982), Norway (Eckblad 1985), Finland (Karsten 1884), Sweden (Kers 1985), Czechoslovakia (Kubikova 1961, Bahadur 1970), Hungary (Szemere 1965), and the U.S.S.R. (Bucholtz 1912). They have also been reported in Taiwan (Wu & Chen 1985), India (Battacharjee & Mukerji 1980, Mukerji et al. 1983), Cuba (Ferrer & Herrera 1980), Mexico and Japan (Trappe 1977).

There are only three reports of the occurrence of the Endogonaceae in Poland (Błaszkowski 1988). Since 1983 the author of this article has undertaken regular investigations on the occurrence and geographic distribution of this group of fungi in Poland, the results of which will be presented in this series.

Material and methods

Each year soil samples were collected from the end of July to the end of November. They were taken from the root zone, from a depth of 5–20 cm, and then refrigerated until processing. The other methods and the general terms used in these studies are the same as those presented in an earlier paper (Błaszkowski 1988). In addition, a polyvinyl alcohol/glycerol/lactic acid solution (PVGL) (Koske & Tessier 1983) was used in the morphological studies of spores and Munsell Soil Color Charts (Munsell Color Company, INC., Baltimore, Maryland 1954) in the observations on spore colour.

All collections were made by the author. They are preserved in PVL and PVGL on microscope slides or in small vials with 5% formalin and deposited in the Department of Plant Pathology (DPP), Academy of Agriculture, Szczecin, Poland.

Acaulospora bireticulata Rothw. & Trappe

This species is distinguishable by the characteristic ornamentation of the outermost spore wall, which consists of a polygonal reticulum overlying the spore surface covered with rounded spines (Fig. 2). In the spores from Poland, the colour, size and dimensions of the structures forming the wall ornamentation agree with the original description. According to Walker's (1983) terminology, the wall structure of *A. bireticulata* spores consists of three walls: an outer, coloured, fairly thick (4–4.4 µm thick in Polish specimens), ornamented, unit wall (wall 1) in the wall group A, and two hyaline, 0.5 µm and ± 1 µm thick, membranous and unit inner walls (walls 2, 3) in the wall group B (Fig. 1).

The Polish collections lack the lateral hyphae tapering to globose to subglobose hyphal termini characteristic of species of the genus *Acaulospora*. These structures usually disappear from maturing spores or fall off during wet-sieving, leaving round scars (Trappe & Schenck 1982), which are seen on the collections from Poland.

A. bireticulata spores are very similar to those of *Scutellospora reticulata* (Koske, Miller & Walker) Walker & Sanders, having the same ornamentation of the outermost spore wall, but even if the suspensor-like cell of *S. reticulata* spores is missing, the two species are easily distinguished by their spore wall structure (3-walled vs. 6-walled).

This species has earlier been found only four times: in a soil sample collected in the field under *Sassafrans albidum* (Nutt.) Ness, in Kentucky, and in a greenhouse pot culture with *Zea mays* L. established in the same soil (Rothwell & Trappe 1979), under *Centrosema pubescens* L. in Florida (Schenck & Smith 1982), and under *Malus domestica* Borkh. in Michigan (Miller et al. 1985).

In Poland *A. bireticulata* was found only twice (Table 1, Fig. 14). It is probably a rare species occurring in small densities.

Material examined

See Table 1; specimens deposited: 812–816 and 957–959 (DPP).

Entrophospora infrequens (Hall) Ames & Schn.

The spores from Poland are as described by Ames and Schneider (1979), though they usually lack, or possess only a fragment of the vesicle connected with the thin outer wall in which they were formed (Figs. 3, 4). In spite of this, the species is relatively easy to recognize by its characteristically ornamented spores (with vacuolated spines) with 3 walls (an evanescent, hyaline outermost wall; a laminate, coloured, ornamented middle wall; a unit, hyaline, smooth inner wall).

Table 1. Frequency of occurrence of *Acaulospora bireticulata* in Poland and chemical properties of soils from which this species was isolated.

Plant family	Plant species	No. of soil sample	No. of spores/ 100 g dry soil	Chemical properties			
				pH (in H_2O)	NO_3	P_2O_5	K_2O
					(mg kg^{-1})		
Gramineae	*Triticum aestivum*	58	1	6.8	29	18	10
	Unknown grass	99	5	5.1	10	14	9

E. infrequens was originally reported from New Zealand by Hall (1977); since then it has been obtained from celery fields in central California, soils under poplar trees, soybean, and corn in Iowa, Illinois, and Wisconsin (Ames & Schneider 1979), among the roots of *Macroptilium* sp. in Florida (Schenck & Smith 1982), under *Bouteloua gracilis* (H.B.K.) Lag ex Steude and *Agropyron smithii* Rydb. in Wyoming (Stahl & Christensen 1982), and under grasses of prairie and cultivated winter wheat in Kansas (Hetrick & Bloom 1983) and *Agave* spp. in the Santa Catalina Mountains in Arizona (Bloss & Walker 1987). The species has never been recorded earlier in Europe.

In Poland *E. infrequens* was found in six samples, taken under both cultivated and wild plants (Table 2, Fig. 14). Its spore density per 100 g dry soil ranged from 1 to 7.. This species probably occurs in the whole of Poland, but with low frequencies.

Material examined

See Table 2; specimens deposited: 668–674 and 964–966 (DPP).

Glomus caledonium (Nicol. & Gerd.) Trappe & Gerd.

In comparison with the original description of this species (Nicolson & Gerdemann 1968), the spores from Poland are sometimes slightly larger (90–224–370 µm in diam *vs.* 130–279 x 120–272 µm) and usually have a considerably thicker wall (3.4–15.0–26.9 µm *vs.* 6–10–16 µm). Other features, permit the conclusion that the spores belong to *G. caledonium*, especially the 2-walled spore wall structure with a very characteristic, colourless, unit outer wall, easily separating from a yellow (5Y 8/8–2.5Y 8/8), laminate inner wall (wall 2), and the shape and dimensions of the subtending hyphae occluded by septa (Figs. 5–7). This species usually formed spores singly in the soil; sporocarps (Fig. 8) were found only in soil sample no. 88 (Fig. 15).

G. caledonium has earlier been identified in Scotland (Nicolson & Gerdemann 1968), the U.S. (Gerdemann & Trappe 1974, Menge et al. 1977, Miller et al. 1985), New Zealand and Australia (Hall 1977, Hall & Abbott 1984). It has often been used in experimental research (e.g. Clarke & Mosse 1981, Tommerup 1984, McGraw & Hendrix 1984).

In Poland *G. caledonium* was isolated for the first time, from 16 soil samples (Fig. 15) taken under cultivated and wild plants. This species was the dominant symbiont of winter wheat crops at Lipki Experimental Station near Szczecin (soil samples no. 104–111).

Material examined

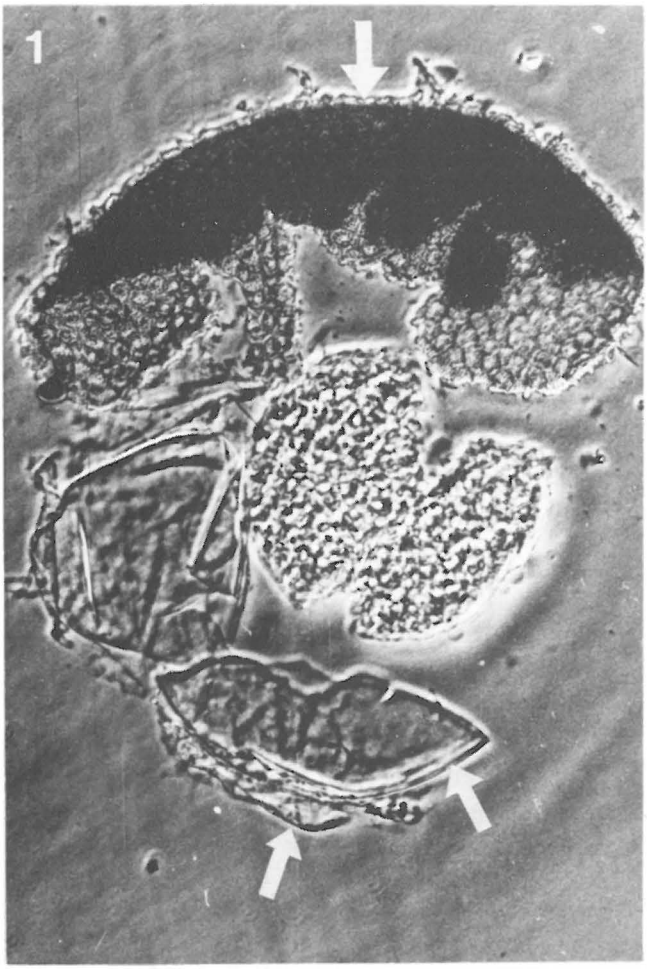
See Table 3; specimens deposited: 661–663, 675–684, 963, and 1020–1021 (DPP).

Scutellospora pellucida (Nicol. & Schenck) Walker & Sanders

The dimensions of the Polish spores, and especially their wall structure fit Koske and Walker's (1986) descriptions very well (Figs. 9–11). However, the spores are sometimes slightly darker having a hyaline to yellow (2.5Y 8/8) (*vs.* hyaline) inner wall in the

Table 2. Frequency of occurrence of *Entrophospora infrequens* in Poland and chemical properties of soils from which this species was isolated.

Plant family	Plant species	No. of soil sample	No. of spores/ 100 g dry soil	Chemical properties			
				pH (in H_2O)	NO_3	P_2O_5 (mg kg^{-1})	K_2O
Cupressaceae	*Juniperus communis*	98	2	5.1	10	14	9
Gramineae	*Festuca rubra*	88	7	6.1	20	17	16
	Sorghum sudanense	8	1	7.0	61	24	41
	Unknown grass	99	2	5.1	10	14	9
Leguminosae	*Trifolium repens*	1	7	5.4	19	22	14
Rosaceae	*Rosa canina*	138	2	6.7	66	20	59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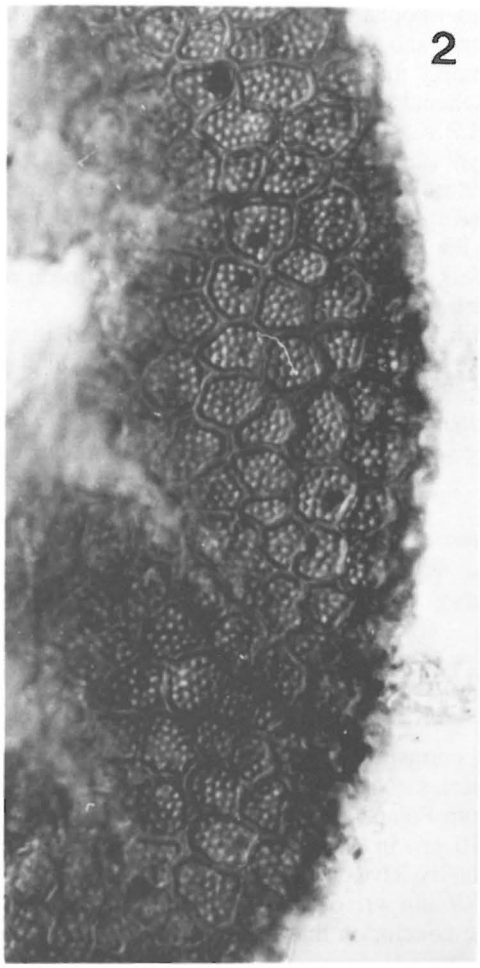
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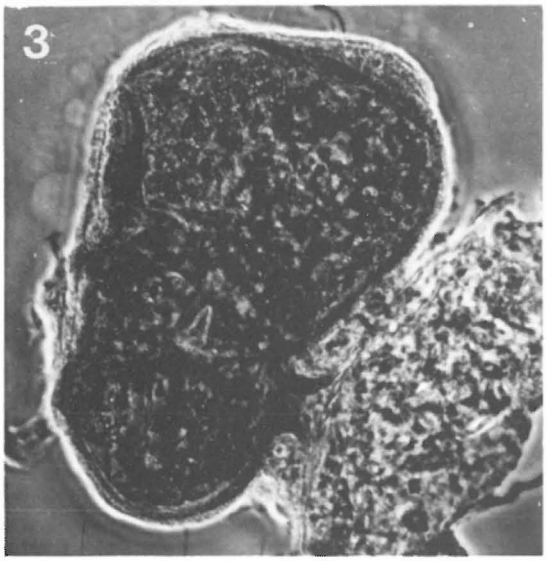
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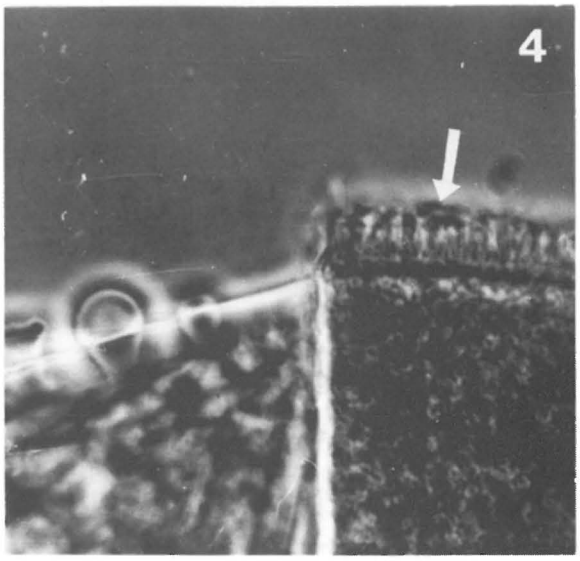
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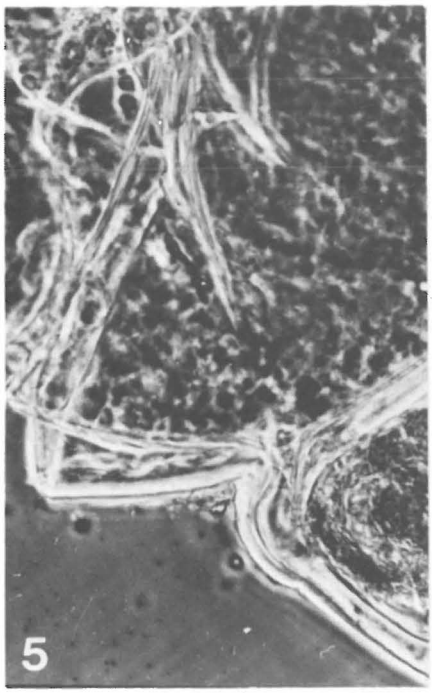
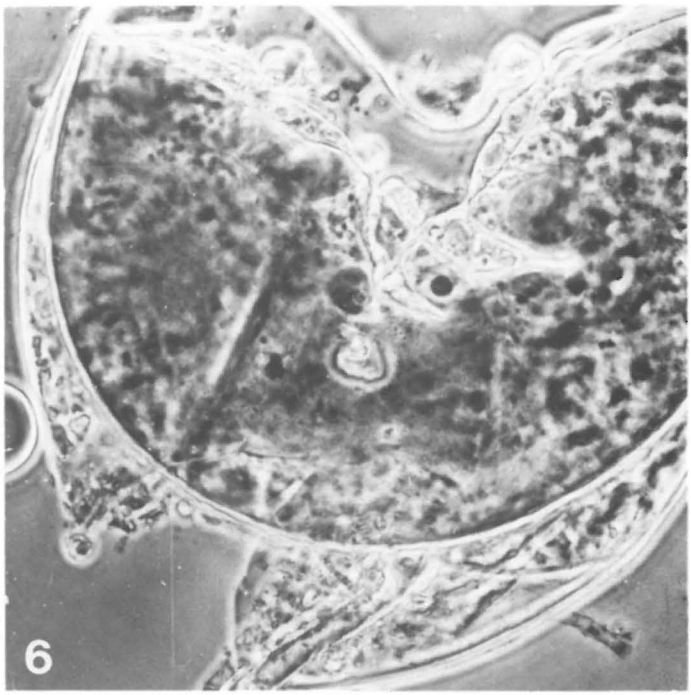
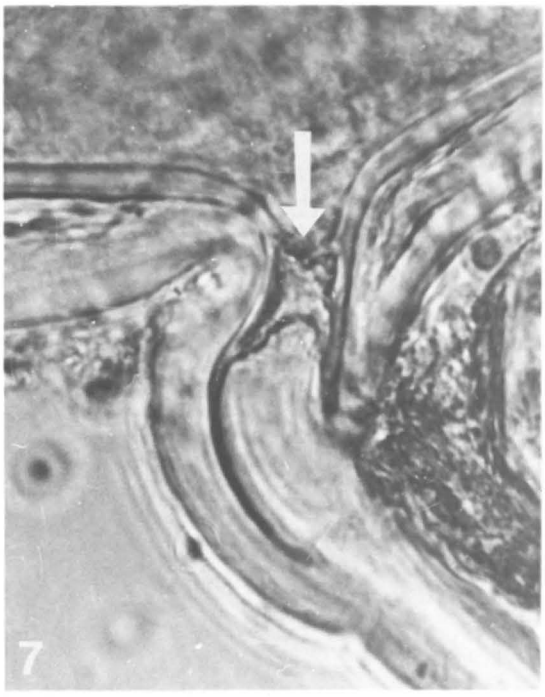
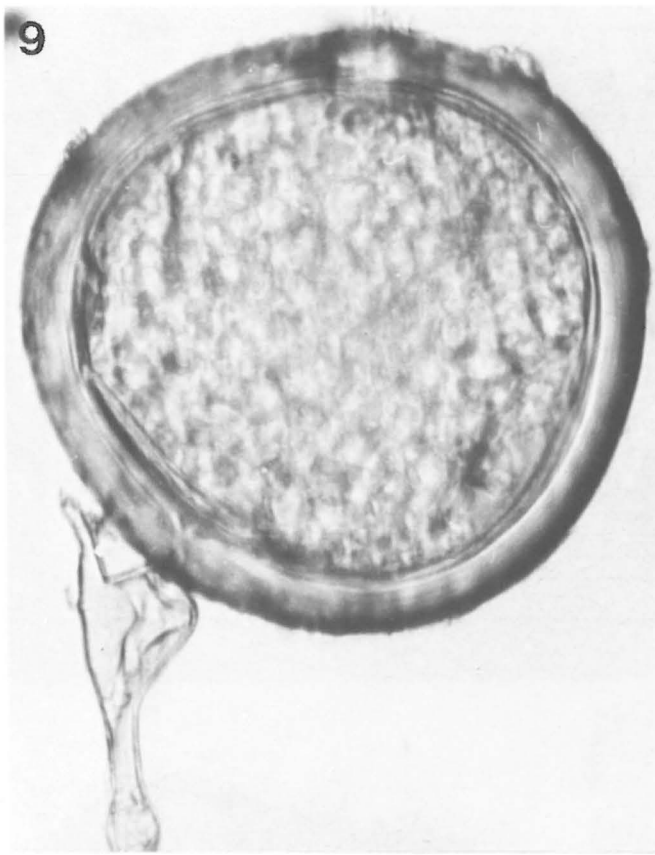


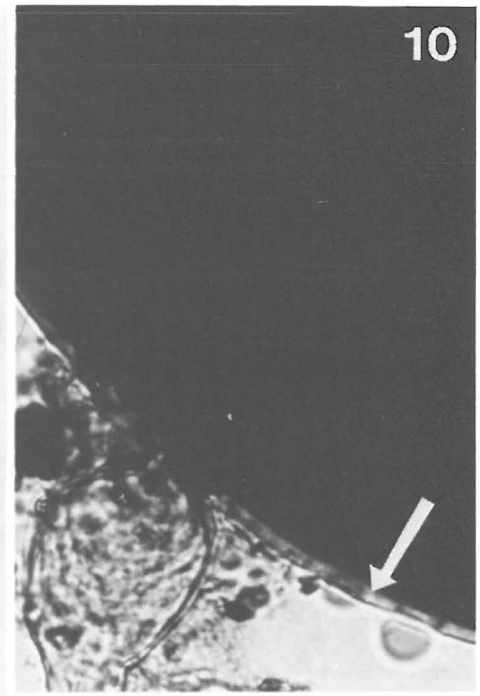


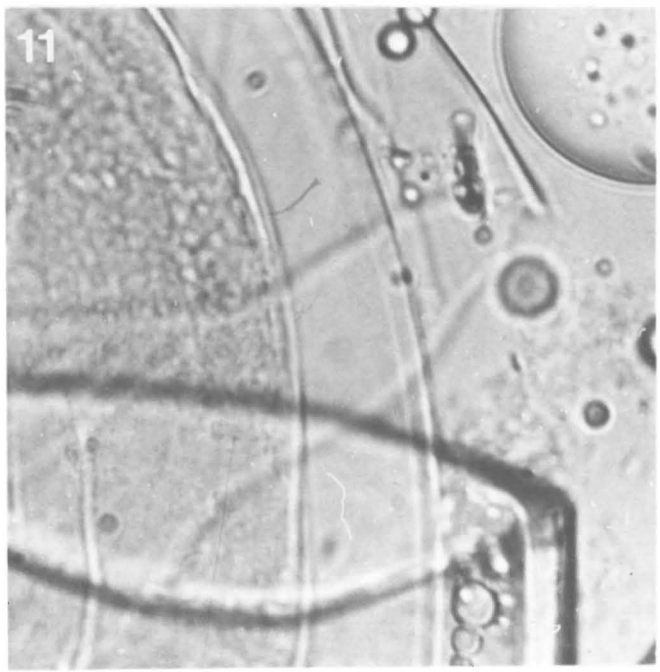


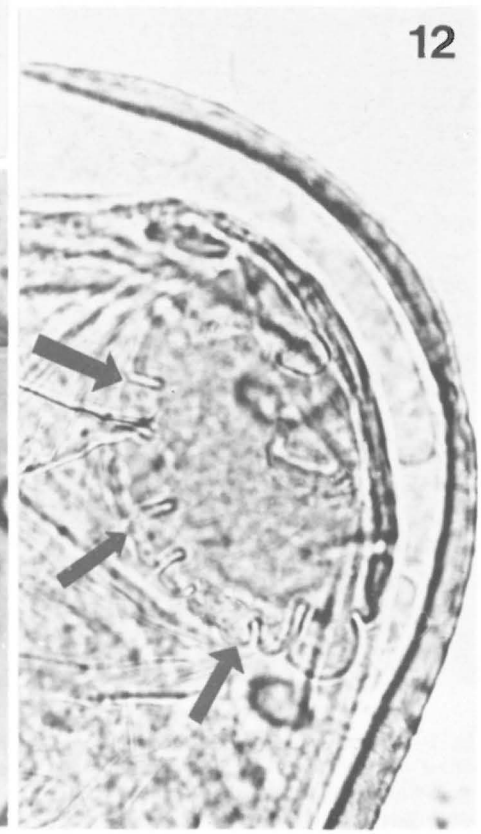
Figs. 1–4. Micrographs of the Endogonaceae. — 1: *Acaulospora bireticulata*, a crushed spore with 3 walls (arrows), phase contrast (PC), x 255. — 2: The reticulum and spines of the outermost wall can be seen, x 698. — 3: *Entrophospora infrequens*, a spore with a fragment of the vesicle, PC, x 379. — 4: A 3-walled spore; the outermost wall has been sloughed and only fragments are visible (arrow), PC, x 1 200.

Figs. 5–8. *Glomus caledonium*. — 5 and 6: Crushed spores with separated walls, both PC, both x 400. — 7: The spore base with the subtending hypha occluded by a septum (arrow); the very thick outer wall separated from the inner one is visible, x 1 200. — 8: A sporocarp, x 209.









Figs. 9–12. *Scutellospora pellucida*. — 9: An intact spore, x 373. — 10: A crushed spore in Melzer's reagent; the unit, unstained outermost wall is visible (arrow), x 820. — 11: A crushed spore showing spore walls, x 1 370. — 12: Germination shield of a spore (arrows), x 629.

Table 3. Frequency of occurrence of *Glomus caledonium* in Poland and chemical properties of soils from which this species was isolated.

Plant family	Plant species	No. of soil sample	No. of spores/ 100 g dry soil	Chemical properties pH (in H_2O)	NO_3	P_2O_5 (mg kg^{-1})	K_2O
Buxaceae	*Buxus sempervirens*	137	1	4.2	38	28	65
Cupressaceae	*Thuja occidentalis*	102	12	5.1	38	11	29
Gramineae	*Festuca rubra*	88	54	5.7	34	19	15
	Glyceria aquatica	141	44	4.8	17	8	10
	Triticum vulgare	104–111	29, 32, 18, 10 13, 10, 29, 39	4.4– 6.4	21– 32	6– 40	7– 10
	Zea mays	91	2	5.6	72	19	17
Rosaceae	*Rosa canina*	123	2	3.9	24	15	16
	Rubus idaeus	120	1	6.5	19	12	26
Solanaceae	*Nicotiana tabacum*	103	10	4.5	46	11	6

wall group A. The worst problem encountered in distinguishing *S. pellucida* spores from those of other light- and smooth-spored species is the difficulty of resolving the spore walls. Wall 1 (a unit outermost wall) was present in all the spores studied, though Melzer's reagent considerably simplified its observation, showing this wall as unstained and closely adhering to a laminate wall (wall 2) that stained dark red (10R 3/6) (Fig. 10). The inner walls in the group B (walls 3–5) posed the greatest problem. Wall 3 (a membranous wall) (Fig. 11) was easy to discern, but walls 4 and 5 (unit walls) were usually seen as a single, laminate or coriaceous wall adhering to an innermost wall (wall 6). All the three walls were best seen when the spores were crushed in PVGL. Wall 6 is amorphous in PVGL.

The features of the germination shields and suspensor-like cells (Figs. 9, 10, 12) also accord with Koske and Walker's description. The auxiliary cells of the Polish specimens are formed singly or in clusters in the soil; they are hyaline to reddish-yellow (7.5YR 7/8), 27–60 x 60–75 µm, with blunt, rounded knobby projections, 15–17.5 x 22.5–30 µm, produced on hyaline hyphae, 2.5–5.0 µm in diam (Fig. 13). They have not been described by Koske and Walker. In comparison with those described by Nicolson and Schenck (1979), they are brighter (*vs.* brown) and somewhat larger (*vs.* 19–38 µm wide; projections 2–9 x 5–15 µm). However, Koske and Walker (1985) recognized that the morphology of auxiliary cells is not especially useful in distinguishing species of the genus *Scutellospora.* The features of the germination shields have probably a similar significance. According to Koske and Walker (1986), *S. pellucida* is one of the most difficult species to determine.

S. pellucida was originally described from a soybean–rhizosphere soil in Florida (Nicolson &

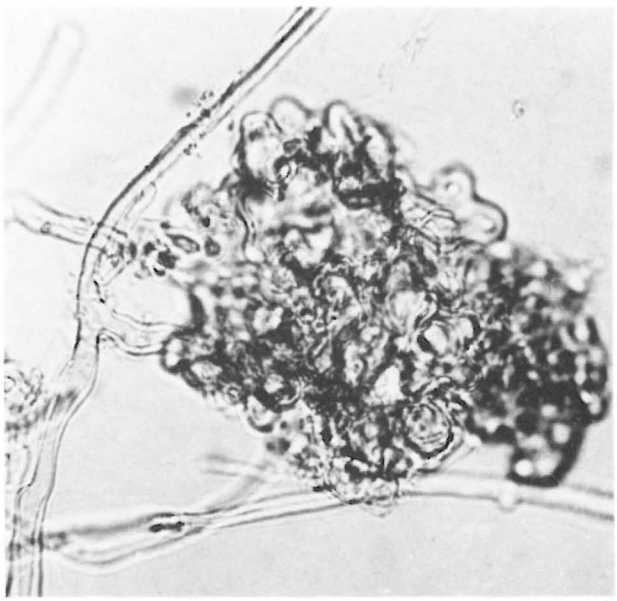


Fig. 13. *Scutellospora pellucida*, a cluster of auxiliary cells, x 702.

Figs. 14–15. Maps of the distribution of the Endogonaceae in Poland. — 14: *Acaulospora bireticulata* and *Entrophospora infrequens* in Poland. The numerals are the numbers of the soil samples. — 15: *Glomus caledonium* and *Scutellospora pellucida* in Poland.

Table 4. Frequency of occurrence of *Scutellospora pellucida* in Poland and chemical properties of soils from which this species was isolated.

Plant family	Plant species	No. of soil sample	No. of spores/ 100 g dry soil	Chemical properties pH (in H_2O)	NO_3	P_2O_5 (mg kg^{-1})	K_2O
Gramineae	*Festuca rubra*	73	45	5.8	22	21	19
	Unknown grass	99	2	5.1	10	14	9
Rosaceae	*Crataegus monogyna*	113, 121, 130	1, 3, 2	4.4–6.2	19–160	10–22	14–25
	Malus domestica	92	1	5.7	74	26	12
	Prunus domestica	74	4	6.6	60	15	15
	Rosa canina	123	15	3.9	24	15	16

Schenck 1979). Since then, it has been found among many cultivated (Schenck & Kinloch 1980, Schenck & Smith 1981, Hetrick & Bloom 1983, Miller et al. 1985) and wild plants (Rose 1980, Hetrick & Bloom 1983). Koske and Walker (1986) and Koske (1987) found it to be a frequent associate with plants of sand dunes. This species was known only from the U.S.

In Poland *S. pellucida* was found in 8 of the 141 soil samples examined (Table 4, Fig. 15). It occurred only in soil samples taken under natural plants. Its spore density was generally low, ranging from 1 to 45 per 100 g dry soil. It seems that *S. pellucida* occurs in the whole of Poland, but with low frequencies.

Material examined

See Table 4; specimens deposited: 468–508, 839–840, and 982–1002 (DPP).

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