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Arbuscular mycorrhizal fungi of the Brda river valley in the Tuchola Forests

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The occurrence of arbuscular mycorrhizal fungi (AMF) associated with 19 plant species from 12 families growing in the Brda river valley in the Tuchola Forests is presented. The most frequently investigated plants were those from the families *Cupressaceae* and *Plantaginaceae*. Examination of trap cultures established from rhizosphere soil-root mixtures of the plants sampled revealed 20 described species of AMF, two undescribed *Glomus* spp., and three species of the genus *Glomus* that were difficult to recognize. The dominating AMF were members of the genus *Glomus*. Among the AMF found, *G. claroideum* was present, a species recorded for the first time in Poland. The distribution in Poland and in the world of the AMF encountered is shown.

Key words: arbuscular mycorrhizal fungi, the Brda river valley, Tuchola Forests.

INTRODUCTION

The knowledge of the occurrence of fungi in the Tuchola Forests mainly regards macromycetes (Hołownia 1959; Lisiewska 1982; Ławrynowicz 1993, 1997; Ławrynowicz et al. 1995; Ławrynowicz and Szkodzik 1998). There is no report on arbuscular mycorrhizal fungi.

Arbuscular mycorrhizal fungi (AMF) of the order *Glomales* (*Zygomycota*; Gerdemann 1968) are among the most common soil fungi. According to Gianinazzi and Gianinazzi-Pearson (1986), they are associated with ca 80% of plants of the Earth.

AMF play a crucial role in the life of plants. They are known to increase the root absorptive area (Bieleski 1973), influence the succession of plants (J a n o s 1980), their competitiveness (A l l e n and A l l e n 1984; F i t t e r 1977), phenology (A l l e n and A l l e n 1986) and pollen production (L a u et al. 1995), equalize the level of nutrition of co-existing plants by formation of hyphal bridges transferring nutrients between them (N e w m a n 1988), and improve soil structure through binding sand grains into aggregates by extramatrical mycorrhizal hyphae (K o s k e et al. 1975; S u t t o n and S h e p p a r d 1976).

The aim of this paper is to present results of investigations of the occurrence of AMF associated with plants of the Brda river valley in the Tuchola Forests.

STUDY AREA

The Tuchola Forests are a part of the South Pomeranian Lake District macroregion (K o n d r a c k i 2000). They occupy an area of about 2400 km^2 and are one of the greatest forest areas in Poland.

The vascular flora of the Tuchola Forests comprises ca 1275 species and their diversity results from, e.g., favourable water and climatic conditions (C e y n o w a-G i e ł d o n and R u t k o w s k i 1993). This area includes many lakes and rivers. One of the main rivers is Brda of a length of 238 km.

The study area was the valley of the Brda river extending from Klonia (53°46′39″N, 17°42′16″E) to Woziwoda (53°40′10″N, 17°54′25″E; Fig. 1). Twenty rhizosphere soil-root mixtures were collected along the bank of the Brda river located between Rytel (43°44′55″N, 17°46′28″E) and Woziwoda. Nine samples came from the valley of the Brda river comprising the area from Rytel to Klonia.

The climate of the Tuchola Forests is markedly influenced by the ocean and continental climates. The growing season ranges from 206 – 210 days. Mean annual air temperature ranges from – 3.1 to 16.4°C (Table 1). Mean annual precipitation ranges from 26 to 77 mm.

Table 1

Air temperature and rainfalls in 1996 and means of these parameters calculated based on data from 1961 – 1990 (after the data of the Chojnice Meteorological Station)

	Years	Month												
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Air temperature (°C)	1996	–5.4	–5.8	–1.5	7.6	11.7	15.0	14.7	17.7	9.9	8.6	4.1	–5.3	5.9
	1961–1990	–3.1	–2.3	1.2	6.2	11.9	15.2	16.4	16.1	12.3	7.8	2.7	–1.1	6.9
Sum of rainfalls (mm)	1961–1990	33	26	30	33	51	70	77	61	50	48	47	38	564

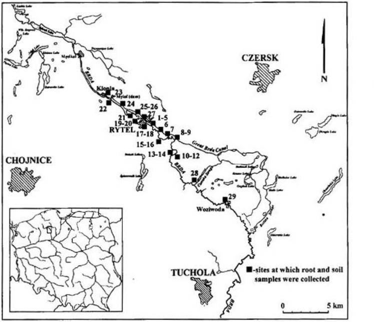


Fig. 1. Sites at which soil-root samples were collected

MATERIALS AND METHODS

Collection of samples, trap and single-species culture establishment. About 0.6–0.8-l rhizosphere soil-root mixtures of sampled plants were collected from a depth of 5–30 cm using a small garden shovel. In the laboratory, the soil-root mixtures were air dried for 2 weeks and subsequently refrigerated at 4°C until processing. To receive a great number of living spores of different developmental stages and to initiate sporulation of non-sporulating species in the field conditions, trap cultures were established. The field-collected soil-root samples were mixed (1/1, v/v) with autoclaved coarse-grained sand coming from the shore of the Baltic Sea. These mixtures were placed in 8 × 12 cm plastic pots (500 cm^3) and seeded with *Plantago lanceolata* L. as the plant host. About 40 seeds were added to each pot. Plants were grown in a greenhouse at 15–30°C with supplemental 8–16 h lighting provided by one SON-T AGRO sodic lamp (Philips Lighting Poland S. A.) placed 1 m above pots. The maximum light intensity was 180 $\mu E\ m^{-2}s^{-1}$ at pot level. Plants were watered 2–3 times a week. No fertilization was applied during the growing period. Trap cultures were harvested after 6 months after plant emergence.

Single-species pot cultures were established from about 50 to 100 newly formed spores stored before inoculation in water at 4°C for 24 h. They were collected in a pipette and transferred onto a compact layer of roots of 10–14-day-old seedlings of *P. lanceolata* placed at the bottom of a hole of ca 1 cm wide and 4 cm deep formed in a wetted growing medium filling 8 cm plastic pots (250 cm^3). The growing medium was an autoclaved sand of maritime dunes adjacent to Świnoujście (pH 6.7; 12 and 26 mg L^{-1} P and K, respectively). Subsequently, the spores were covered with another layer of roots coming from 4–6 plants of the host. Finally, the roots and sandwiched spores were buried in the growing medium. The cultures were harvested after 4–12 months and spores extracted.

Isolation and identification of AMF. Spores were extracted by wet sieving and decanting (Gerdemann and Nicolson 1963). Morphological properties of spores, their subcellular structures and developmental stages during differentiation were determined based on at least 100 spores mounted in polyvinyl alcohol/lactic acid/glycerol (PVLG; Koske and Tessier 1983) and a mixture of PVLG Melzer's reagent (1:1, v/v). Developmental stages of some of the fungi found were determined based on newly formed spores extracted from both trap and single species cultures, the latter being harvested at ca 20–30-day intervals. The spores represented all stages of differentiation of the fungus. The degree of maturity of spores was assessed based on appearance under an Olympus SZX9 dissecting microscope. The main properties considered were colour and size of spores. Spores were crushed to varying degrees by applying pressure to the cover slip and then stored at 65°C for 24 h to clear their contents from oil droplets. Examination of such prepared specimens was performed using a Zaiss compound microscope equipped with differential interference contrast optics. The fungi were identified according to their original descriptions (Schenck and Pérez 1990), revisions (Franke and Morton 1994; Stürmer and Morton 1997), information and specimens obtained from Prof. R. E. Koske (Rhode Island University, U.S.A.), Prof. J. M. Morton (West Virginia University, U.S.A.), Prof. J. M. Trappe (Oregon State University, U.S.A.), and Dr. C. Walker (U.K.). Vouchers of all the fungal species recovered are preserved in the authors' collections.

Terminology of spore structure is that suggested by Franke and Morton (1994) and Stürmer and Morton (1997).

Plants were recognized according to Szafer et al. (1969). Nomenclature of plants is that of Mirek et al. (1995).

RESULTS AND DISCUSSION

In 1996, along the Brda river extending from Klonia to Woziwoda, 29 root and adjacent soil samples were collected (Fig. 1). The samples represented 19 species from 12 plant families (Table 2). The plant families most frequently examined were the *Cupressaceae*, followed by the *Plantaginaceae*, *Asteraceae*, and *Rosaceae*. The other plant families were represented by 1 – 2 soil and root samples. The plant species most frequently investigated were *Juniperus communis* and *Plantago lanceolata*.

After a ca. 6-month cultivation of the root-rhizosphere soil samples in trap cultures with *P. lanceolata* as the plant host, spores of AMF were found in 27 traps, i.e., 93.1% of all the cultures established. The spores represented three of the six genera of the order *Glomales*. No spores of the genera *Entrophospora*, *Gigaspora*, and *Sclerocystis* were revealed.

Table 2

Plants examined and soil-root samples in which the occurrence of arbuscular mycorrhizal fungi were investigated

Family and species of plants	Number of sample
Asteraceae	
Helichrysum arenarium (L.) Moench	26
Leonthodon autumnalis L.	23
Leonthodon hispidus L.	1
Solidago virgaurea L.	12
Cupressaceae	
Juniperus communis L.	3, 6, 7, 15, 17 – 19, 24
Dipsacaceae	
Knautia arvensis (L.) J. M. Coult.	21
Fabaceae	
Medicago lupulina L.	29
Geraniaceae	
Erodium cicutarium (L.) L'Hér.	22
Hypericaceae	
Hypericum perforatum L.	16
Plantaginaceae	
Plantago lanceolata L.	13, 14, 25, 27
Plantago media L.	8
Poaceae	
Elymus arenarius L.	5
Festuca gigantea (L.) Vill.	10
Rosaceae	
Alchemilla monticola Opiz	9
Geum nivale L.	2
Rosa canina L.	20
Rubiaceae	
Galium aparine L.	11
Salicaceae	
Salix caprea L.	4
Salix fragilis L.	28

The AMF most frequently occurring in the trap cultures were members of the genus *Glomus* (Table 3). They were identified in 33.3 to 100% of the cultures (av. 93.1). In cultures representing plant families most frequently sampled, the occurrence of spores of the genus *Glomus* ranged from 64.3% (*Cupressaceae*) to 90.0% (Plantaginaceae). Spores of the genus *Acaulospora* were found in an average of 27.6% of the cultures examined. Most spores of this genus were found in the soil representing the plant family *Hypericaceae* (33.3%; Table 3). The members of the genus *Scutellospora* were isolated from an average of 17.2% of the cultures, and the culture containing most spores of this genus was that with the *Hypericum perforatum* (*Hypericaceae*) rhizosphere soil-root mixture (Table 3).

Table 3

Frequency of occurrence of three genera of arbuscular mycorrhizal fungi in 11 plant families

Plant family	n	Frequency of occurrence (%)		
		Acaulospora	*Glomus*	*Scutellospora*
Asteraceae	4	22.2	66.7	11.1
Cupressaceae	8	21.4	64.3	14.3
Dipsacaceae	1	–	100.0	–
Fabaceae	1	–	100.0	–
Geraniaceae	1	–	100.0	–
Hypericaceae	1	33.3	33.3	33.3
Plantaginaceae	5	10.0	90.0	–
Poaceae	2	–	100.0	–
Rosaceae	3	16.7	83.3	–
Rubiaceae	1	–	100.0	–
Salicaeae	2	–	100.0	–

Explanation: n – number of soil-root samples investigated

The predominance of AMF of the genus *Glomus* found in the trap cultures with mixtures of rhizosphere soils and roots coming from under plants colonizing the Brda valley correspond with many earlier findings showing that *Glomus* spp. are the most frequently occurring AMF in different regions of the world (e. g., Błaszkowski 1993a; Gerdemann and Trappe 1974; Koske and Tews 1987; Tadych and Błaszkowski 2000; Vestberg et al. 1999). However, almost all the findings mentioned above resulted from field-collected soils that may harbour a high proportion of infrequently or nonsporulating species of AMF (Brunrett et al. 1999; Stutz and Morton 1996). Despite that, recent investigation results (Brunrett et al. 1999; Błaszkowski et al. 2000; Iwaniuk and Błaszkowski, unpubl.) indicated that *Glomus* spp. also dominated in pot-cultured field soils coming from many both uncultivated and cultivated sites. Thus, members of the genus *Glomus* are better adapted to a wide range of changing chemical and physical soil conditions than those of the other genera of the order *Glomales*, as also, e. g., Anderson et al. (1984), Daniels and Trappe (1980), Klironomos et al. (1993), and Brunrett et al. (1999) suggested.

Species of the genera *Gigaspora* and *Scutellospora* prefer warmer and more sandy soils (Koske 1981; Schenck et al. 1975). *Acaulospora* spp. occur more frequently in acid soils (Klironomos et al. 1993; Porter et al. 1987), but infrequently predominate in AMF communities (Błaszkowski 1991a; Gerdemann and Trappe 1974).

Table 4
Occurrence of three genera of arbuscular mycorrhizal fungi in 19 plant species

Plant species	n	Frequency of occurrence		
		Acaulospora	*Glomus*	*Scutellospora*
Alchemilla monticola	1	+	+	–
Elymus arenarius	1	–	+	–
Erodium cicutarium	1	–	+	–
Festuca gigantea	1	–	+	–
Galium aparine	1	–	+	–
Geum rivale	1	–	+	–
Helichrysum arenarium	1	–	+	–
Hypericum perforatum	1	+	+	+
Juniperus communis	8	+	+	+
Knautia arvensis	1	–	+	–
Leonthodon autumnalis	1	–	–	–
Leonthodon hispidus	1	+	+	–
Medicago lupulina	1	–	+	–
Plantago lanceolata	4	+	+	–
Plantago media	1	–	+	–
Rosa canina	1	–	+	–
Salix caprea	1	–	+	–
Salix fragilis	1	–	–	–
Solidago virgaurea	1	+	+	+

Explanations: n – number of soil-root samples investigated; + – present, – – absent

The first-generation trap cultures with rhizosphere soil-root mixtures indicated that AMF were associated with 17 of the 19 plant species sampled (Table 4). No spores were found in cultures representing *Knautia arvensis* and *Salix fragilis*, although other investigation results show the former plant species to host AMF (H a r l e y and H a r l e y 1987). *Salix fragilis* has been associated with ectomycorrhizal fungi (H a r l e y and H a r l e y 1987).

All the spore populations of AMF recovered contained members of the genus *Glomus*, and 11 plant species hosted only fungi of this genus.

Fungi of the genus *Acaulospora* occurred among roots of 6 plant species, and *Scutellospora* spp. were harboured by only three plant species.

The spore populations of AMF recovered from the trap cultures comprised 20 described species, two undesribed *Glomus* spp., and three species of *Glomus* that were difficult to identify (Table 5).

Table 5
Arbuscular fungi found in the Brda river valley

Fungal species	n	Number of soil-root samples	Frequency of occurrence (%)
Acaulospora bireticulata	1	6	3.45
Acaulospora lacunosa	1	18	3.45
Acaulospora paulineae	1	12	3.45
Acaulospora rugosa	1	17	3.45
Acaulospora trappei	5	1, 9, 12, 13, 16	17.24
Glomus aggregatum	4	1, 2, 4, 5, 27	17.24
Glomus claroideum	2	3, 4	6.90
Glomus constrictum	8	2–8, 26, 28	31.03
Glomus etunicatum	2	19, 25	6.90
Glomus fasciculatum	4	4, 7, 19, 25	13.79
Glomus geosporum	2	8, 9	6.90
Glomus intraradices	1	14	3.45
Glomus laccatum	10	7, 10–12, 14, 15, 17, 18, 20, 22	34.48
Glomus macrocarpum	1	6	3.45
Glomus mosseae	1	13	3.45
Glomus occultum	1	1	3.45
Glomus pustulatum	2	16, 17	6.90
Glomus rubiforme	7	2–4, 8, 12, 15, 24	24.14
Glomus undescribed 1	2	12, 13	6.90
Glomus undescribed 2	2	4, 6	10.34
Glomus unrecognized 1	3	5, 21, 28	3.45
Glomus unrecognized 2	1	5	3.45
Glomus unrecognized 3	1	28	3.45
Scutellospora armeniaca	2	16, 17	6.90
Scutellospora dipurpurescens	3	7, 12, 14	10.34

Explanation: n — number of soil-root samples investigated

The AM fungal species most frequently encountered was *G. laccatum* (present in 34.5% of cultures; Table 5). Relatively frequently found fungi also were *G. constrictum* and *G. rubiforme*.

ARBUSCULAR MYCORRHIZAL FUNGI IN THE BRDA RIVER

Acaulospora bireticulata Rothwell et Trappe
n = 1:6, Figs 2–4.
Plant host: *J. communis*

In Poland, *A. bireticulata* has earlier been found in cultivated soils and dunes adjacent to Świnoujście (Błaszkowski 1989, 1995, 1997). Schenck and Smith (1982) encountered spores of *A. bireticulata* in the root zone of *Centrosema pubescens* L. growing in Florida. Miller et al. (1985) recognized this fungus associated with *Malus domestica* Borkh. in Michigan. Walker (pers. comm.) identified *A. bireticulata* in dunes of the Great Britain. *Acaulospora bireticulata* has been described based on spores recovered from under *Sassafrans albidum* (Nutt.) Ness growing in Kentucky (Rothwell and Trappe 1979).

Acaulospora lacunosa Morton
n = 1:18, Fig. 5.
Plant host: *J. communis*

This fungus commonly occurs in sandy dune soils of the Baltic Sea coast (Błaszkowski 1993a, 1994a; Tadych and Błaszkowski 2000) and has frequently been revealed in cultivated and other uncultivated soils of Poland (Błaszkowski 1991a; Błaszkowski and Tadych, pers. observ.). According to Koske and Gemma (1997), *A. lacunosa* is a relatively common inhabitant of dunes of the U. S. Atlantic coast from Massachusetts to Virginia. *Acaulospora lacunosa* has originally been recovered from among the roots of *Andropogon virginicus* L. in West Virginia (Morton 1986).

Acaulospora paulineae Błaszk.
n = 1:12, Fig. 6.
Plant host: *Solidago virgaurea*

In Poland, *A. paulineae* has earlier been recorded in dunes of the Gdańsk coast, the Hel Peninsula, and the Słowiński National Park (Błaszkowski 1993a, 1994a; Tadych and Błaszkowski 2000), as well as in cultivated sites of the Western Pomerania and the Pomerania voivodeships. Koske et al. (1997) encountered this fungus associated with *Agrostis canina*

Huds., *A. palustris* L., and *Poa annua* L., perennial turf species of golf greens of Rhode Island, U. S. A. Recently, *A. paulineae* has been recognized in dunes adjacent to Tel-Aviv, Israel (Błaszkowski et al. 2000).

Acaulospora rugosa Morton
n = 1:17, Fig. 7.
Plant host: *J. communis*

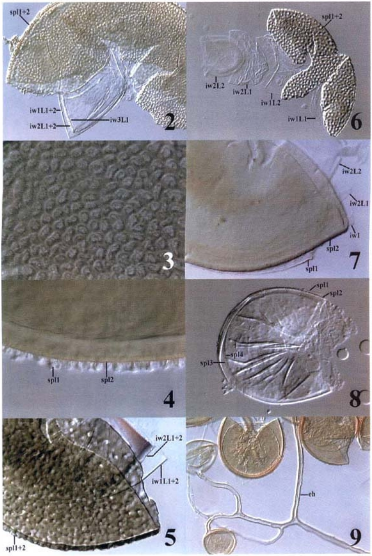
Błaszkowski (1990) recovered *A. rugosa* from among roots of *Calamagrostis arundinacea* (L.) Roth. growing in a forest. This species has been one of the most frequently occurring AMF in the root zone of plants colonizing maritime dune soils of the Słowiński National Park (Tadych and Błaszkowski 2000) and has been a frequent inhabitant of the inland dunes of the Błędowska Desert (Błaszkowski and Tadych, pers. observ.). *Acaulospora rugosa* has been described from spores isolated from under *Andropogon virginicus* growing in West Virginia (Morton 1986).

Acaulospora trappei Ames et Linderman
n = 5:1, 9, 12, 13, 16, Fig. 8.
Plant host: *Alchemilla monticola*, *H. perforatum*, *Leonthodon hispidus*, *P. lanceolata*, *S. virgaurea*

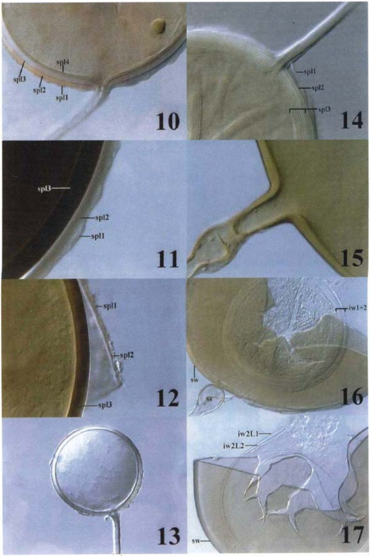
In Poland, *A. trappei* has earlier been found under *Festuca rubra* L. colonizing dune soils of the Błędowska Desert (Błaszkowski et al. 1999; Błaszkowski and Tadych, pers. observ.). Tadych and Błaszkowski (2000) encountered it in dunes of the Słowiński National Park. This species has also occurred in cultivated (Haas and Menge 1990) and uncultivated (Błaszkowski et al. 2000) soils of Israel, and in the root zone of *Hyacinthoides non-scripta* (L.) Chouard ex Rothm. growing at Pretty Wood, Castle Howard, north Yorkshire (Merryweather and Fitter 1998). *Acaulospora trappei* has originally been known from *Lolium longiflorum* Thunb. fields along southern Oregon and northern California coastal areas (Ames and Linderman 1976).

Glomus aggregatum Schenck et Smith emend. Koske
n = 5:1, 2, 4, 5, 27, Fig. 9.
Plant host: *Elymus arenarius*, *Geum nivale*, *L. hispidus*, *P. lanceolata*, *Salix caprea*

In Poland, *G. aggregatum* has earlier been found among roots of many plants colonizing the Baltic Sea coast (Błaszkowski 1991a, 1994a, 1995; Tadych and Błaszkowski 2000) and sandy soils of the banks of the Odra river (Błaszkowski 1991b). It is commonly associated with cultivated plants of Poland (Błaszkowski 1991a).



Figs 2–9. Some arbuscular fungi found in the Brda river valley. 2–4. *Acaulospora bireticulata*. 5. *Acaulospora lacunosa*. 6. *Acaulospora paulineae*. 7. *Acaulospora rugosa*. 8. *Acaulospora trappei*. 9. *Glomus aggregatum*



Figs 10–17. 10. *Glomus claroideum*. 11. *Glomus constrictum*. 12. *Glomus geosporum*. 13–14. *Glomus laccatum*. 15. *Glomus mosseae*. 16. *Scutellospora armeniaca*. 17. *Scutellospora dipurpurescens*. Figs 2, 9, 13, 16, 17, ×250; 3, 4, 7, 8, 11, 12, 14, 15, ×1000; 5, 10, ×625; 6, ×313; all differential interference contrast

This fungus has been the third species in frequency of occurrence in soils of the Błędowska Desert (Błaszkowski and Tadych, pers. observ.). *Glomus aggregatum* regularly occurred in dunes of the eastern coast of North America (Dalpé 1989; Friese and Koske 1991; Gemma and Koske 1989; Koske 1987; Sylvia 1986; Sylvia and Will 1988), Wisconsin (Koske and Tews 1987), San Miguel Island (Halvorson and Koske 1987; Koske and Halvorson 1989), and Hawaii (Koske 1988).

Glomus claroideum **Schenck et Smith**
n = 2:3, 4, Fig. 10.
Plant host: *J. communis*, *S. caprea*

This paper is the first report of the presence of *G. claroideum* in Poland. This fungus has a worldwide distribution, having been found in, e.g., USA, Mexico, many European countries, and China (Estrada-Torres et al. 1992; An et al. 1993; Mei-Qing et al. 1992; Walker and Vestberg 1998). Walker and Vestberg (1998) considered *G. maculosum* Miller et Walker, *G. fistulosum* Skou et Jakobsen, and *G. multisubstensum* Mukerji, Bhattacharjee et Tewari to be synonyms of *G. claroideum*.

Glomus constrictum **Trappe**
n = 9:2−5, 6−8, 26, 29, Fig. 11.
Plant host: *E. arenarius*, *G. nivale*, *Helichrysum arenarium*, *J. communis*, *Medicago lupulina*, *P. lanceolata*, *S. caprea*

Glomus constrictum is one of the most frequently found AMF in cultivated and uncultivated soils of Poland (Błaszkowski 1990b, 1991a, 1993a, 1994a, 1995; Tadych and Błaszkowski 2000; Błaszkowski and Tadych, pers. observ.). It also frequently occurred in cultivated (Błaszkowski et al. 2000; Haas and Menge 1990; Hetrick and Bloom 1983) and uncultivated sites (Błaszkowski et al. 2000; Dalpé 1989; Koske 1987, 1988; Stürmer and Bellei 1994) of other regions of the world. *Glomus constrictum* has been described based on spores encountered in Mexico, California, and Guadeloupe (Trappe 1977).

Glomus etunicatum **Becker et Gerd.**
n = 2:19, 25.
Plant host: *J. communis*, *P. lanceolata*

In Poland, *G. etunicatum* has been identified in many dune sites of the Baltic Sea coast (Błaszkowski 1991a, 1993a, 1994a; Tadych and

Błaszkowski 2000) and in inland dunes of the Błędowska Desert (Błaszkowski and Tadych, pers. observ.). Błaszkowski (1991a) found it to occur commonly in cultivated soils. *Glomus etunicatum* has also occurred in dunes (Koske and Halvorson 1981, 1989; Koske and Tews 1987; Stürmer and Bellei 1994) and cultivated sites (Błaszkowski et al. 2000; Talukdar and Germida 1993) of other regions of the world. Becker and Gerdemann (1977) described this fungus from spores recovered from under *Andropogon scoparius* Michx. and *Zea mays* L. growing in Illinois.

Glomus fasciculatum (Thaxter) Gerd. et Trappe emend. Walker et Koske
n = 4:4, 7, 19, 25.
Plant host: *J. communis*, *P. lanceolata*, *S. caprea*

Glomus fasciculatum has been present in dunes of the Baltic Sea coast (Błaszkowski 1991a, 1993a, 1994a, 1995; Tadych and Błaszkowski 2000), the Błędowska Desert (Błaszkowski and Tadych, pers. observ.), and other Polish sites with both cultivated and uncultivated plants (Błaszkowski 1991a). This fungus has a worldwide distribution (Giovannetti and Nicolson 1983; Puppi and Riess 1987; Nicolson and Johnston 1979; Dalpé 1989; Bergen and Koske 1984; Gemma and Koske 1989; Koske and Halvorson 1981; Rose 1988; Talukdar and Germida 1993).

Glomus geosporum (Nicol. et Gerd.) Walker
n = 2:8, 9, Fig. 12.
Plant host: *A. monticola*, *Plantago media*

This fungus has been revealed in different regions of Poland as associated with roots of cultivated and uncultivated plants (Błaszkowski 1991a, 1994a). Błaszkowski et al. (2000) and Haas and Menge (1990) recognized it among spores of AMF isolated from dunes and cultivated sites of Israel. Rose (1980) found *G. geosporum* in sandy soils of Oregon, California, and Florida. Johnson (1977) recovered this species from among roots of forest plants of New Zealand.

Examination of trap cultures conducted by the authors of this paper suggests *G. geosporum* to be one of the most frequently component of AMF communities of different cultivated sites of Poland. In earlier studies, this fungus was probably frequently omitted due to its irregular sporulation and an erroneous recognition. *Glomus geosporum* highly resembles *G. caledonium* (Nicol. et Gerd.) Trappe et Gerd. in colour, size, and the properties of its subtending hyphae. Ontogenetical investigations conducted recently (Iwaniuk and Błaszkowski, unpubl.) showed that the spore wall structure of *G. geosporum* consists of three layers, whereas that of *G. caledonium* is 4-layered (Błaszkowski, pers. observ.; Morton 1996).

Glomus intraradices **Schenck et Smith**
n = 1: 14
Plant host: *P. lanceolata*

Glomus intraradices has been associated with roots of dune plants growing near Świnoujście (Błaszkowski 1995), the Słowiński National Park (Tadych and Błaszkowski 2000), and the Błędowska Desert (Błaszkowski and Tadych, pers. observ.). This fungus has also been found in dunes of Israel (Błaszkowski et al. 2000), Madras (Mohankumar et al. 1988), Canada (Dalpé 1989), San Miguel Island (Halvorson and Koske 1987; Koske and Halvorson 1989), and Hawaii (Koske 1988; Koske and Gemma 1996). *Glomus intraradices* has originally been described based on spores isolated from under different plants growing in Florida (Schenck and Smith 1982).

Glomus laccatum **Błaszk.**
n = 10: 7, 10–12, 14, 15, 17, 18, 20, 22. Fig. 13–14.
Plant host: *Erodium cicutarium*, *Festuca gigantea*, *Galium aparine*, *J. communis*, *P. lanceolata*, *Rosa canina*, *S. virgaurea*

Glomus laccatum has earlier infrequently been recorded in Poland. Błaszkowski (1988) described this fungus based on spores revealed in the rhizosphere soil of *Festuca* sp. growing in Jastrzębia Góra. Later, Błaszkowski (1994a) and Tadych and Błaszkowski (2000) found its presence among roots of *Ammophila arenaria* (L.) Link and *Helictotrichon pubescens* (Huds.) Pilg. growing in the Hel Peninsula and the Słowiński National Park. Other investigations (Iwaniuk and Błaszkowski, unpubl.) indicate that *G. laccatum* is a relatively frequent inhabitant of both cultivated and uncultivated sites of Poland. Walker (pers. comm.) found this fungus in soils of Great Britain. The infrequent disclosures of *G. laccatum* in field-collected soil samples may result from the lack or irregular sporulation of this fungus in the field conditions or a low persistency of its spores. In the field, a great part of AMF either do not sporulate or their sporulation is infrequent and seasonal (Stürmer and Bellei 1994; Stutz and Morton 1996). *Glomus laccatum* forms small, hyaline spores with a delicate spore wall that may easily be decomposed by soil microorganisms. Many soil microorganisms are parasites of AMF (Lee and Koske 1994).

Glomus laccatum has originally been described as producing spores with one-layered spore wall (Błaszkowski 1988). Ontogenetic investigations (Błaszkowski, unpubl.) revealed the spore wall structure to be consisted of two layers, an evanescent outer layer and an inner laminate layer comprising loose sublayers (laminae).

Glomus macrocarpum Tul. et Tul.
n = 1
Plant host: *J. communis*

Literature data indicate that *G. macrocarpum* is a widely distributed fungus in the world, although its occurrence is very irregular (Błaszkowski 1991a, 1993b, 1994a, 1995; Błaszkowski and Tadych, pers. observ.; Dalpé 1989; Godfrey 1957; Hall and Abbott 1984; Puppi and Riess 1987; Schenck and Smith 1981; Koske and Tews 1987; Tadych and Błaszkowski 2000).

Glomus mosseae (Nicol. et Gerd.) Gerd. et Trappe
n = 1:13. Fig. 15.
Plant host: *P. lanceolata*

Glomus mosseae is a frequent component of communities of AMF associated with plants of different regions of the world (Błaszkowski 1993a). Błaszkowski (1993a) found this species to be the third in frequency of occurrence of AMF in Poland; it markedly preferred cultivated soils.

Glomus occultum Walker
n = 1:1
Plant host: *L. hispidus*

Glomus occultum irregularly occurs in different sites of Poland (Błaszkowski 1990). Mohankumar et al. (1988) revealed it in sandy beach soils of the Madras coast. Walker et al. (1982) recovered this fungus from under *Populus* spp. in Iowa. Koske (1987) found it in dunes distributed from New Jersey to Virginia. According to Morton (1985), *G. occultum* is common in soils of West Virginia. Pfleger and Steward (1989) encountered this species in Minnesota.

Glomus pustulatum Koske, Friese, Walker et Dalpé
n = 2:16, 17
Plant host: *H. perforatum*, *J. communis*

In Poland, *G. pustulatum* has earlier been recorded in dune sands of the Słowiński National Park (Błaszkowski 1994b; Tadych and

B ł a s z k o w s k i 2000), Świnoujście (B ł a s z k o w s k i 1995), and the Błędowska Desert (B ł a s z k o w s k i and T a d y c h, pers. observ.). Other reports of this fungus are those from maritime dunes of Madras (M o h a n k u m a r et al. 1988), Canada (D a l p é 1989), and the USA (K o s k e et al. 1986).

Glomus rubiforme (Gerd. et Trappe) Almedia et Schenck
n = 7:2–4, 8, 12, 15, 24
Plant host: *G. nivale*, *J. communis*, *P. media*, *S. caprea*, *S. virgaurea*

In Poland, *G. rubiforme* has been found associated with plants of forests, dunes, heaps, and cultivated sites (B ł a s z k o w s k i 1998; T a d y c h and B ł a s z k o w s k i 2000; B ł a s z k o w k i and T a d y c h, pers. observ.). This fungus has also been revealed among roots of plants of New Zealand (H a l l 1977), Canada (D a l p é 1989), and Rhode Island (F r i e s e and K o s k e 1991). *Glomus rubiforme* has been described based on specimens collected under cultivated and uncultivated plants of Oregon and Washington.

Glomus undescribed 1
n = 2:12, 13
Plant host: *P. lanceolata*, *S. caprea*

This fungus has earlier been recovered from maritime dunes adjacent to Świnoujście (B ł a s z k o w s k i and T a d y c h, pers. observ.) and those neighbouring Tel-Aviv, Israel (B ł a s z k o w s k i et al. 2000).

Glomus undescribed 2
n = 2:4, 6
Plant host: *J. communis*, *S. caprea*

This fungus has earlier been found in maritime dunes adjacent to Świnoujście (B ł a s z k o w s k i and T a d y c h, pers. observ.).

Glomus sp. unrecognized 1
n = 3:5, 21, 29
Plant host: *E. arenarius*, *K. arvensis*, *M. lupulina*

Glomus sp. unrecognized 2
n = 1:5
Plant host: *E. arenarius*

Glomus sp. unrecognized 3
n = 1:29
Plant host: *M. lupulina*

Scutellospora armeniaca **Błaszk.**
n = 2:16, 17. Fig. 16.
Plant host: *H. perforatum*, *J. communis*

Scutellospora armeniaca has occurred in dune sands of the Gdańsk coast and the Słowiński National Park (Błaszkowski 1992, 1995; Tadych and Błaszkowski 2000). This species has been the most frequently occurring AMF in soils of the Błędowska Desert (Błaszkowski and Tadych, pers. observ.).

Scutellospora dipurpurescens **Morton et Koske**
n = 3:7, 12, 14. Fig. 17.
Plant host: *J. communis*, *P. lanceolata*, *S. virgaurea*

Scutellospora dipurpurescens is the most frequently occurring species of the genus *Scutellospora* in Poland. It was identified in non-dune cultivated and uncultivated sites (Błaszkowski 1991a), dunes of the Hel Peninsula (Błaszkowski 1994a), the Słowiński National Park (Tadych and Błaszkowski 2000), and the Błędowska Desert (Błaszkowski and Tadych, pers. observ.). Błaszkowski et al. (2000) found it associated with roots of *Cenothera drumondi* (Hook) colonizing dunes o Israel. Morton and Koske (1988) described *S. dipurpurescens* from spores encountered in West Virginia.

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Arbuskularne grzyby mikoryzowe doliny rzeki Brdy w Borach Tucholskich

Streszczenie

Przedstawiono występowanie arbuskularnych grzybów mikoryzowych (AGM) związanych z 19 gatunkami z 12 rodzin roślin rosnących w dolinie rzeki Brdy w Borach Tucholskich. Najczęściej badano rośliny z rodzin *Cupressaceae* i *Plantaginaceae*. Badania kultur pułapkowych utworzonych z mieszanin gleby ryzosferowej i korzeni badanych roślin ujawniły 20 opisanych gatunków AGM, dwa nie opisane *Glomus* spp. i trzy gatunki z rodzaju *Glomus*, których nie rozpoznano. Grzybami dominującymi byli przedstawiciele rodzaju *Glomus*. Wśród obserwowanych grzybów znalazł się *G. claroideum*, gatunek wcześniej nie notowany w Polsce. Przedstawiono rozmieszczenie znalezionych AGM w Polsce i w świecie.