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Arbuscular fungi and mycorrhizae of agricultural soils of the Western Pomerania
Part I. Occurrence of arbuscular fungi and mycorrhizae

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This paper presents results of three-year investigations on the occurrence of arbuscular mycorrhizal fungi and arbuscular mycorrhizae of the phylum Glomeromycota in agricultural soils of the Western Pomerania, north-western Poland. The occurrence of these fungi was determined basing on soil-root mixtures collected from both the field and trap cultures.

Key words: arbuscular fungi, agricultural soils, occurrence, Western Pomerania, Poland

INTRODUCTION

The most widely distributed soil fungi of a key importance for plants are arbuscular mycorrhizal fungi (AMF; Gerdemann 1968) of the phylum Glomeromycota (Schüßler, Schwazott and Walker 2001). They co-exist in an obligate symbiosis with at least 80% of all plants of the world (Gianinnazzi and Gianinazzi-Pearson 1986).

The co-existence of AMF and plants leads to a wide range of bilateral advantages (Smith and Read 1997). However, the effectiveness of mycorrhizae in influencing plants has mainly depended on the ability of AMF to generate the changes (Dodd et al. 1990). The ability has been different in different species or even strains of these fungi (Abbott and Robson 1981) and there is almost lack of information of its origin (Giovannetti and Gianinazzi-Pearson 1994). Additionally, in agricultural sites, the effectiveness of arbuscular mycorrhizae has depended on the degree of adaptation of species of AMF to the agrotechnical practices and chemicals applied both during vegetation of plants and after their harvest (Błaszkowski 1991; Jansa et al. 2002), as well as to the species and cultivars of the plants produced (Azcón and Ocampo 1981).

The aim of this study was to determine the occurrence of AMF and arbuscular mycorrhizae associated with plants cultivated in agricultural sites of the Western Pomerania.

MATERIALS AND METHODS

Study area. The area of studies of the occurrence of AMF and arbuscular mycorrhizae in agricultural plants was the Western Pomerania located in north-western Poland (N52°37'E14°34'-N53°54'E14°22' x N53°17'E16°42'-N54°33'E16°40'); Fig. 1, Tab. 1). Samples of rhizosphere soils and roots were collected in 109 localities.

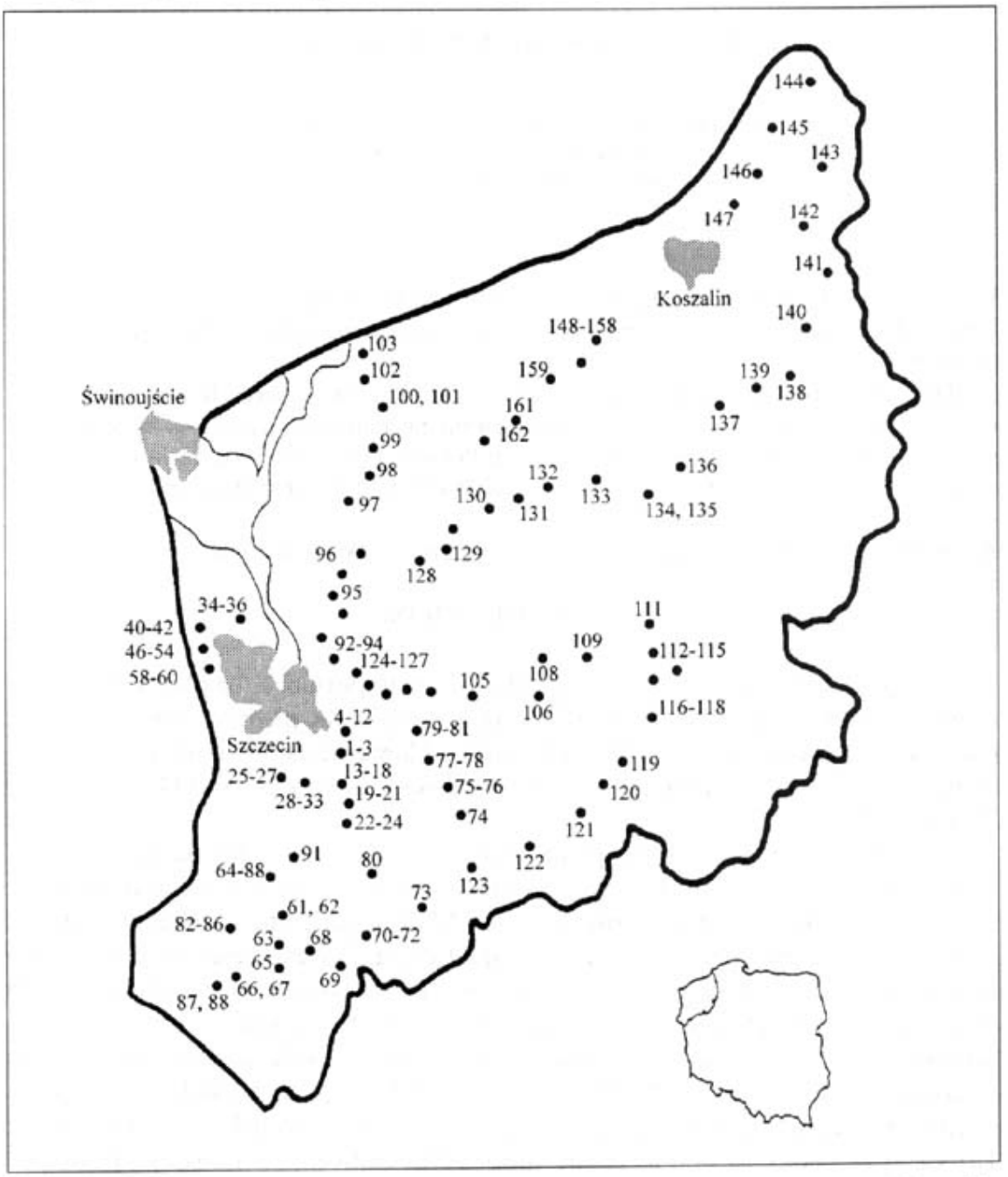

Fig. 1. Sites of collection of rhizosphere soil and root samples from under plants cultivated in the Western Pomerania (see Table 1)

Table 1
The sites of collection of samples of rhizosphere soils and roots of plants cultivated in the Western Pomerania

Locality	Plant species	Date of collection	Number of sample (see Fig. 1)
1	2	3	4
Stare Czarnowo	*Beta vulgare*	5.09.1998	1-3
Kołbacz	*Brassica oleracea*	5.09.1998	4-6
Kołbacz	*Fragaria vesca*	5.09.1998	7-9
Kołbacz	*Triticum aestivum*	5.09.1998	10-12
Będogoszcz	*Triticum aestivum*	5.09.1998	13-15
Będogoszcz	*Beta vulgaris*	5.09.1998	16-18
Zabów	*Triticum aestivum*	5.09.1998	19-21
Stare Chrapowo	*Zea mays*	5.09.1998	22-24
Gardno	*Triticum aestivum*	5.09.1998	25-27
Drzenin	*Beta vulgare*	5.09.1998	28-30
Gardno	*Triticum aestivum*	6.09.1998	31-33
Dobra Szczecińska	*Triticum aestivum*	6.09.1998	34-36
Stobno	*Beta vulgare*	6.09.1998	37-39
Małe Stobno	*Triticum secalum*	6.09.1998	40-42
Bobolin	*Beta vulgare*	6.09.1998	43-45
Bobolin	*Zea mays*	6.09.1998	46-48
Bobolin	*Triticum aestivum*	6.09.1998	49-51
Warnik	*Triticum aestivum*	6.09.1998	52-54
Smolęcin	*Zea mays*	6.09.1998	55-57
Smolęcin	*Triticum aestivum*	6.09.1998	58-60
Trzcińsko Zdrój	*Brassica oleracea*	12.07.1999	61
Trzcińsko Zdrój	*Triticum aestivum*	12.07.1999	62
Stołeczna	*Triticum aestivum*	12.07.1999	63
Piaseczno	*Triticum aestivum*	12.07.1999	64
Babin	*Triticum aestivum*	12.07.1999	65
Warnice	*Triticum aestivum*	12.07.1999	66
Krężelin	*Secale cereale*	12.07.1999	67
Pszczelnik	*Secale cereale*	12.07.1999	68
Myślibórz	*Triticum secalum*	12.07.1999	69
Ławy	*Triticum secalum*	12.07.1999	70
Sumiak	*Avena sativa*	13.07.1999	71
Kinice	*Triticum aestivum*	13.07.1999	72
Rychnów	*Triticum secalum*	13.07.1999	73
Dzikowo	*Brassica napus*	13.07.1999	74
Jedlice	*Triticum secalum*	13.07.1999	75
Derczewo	*Triticum aestivum*	13.07.1999	76
Sitno	*Brassica napus*	13.07.1999	77
Sitno	*Secale cereale*	13.07.1999	78
Kierzków	*Secale cereale*	13.07.1999	79
Strzeszów	*Secale cereale*	14.07.1999	80
Barwice	*Avena sativa*	14.07.1999	81
Barwice	*Triticum aestivum*	14.07.1999	82
Narost	*Avena sativa*	14.07.1999	83
Narost	*Avena sativa*	14.07.1999	84
Witnica	*Avena sativa*	14.07.1999	85

Tab. 1 cont.

Witnica	*Brassica napus*	14.07.1999	86
Gądno	*Secale cereale*	14.07.1999	87
Klępin	*Triticum aestivum*	14.07.1999	88
Łaziszcze	*Triticum aestivum*	14.07.1999	89
Grzybno	*Triticum aestivum*	14.07.1999	90
Swobnicz	*Secale cereale*	14.07.1999	91
Barnim	*Beta vulgaris*	21.09.1999	92
Wójcin	*Beta vulgaris*	21.09.1999	93
Zalęcin	*Beta vulgaris*	21.09.1999	94
Mechowo	*Beta vulgaris*	21.09.1999	95
Białuń	*Brassica oleracea*	21.09.1999	96
Świętoszewo	*Secale cereale*	1.10.1999	97
Moracz	*Beta vulgaris*	1.10.1999	98
Wodzisław	*Triticum aestivum*	1.10.1999	99
Mechowo	*Triticum aestivum*	1.10.1999	100
Ciesław	*Brassica napus*	1.10.1999	101
Dobrzyń	*Secale cereale*	1.10.1999	102
Gostyń	*Beta vulgaris*	1.10.1999	103
Gostyń	*Triticum aestivum*	1.10.1999	104
Ulikowo	*Brassica napus*	22.06.2000	105
Pęzino	*Brassica napus*	22.06.2000	106
Tarnowo	*Secale cereale*	22.06.2000	107
Błotno	*Avena sativa*	22.06.2000	108
Bytowo	*Secale cereale*	22.06.2000	109
Storkowo	*Brassica napus*	22.06.2000	110
Storkowo	*Avena sativa*	22.06.2000	111
Gudowo	*Brassica napus*	22.06.2000	112
Linowno	*Triticum secalum*	22.06.2000	113
Stawno	*Hordeum vulgare*	25.06.2000	114
Osiek Drawski	*Hordeum vulgare*	25.06.2000	115
Żabinek	*Hordeum vulgare*	25.06.2000	116
Giżyno	*Triticum aestivum*	25.06.2000	117
Dębsko	*Hordeum vulgare*	25.06.2000	118
Wardyń	*Triticum aestivum*	25.06.2000	119
Krzęcin	*Hordeum vulgare*	25.06.2000	120
Przekolno	*Triticum aestivum*	25.06.2000	121
Bolewice	*Hordeum vulgare*	25.06.2000	122
Brzezina	*Triticum aestivum*	25.06.2000	123
Dolice	*Hordeum vulgare*	25.06.2000	124
Morzyca	*Triticum aestivum*	25.06.2000	125
Kolin	*Hordeum vulgare*	25.06.2000	126
Witkowo	*Triticum aestivum*	25.06.2000	127
Kulice	*Zea mays*	14.07.2000	128
Jarchlino	*Secale cereale*	14.07.2000	129
Łososnica	*Avena sativa*	14.07.2000	130
Rusinowo	*Brassica napus*	14.07.2000	131
Osowo	*Avena sativa*	14.07.2000	132
Oparzno	*Brassica napus*	14.07.2000	133
Łąkowo	*Avena sativa*	14.07.2000	134
Kołacz	*Hordeum vulgare*	14.07.2000	135
Sadkowo	*Secale cereale*	14.07.2000	136
Rudno	*Avena sativa*	14.07.2000	137

Tab. 1 cont.

Tychowo	*Secale cereale*	14.07.2000	138
Warnino	*Hordeum vulgare*	14.07.2000	139
Kanin	*Triticum aestivum*	14.07.2000	140
Drzewiany	*Triticum aestivum*	14.07.2000	141
Żydowo	*Avena sativa*	14.07.2000	142
Stary Kraków	*Avena sativa*	18.07.2000	143
Naćmierz	*Triticum aestivum*	18.07.2000	144
Sulimice	*Avena sativa*	18.07.2000	145
Sińczyca	*Triticum aestivum*	18.07.2000	146
Krupy	*Secale cereale*	18.07.2000	147
Słowino	*Triticum aestivum*	18.07.2000	148
Rzyszczewo	*Triticum aestivum*	18.07.2000	149
Kraśnik Koszaliński	*Triticum aestivum*	18.07.2000	150
Warnino	*Avena sativa*	18.07.2000	151
Świemino	*Brassica napus*	18.07.2000	152
Karwin	*Triticum aestivum*	18.07.2000	153
Robuń	*Triticum aestivum*	18.07.2000	154
Gościno	*Brassica napus*	18.07.2000	155
Unieradz	*Secale cereale*	18.07.2000	156
Nierzyn	*Avena sativa*	18.07.2000	157
Siemyśl	*Hordeum vulgare*	18.07.2000	158
Białokury	*Triticum aestivum*	18.07.2000	159
Gorawino	*Secale cereale*	18.07.2000	160
Starnin	*Avena sativa*	18.07.2000	161
Rymań	*Triticum aestivum*	18.07.2000	162

Climatic conditions. The climatic conditions of the Western Pomerania were characterized based on meteorological data coming from six measuring stations located in Koszalin, Piła, Resko, Szczecin, Szczecinek, and Świnoujście.

Considering the mean annual values of temperature and total precipitations, the year 1998 was much cooler and more humid than the years 1999 and 2000. Except for 1998, in 1999 and 2000, temperature in the northern and eastern parts was slightly lower than in the other parts of the province, where the values were similar. In 1999 and 2000, the northern regions also were more humid than the others.

Collection of samples and establishment of trap and single-species cultures. About 2-l rhizosphere soil-root mixtures of sampled plants were collected from a depth of 5-30 cm using a small garden shovel. In 1998, the mixtures were collected in September, in 1999 in July, September and October, and in 2000 in June and July. In the laboratory, the soil-root mixtures were air dried for 2 weeks and subsequently refrigerated at 4°C until processing. Then, ca. 100 g of a soil-root mixture was separated from each field sample to reveal AMF sporulating in the field conditions. To receive a great number of living spores of different developmental stages and to initiate sporulation of non-sporulating species in the field, trap cultures were established from the other part of each field sample. Each sample was first divided into three equal parts and then mixed (1/1, v/v) with an autoclaved coarse-grained sand coming from the bank of the Baltic Sea. The methods used to establish both trap and single-species cultures are as those characterized earlier (Błaszkowski 2003).

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 and Melzer's reagent (1:1, v/v). The preparation of spores and their identification were as those described earlier (Błaszkowski 2003). Vouchers of all the fungal species recovered are preserved in the authors' collections. Color microphotographs of spores and mycorrhizae of the AM fungal species found can be viewed at the URL http://www.agro.ar.szczecin.pl/~jblaszkowski/.

Presence of mycorrhizae was determined following clearing and staining of roots (Błaszkowski 2003; Phillips and Hayman 1970).

Terminology of spore structure is that suggested by Franke and Morton (1994) and Stürmer and Morton (1997). The classification of AMF used is that of Schüßler et al. (2001).

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

Soil characteristics. Soil chemical and physical measurements included the determinations of pH (in 1 N KCl), contents of organic carbon, nitrogen (%), phosphorous, and potassium (mg 100 g^{-1} of soil).

Statistical analysis. Differences in the structure of arbuscular fungal communities were investigated by determining the frequency of occurrence of species, spore abundance and species richness, and by calculating dominance coefficients (Górny and Gruma 1981). Frequency of occurrence was calculated by determining the percentage of samples from which spores of a particular species were recovered. Spore abundance and species richness were defined by determining the number of spores and species, respectively, occurring in 100 g dry soil. Dominance coefficient expresses the proportion of the number of spores of a particular species in all spores of AMF recovered.

Relationships between spore count data, values of mycorrhizal colonization, and soil chemical and physical properties were assessed by a linear correlation analysis.

The similarity of the species composition of the AMF revealed in cultivated sites of the Western Pomerania (this study) and the Szczecin Province (Błaszkowski 1993) was determined using a coefficient of similarity (Koske and Tews 1987). The equation is: C=2w/a+b, where w=the number of species common to both the fungal communities compared, a=the number of species of the first community, b=the number of species of the second community.

RESULTS

Arbuscular fungi

General data. During a three-year study, the occurrence of AMF in agricultural soils of the Western Pomerania was determined based on 162 soil and root mixtures collected in 109 localities (Fig. 1). The samples represented 10 plant species belonging to four families (Tab. 2). The plant family most frequently examined was the Poaceae (121 samples, 6 plant species), followed by the Brassicaceae (17 samples, 2 species) and Chenopodiaceae (21 samples, 1 species).

Most soil and root samples came from under *T. aestivum* (58; Tab. 2).

Table 2
Plants and localities in which the occurrence of arbuscular mycorrhizal fungi was examined

Plant	Locality (see Fig. 1, Table 1)
BRASSICACEAE	
Brassica napus L.	61, 74, 77, 86, 101, 105, 106, 110, 112, 131, 133, 152, 155
Brassica oleracea L.	4, 5, 6, 96
CHENOPODIACEAE	
Beta vulgaris L.	1, 2, 3, 16, 17, 18, 28, 29, 30, 37, 38, 39, 43, 44, 45, 92, 93, 94, 95, 98, 103
POACEAE	
Avena sativa L.	71, 81, 83, 84, 85, 108, 111, 130, 132, 134, 137, 142, 143, 145, 151, 157, 161
*Hordeum vulgare*L.	114, 115, 116, 118, 120, 122, 124, 126, 135, 139, 158
Secale cereale L.	67, 68, 78, 79, 80, 87, 91, 97, 102, 107, 109, 129, 136, 138, 147, 156, 160
Triticum aestivum L.	10, 11, 12, 13, 14, 15, 19, 20, 21, 25, 26, 27, 31, 32, 33, 34, 35, 36, 49, 50, 51, 52, 53, 54, 58, 59, 60, 62, 63, 64, 65, 66, 72, 76, 82, 88, 89, 90, 99, 100, 104, 117, 119, 121, 123, 125, 127, 140, 141, 144, 146, 148, 149, 150, 153, 154, 159, 162
XTriticosecale Wittmack	40, 41, 42, 69, 70, 73, 75, 113
Zea mays L.	22, 23, 24, 46, 47, 48, 55, 56, 57, 128
ROSACEAE	
Fragaria vesca L.	7, 8, 9

From the soil samples examined, a total of 25707 spores of AMF were isolated; 7453 spores came from field-collected soils, and 18254 from trap cultures. The spores represented seven of the eight existing genera of the phylum Glomeromycota (Schüßler et al. 2001). Among the spores recovered, 26 species were recognized.

Occurrence of AMF. Spores of AMF occurred in 155 soil and root samples collected in the field, i. e., in 95.7% of all the samples collected. The spore population comprised 16 species and one undescribed morphotype of the genus *Glomus*. Most (12) taxa came from the genus *Glomus*.

Of the 486 trap cultures established, 462 (95.1%) contained spores of AMF. Most cultures with AMF were found when the plant host was *Z. mays* (98.1%).

Culturing of soil-root mixtures in trap cultures revealed eight species (*Ac. capsicula*, *Arch. trappei*, *Gl. clarum*, *Gl. etunicatum*, *Gl. intraradices*, *Gl. spurcum*, *Gl. verruculosum*, *P. occultum*) and four undescribed morphotypes (one each of *Acaulospora*, *Entrophospora*, *Gigaspora*, and *Scutellospora*) earlier not found in the field-collected samples.

Although the total number of the fungal species revealed did not depend on the species of the plant host used in trap cultures, more members of the genus *Glomus* were isolated from cultures with *P. lanceolata* and *Z. mays* (13 species each vs. 11 from cultures with *S. vulgare*), and three of the four species of *Acaulospora* were found only in cultures with *S. vulgare*.

Of the AMF found to sporulate in the field, 12 species and one morphotype of the genus *Glomus* produced spores in trap cultures. Spores of *Gl. fuegianum*, *Gl. macrocarpum*, *Gl. microcarpum*, and *Scu. pellucida* were revealed only in soil-root samples coming from the field.

Considering the results of studies of both field samples and trap cultures, the AMF markedly most frequently occurring in the soil-root samples examined were

members of the genus *Glomus* (Tab. 3). *Glomus* species were associated with roots of all plants of the families Brassicaceae and Rosaceae. Of the plants of the family Poaceae, which were most frequently examined (n=121), 98.2% hosted *Glomus* spp. Only ca. 5% of plants of the family Chenopodiaceae were not associated with species of the genus *Glomus*.

Other AMF relatively frequently revealed in this study were members of the genera *Acaulospora*, *Archaeospora*, and *Scutellospora* (Tab. 3). Species of *Acaulospora* more frequently co-existed with plants of the family Chenopodiaceae. *Archaeospora trappei*, the only species of this genus found in this study, was most frequently associated with plants of the family Chenopodiaceae. Species of *Scutellospora* were most frequently recovered from samples representing the family Poaceae.

Of the plant species considered, only *A. sativa*, *Be. vulgaris*, and *T. aestivum* not always harboured fungi of the genus *Glomus* (Tab. 4). However, the values of the frequency of occurrence of *Glomus* spp. among roots of these plant species exceeded 94%.

Fungi of the genus *Acaulospora* most frequently co-occurred with *Br. oleracea* (Tab. 4).

Archaeospora trappei most frequently co-existed with *Z. mays* (Tab. 4).

Spores of *Entrophospora infrequens*, the only member of this genus recorded in this study, occurred not numerously and infrequently (Tab. 4). They were found only in trap cultures with rhizosphere soil-root mixtures of *S. cereale*, *T. aestivum*, and *XTriticosecale*.

Spores of the genus *Gigaspora* occurred only in trap cultures with mixtures of soils and roots representing *S. cereale*, *T. aestivum*, and *XTriticosecale* (Tab. 4).

Spores of the genus *Scutellospora* were most frequently associated with roots of *S. cereale* and *A. sativa* (Tab. 4).

Paraglomus occultum, the only species of the genus revealed in this study, was found only in four trap cultures representing *Be. vulgaris*, *T. aestivum*, and *Z. mays* (Tab. 4).

Participation of seven genera of arbuscular fungi in spore populations of these fungi isolated from under four families of cultivated plants. In the spore population of AMF isolated, the markedly highest participation had members of the genus *Glomus* (Tab. 5). Fungi of this genus were most numerously represented among spores isolated from under plants of the family Chenopodiaceae.

Species of the genus *Acaulospora* ranked second; however, their participation in the total number of spores isolated did not exceed 5%. Fungi of this genus were also most numerously recovered from soil-root samples coming from under plants of the family Chenopodiaceae.

The participation of spores of the other genera in the spore populations of AMF recovered ranged from 0.1% (*Entrophospora*, *Scutellospora* – Poaceae) to 1.51% (*Archaeospora* – Chenopodiaceae).

Participation of seven genera of arbuscular fungi in spore populations of these fungi isolated from under 10 species of cultivated plants. The members of the genus *Glomus* predominated (a participation of >50%) in the spore populations of AMF recovered from among roots of *Be. vulgaris*, *Br. napus*, *S. cereale*, and *T. aestivum* (Tab. 6). The lowest number of spores of this genus came from under *H. sativum*.

Most spores of the genus *Acaulospora* were isolated from trap cultures contain-

Table 3

The frequency of occurrence of seven genera of arbuscular mycorrhizal fungi among roots of four plant families (%)

Plant family	*Acaulospora*	*Archaeospora*	*Entrophospora*	*Gigaspora*	*Glomus*	*Paraglomus*	*Scutellospora*
Chenopodiaceae							
A*	9.5				95.2		4.8
B		4.8			95.2		
C	4.8	9.5			90.5	4.8	
D	4.8	4.8			95.2		
Brassicaceae							
A	5.9				100.0		
B					82.4		
C					88.2		
D					100.0		
Poaceae							
A	1.7				95.0		10.7
B		1.7	0.8	1.7	94.2	0.8	4.1
C	1.7	1.7	0.8		95.0	0.8	6.6
D		4.1	1.7		97.5		3.3
Rosaceae							
A					100.0		
B					100.0		
C					100.0		
D					100.0		

A* – field samples; trap cultures with *P. lanceolata* (B), *S. vulgare* (C), *Z. mays* (D)

Table 4

The frequency of occurrence of seven genera of arbuscular mycorrhizal fungi among roots of ten plant species (%)

Plant species	*Acaulospora*	*Archaeospora*	*Entrophospora*	*Gigaspora*	*Glomus*	*Paraglomus*	*Scutellospora*
	1	2	3	4	5	6	7
Avena sativa							
A*					94.1		5.9
B					94.1		5.9
C					94.1		11.8
D		5.9			94.1		5.9
Beta vulgaris							
A	9.5				95.2		4.8
B		4.8			95.2		
C	4.8	9.5			90.5	4.8	
D	4.8	4.8			95.2		
Brassica napus							
A					100.0		
B					76.9		
C					92.3		
D					100.0		
Brassica oleracea							
A	25.0				100.0		
B					100.0		
C					75.0		
D					100.0		
Fragaria vesca							
A					100.0		
B					100.0		
C					100.0		
D					100.0		

Hordeum vulgare							
A					100.0		9.1
B					100.0		18.2
C		9.1			100.0		
D					100.0		
Secale cereale							
A	5.9				100.0		29.4
B		5.9			94.1		5.9
C	5.9	5.9	5.9		100.0		17.6
D					100.0		
Triticum aestivum							
A	1.7				93.1		8.6
B	1.7	1.7			94.8	1.7	
C					94.8		5.2
D		3.5	1.7		96.6	1.7	5.2
XTriticosecale							
A					87.5		12.5
B				25.0	75.0		
C			12.5		75.0		
D					100.0		
Zea mays							
A					100.0		
B					100.0		10.0
C	10.0				100.0	10.0	
D		20.0			100.0		

A* – field samples; trap cultures with *P. lanceolata* (B), *S. vulgare* (C), *Z. mays* (D)

Table 5

The participation* of spores of seven genera of arbuscular mycorrhizal fungi in spore populations of these fungi isolated from under of four plant families (%)

Plant family	*Acaulospora*	*Archaeospora*	*Entrophospora*	*Gigaspora*	*Glomus*	*Paraglomus*	*Scutellospora*
Chenopodiaceae							
A**	0.06±0.01***				54.54±5.06		0.03±0.01
B		1.51±0.35			16.51±2.81		
C	0.03±0.07	0.58±0.14			13.86±0.98	0.12±0.02	
D	4.28±0.98	0.84±0.19			15.75±1.35		
Brassicaceae							
A	0.15±0.1				26.27±3.12		
B					21.59±6.44		
C					9.83±1.59		
D					42.36±5.38		
Poaceae							
A	0.03±0.01				24.73±4.17		0.18±0.05
B		0.13±0.03	0.01±0.04	0.01±0.02	17.85±1.50	0.13±0.002	0.06±0.02
C	0.03±0.01	0.05±0.04	0.05±0.04		13.87±1.27	0.03±0.03	0.07±0.01
D		0.66±0.11	0.01±0.001		42.42±3.50		0.01±0.001
Rosaceae							
A					32.67±4.17		
B					43.13±18.71		
C					15.63±3.64		
D					8.57±2.82		

* the number of spores of a given genus divided by the number of all spores of arbuscular fungi in samples representing a given plant family and multiplied by 100
** A – field samples; trap cultures with *P. lanceolata* (B), *S. vulgare* (C), *Z. mays* (D)
*** S.D. – standard deviation

ing rhizosphere soil-root mixtures of *Be. vulgaris*, when the host plant was *Z. mays*.

The participation of spores of the other genera in the spore populations of AMF recovered was low and ranged from 0.01 to 1.51%.

Frequency of occurrence of species of AMF. In the field-collected rhizosphere soil-root samples, the species of AMF most frequently found (present in >20% of samples) were *Gl. caledonium*, *Gl. constrictum*, *Gl. deserticola*, *Gl. dominikii*, and *Gl. mosseae* (Tab. 7). Relatively frequently (present in 10-20% of samples) also occurred *Gl. claroideum* and *Scu. dipurpurescens*.

The arbuscular fungi most frequently occurring in trap cultures were *Gl. caledonium*, *Gl. claroideum*, *Gl. constrictum*, *Gl. deserticola*, *Gl. dominikii*, and *Gl. mosseae* (Tab. 7). Their occurrence did not generally depend on the plant host species used.

Considering the frequency of occurrence of the AMF revealed in soil-root samples coming from both the field and trap cultures with the three plant hosts used, the arbuscular fungal species occurring most frequently in cultivated soils of the Western Pomerania were *Gl. deserticola* (present in 76.5% samples), followed by *Gl. mosseae* (66.7%), *Gl. claroideum* (48.8%), *Gl. caledonium* (40.1%), and *Gl. dominikii* (30.3%; Tab. 7). Of them, *Gl. deserticola* and *Gl. dominikii* were more frequently found in field-collected samples, whereas the other species more frequently occurred in trap cultures.

Dominance. In the field-collected soil-root samples, the eudominants (a coefficient of dominance of D>10.0%) were *Gl. deserticola* and *Gl. dominikii* (Tab. 8). Of the species encountered, none classified to dominants (D=5.1-10.0%). The subdominants (D=2.1-5.0%) were *Gl. constrictum* and *Gl. mosseae*.

Except for *Gl. constrictum* found to be a subdominant in trap cultures with the plant host *S. vulgare* (Tab. 8), the species composition of the fungi dominating in the cultures was identical and the position of the fungal species in the rank established only slightly changed depending on the species of the trap plant used.

When spores recovered from both field samples and trap cultures with the three plant host species used were considered, the eudominants of the agricultural soils of the Western Pomerania were *Gl. claroideum*, *Gl. deserticola*, *Gl. dominikii*, and *Gl. mosseae* (Tab. 8). The group of dominants was formed by *Gl. caledonium* and an undescribed *Glomus* sp. *Glomus constrictum* was a subdominant.

The higher number of spores and species of the genus *Glomus* in the spore populations of AMF isolated in this study (Tabs 3, 5, 7) agrees with the earlier literature reports of a good adaptation of these fungi to a wide range of physical and chemical soil conditions (Anderson, Liberta and Dickman 1984; Grey 1991; Haas and Menge 1990; Jansa et al. 2002; Porter, Robson and Abbott 1987). Daniels and Trappe (1980) found that the optimal temperature for germination of spores of *Glomus* spp. is 14-22°C, i. e., a temperature range of the growing season of north-western Poland (Koźmiński and Michalska 2001). In contrast, species of the genera *Gigaspora* and *Scutellospora* preferred warmer (Koske 1987; Schenck, Graham and Green 1975) and more sandy soils (Błaszkowski 1993). Koske (1987) proved statistically that temperature was the main abiotic factor differentiating the structure of AM fungal populations along a dune transect extending from New Jersey to Virginia. According to Pirozynski (1968), temperature is the main factor regulating the distribution of fungi in general.

The disclosure in trap cultures of eight species and four undescribed morphotypes

Table 6

The participation* of spores of seven genera of arbuscular mycorrhizal fungi in spore populations of these fungi isolated from under of ten plant species (%)

Plant species	*Acaulospora*	*Archaeospora*	*Entrophospora*	*Gigaspora*	*Glomus*	*Paraglomus*	*Scutellospora*
	1	2	3	4	5	6	7
Avena sativa							
A**					38.53±3.31***		0.32±0.08
B					15.86±0.69		0.06±0.01
C					20.25±1.61		0.32±0.08
D		0.19±0.05			29.39±1.72		0.06±0.01
Beta vulgaris							
A	0.06±0.01				54.54±5.06		0.03±0.01
B		1.51±0.35			16.51±2.81		
C	0.03±0.01	0.58±0.14			13.86±0.98	0.12±0.02	
D	4.28±0.98	0.84±0.19			15.75±1.35		
Brassica napus							
A					29.29±1.39		
B					54.44±1.57		
C					6.31±0.45		
D					50.79±4.92		
Brassica oleracea							
A	0.40±0.20				21.48±5.88		
B					34.26±12.40		
C					15.28±2.31		
D					28.99±6.78		
Fragaria vesca							
A					32.67±6.34		
B					43.13±18.71		
C					15.63±3.64		

D					8.57±2.82		
Hordeum vulgare							
A					30.78±2.25		0.05±0.02
B					19.79±1.52		0.16±0.04
C		0.11±0.03			19.79±1.44		
D					29.31±2.74		
Secale cereale							
A	0.24±0.04				52.85±4.17		0.84±0.11
B		0.36±0.09			11.14±0.61		0.18±0.04
C	0.06±0.01	0.42±0.10	0.06±0.01		13.72±0.82		0.24±0.03
D					19.29±3.41		
Triticum aestivum							
A	0.01±0.001				19.26±4.17		0.12±0.01
B	0.01±0.001	0.16±0.02			18.47±0.51	0.21±0.03	
C					11.96±0.23		0.03±0.002
D		0.95±0.11	0.01±0.001		50.56±3.65	0.02±0.03	0.03±0.003
XTriticosecale							
A					38.51±7.62		0.13±0.05
B				0.27±0.09	15.41±3.08		
C			0.13±0.05		12.30±1.50		
D					31.62±4.07		
Zea mays							
A					9.74±1.35		
B					27.26±2.98		0.05±0.02
C	0.49±0.15				18.60±2.44	0.32±0.10	
D		0.81±0.24			42.13±3.82		

* the number of spores of a given genus divided by the number of all spores of arbuscular fungi in samples representing a given plant species and multiplied by 100
** A – field samples; trap cultures with *P. lanceolata* (B), *S. vulgare* (C), *Z. mays* (D)
*** S.D. – standard deviation

Table 7
The frequency of occurrence of arbuscular mycorrhizal fungi among roots of plants cultivated in the Western Pomerania (%)

Fungal species	Frequency of occurrence			
	Field samples	Trap cultures with		
		Plantago lanceolata	*Sorghum vulgare*	*Zea mays*
Acaulospora capsicula			0.62	
Acaulospora paulinae	2.47		0.62	
Acaulospora thomii	0.62		0.62	
Undescribed *Acaulospora* sp.			0.62	1.23
Archaeospora trappei		2.47	2.47	3.70
Gigaspora sp.		0.62		
Entrophospora infrequens		0.62	0.62	0.62
Undescribed *Entrophospora* sp.				0.62
Glomus aggregatum	1.85	0.62		
Glomus caledonium	20.99	29.63	25.92	40.12
Glomus claroideum	11.73	33.33	29.01	48.76
Glomus clarum		0.62		
Glomus constrictum	26.54	21.60	17.90	16.05
Glomus deserticola	76.54	48.15	47.53	40.74
Glomus dominikii	30.25	21.60	20.99	19.13
Glomus etunicatum		1.23	0.62	0.62
Glomus fasciculatum	3.70	1.85	2.47	2.47
Glomus fuegianum	0.62			
Glomus geosporum	1.85	3.09	3.09	4.32
Glomus intraradices			0.62	0.62
Glomus laccatum		2.47	2.47	6.17
Glomus macrocarpum	4.94			
Glomus microcarpum	0.62			
Glomus mosseae	37.65	54.32	60.49	66.67
Glomus spurcum		0.62		1.23
Glomus verruculosum				0.62
Undescribed *Glomus* sp.	4.32	6.79	5.55	5.55
Paraglomus occultum		0.62	1.23	0.62
Scutellospora dipurpurescens	9.26	0.62	4.32	0.62
Scutellospora pellucida	1.23			
Undescribed *Scutellospora* sp.		0.62		

earlier not found in field-collected samples (Tab. 7) supports the conclusions of, e. g., Błaszkowski, Adamska and Czerniawska (2002), Stütz and Morton (1996) and Jansa et al. (2002) that a great part of AMF does not sporulate in the field at all or their sporulation is seasonal.

Table 8
The dominance of arbuscular mycorrhizal fungi isolated from under cultivated plants of the Western Pomerania (%)

Fungal species	Dominance			
	Field samples	Trap cultures with		
		Plantago lanceolata	*Sorghum vulgare*	*Zea mays*
Acaulospora capsicula			0.03	
Acaulospora paulinae	0.11	1.53	0.03	
Acaulospora thomii	0.03		0.11	
Undescribed *Acaulospora* sp.	0.25		1.47	
Archaeospora trappei		0.82	1.55	
Gigaspora sp.		0.04		
Entrophospora infrequens		0.02	0.03	
Undescribed *Entrophospora* sp.				0.01
Glomus aggregatum	0.36	0.04		
Glomus caledonium	1.42	4.07	6.95	7.30
Glomus claroideum	0.78	44.96	19.62	49.60
Glomus clarum		0.08		
Glomus constrictum	2.52	2.03	2.06	0.75
Glomus deserticola	75.99	14.46	21.18	8.35
Glomus dominikii	14.05	6.38	7.92	2.25
Glomus etunicatum		0.38		
Glomus fasciculatum	0.46	0.28	0.17	0.05
Glomus fuegianum	0.10			
Glomus geosporum	0.29	0.93	0.42	1.39
Glomus intraradices			0.08	0.07
Glomus laccatum		0.28	0.93	1.47
Glomus macrocarpum	0.24			
Glomus microcarpum	0.04			
Glomus mosseae	2.60	18.83	31.76	23.26
Glomus spurcum		0.06		0.46
Glomus verruculosum				0.05
Undescribed *Glomus* sp.	0.25	4.87	6.98	1.55
Paraglomus occultum		0.48	0.28	0.02
Scutellospora dipurpurescens	0.70	0.22	0.37	0.01
Scutellospora pellucida	0.05			
Undescribed *Scutellospora* sp.		0.02		

The relatively lower species diversity of the spore populations of the genus *Glomus* isolated from trap cultures with the plant host *S. vulgare* than from those with *P. lanceolata* and *Z. mays* and the presence of three *Acaulospora* spp. in cultures with *S. vulgare* (only one *Acaulospora* sp. in cultures with *Z. mays* and lack of spores of this genus in cultures with *P. lanceolata*; Tab. 7)) correspond with the earlier literature reports of a high influence of a plant host species on the development of AMF in trap cultures (Brundrett, Abbott and Jasper 1999; Brundrett, Jaspper

Table 9

The spore abundance and species richness of arbuscular mycorrhizal fungi among roots of four plant families

Plant family	Spore abundance				Species richness			
	Field samples*	Trap cultures with**			Field samples	Trap cultures with		
		P. lanceolata	*S. vulgare*	*Z. mays*		*P. lanceolata*	*S. vulgare*	*Z. mays*
	av.±S.D.	av.±S.D.	av.±S.D.	av.±S.D.	av.±S.D.	av.±S.D.	av.±S.D.	av.±S.D.
Chenopodiaceae	89.9±167.0	28.7±41.8	22.5±27.8	34.1±54.0	2.3±1.6	2.1±1.0	2.5±1.2	2.2±1.0
Brassicaceae	30.5±25.1	25.1±49.3	11.2±14.9	48.9±56.1	2.9±1.1	1.8±1.1	1.8±1.1	2.4±1.0
Poaceae	36.4±53.0	36.7±48.7	22.5±26.3	70.0±297.6	2.3±1.3	2.4±1.2	2.3±1.2	3.0±2.1
Rosaceae	115.7±67.0	152.7±198.7	55.3±38.6	30.3±29.9	2.0±1.0	3.0±0.0	2.3±1.5	3.0±1.0

* in 100 g dry soil
** in 50 g dry soil
S.D. – standard deviation

Table 10

The spore abundance and species richness of arbuscular mycorrhizal fungi among roots of ten plant species

Plant species	Spore abundance				Species richness			
	Field samples*	Trap cultures with**			Field samples	Trap cultures with**		
		P. lanceolata	*S. vulgare*	*Z. mays*		*P. lanceolata*	*S. vulgare*	*Z. mays*
	av.±S.D.	av.±S.D.	av.±S.D.	av.±S.D.	av.±S.D.	av.±S.D.	av.±S.D.	av.±S.D.
Avena sativa	32.9±52.3	13.6±10.7	18.7±24.9	27.8±26.8	2.1±1.1	2..4±1.0	2.1±1.1	3.1±0.9
Beta vulgaris	89.9±167.0	28.7±41.8	22.5±27.8	34.1±54.0	2.3±1.6	2.1±1.0	2.5±1.2	2.2±1.0
Brassica napus	27.2±16.8	12.8±18.1	5.7±5.1	47.1±59.3	3.1±1.0	1.9±1.2	1.6±1.0	2.3±1.1
Brassica oleracea	41.5±45.1	65.0±94.2	29.0±22.9	55.0±51.5	2.3±1.5	1.8±1.5	2.3±1.5	2.8±0.5
Fragaria vesca	115.7±67.0	152.7±198.7	55.3±38.6	30.3±29.9	2.0±1.0	3.0±0.0	2.3±1.5	3.0±1.0

Hordeum vulgare	51.5±41.6	33.5±27.8	33.3±26.3	49.0±51.3	3.1±0.9	3.3±0.9	2.9±1.2	3.2±1.3
Secale cereale	52.5±71.3	10.7±10.4	14.7±12.3	19.9±11.8	2.8±1.3	2.4±1.0	2.8±1.3	2.6±1.1
Triticum aestivum	33.5±52.2	35.5±58.6	22.8±26.0	103.8±425.0	2.1±1.3	2.4±1.2	2.2±1.6	2.6±1.1
XTriticosecale	35.8±56.4	15.9±24.2	11.4±11.1	29.5±30.0	2.4±1.6	2.0±1.6	1.5±0.9	2.5±0.8
Zea mays	19.2±24.4	50.4±55.1	35.9±45.8	79.4±69.2	2.3±1.1	2.6±1.0	2.4±1.2	2.7±1.1

* in 100 g dry soil
** in 50 g dry soil
S.D. – standard deviation

and Ashwath 1999; Jansa et al. 2002). According to Bever et al. (1996), the most important factor restricting the development of some taxa of AMF is the degree of their adjustment to a plant host.

The main reasons of the lack of sporulation of *Gl. fuegianum*, *Gl. macrocarpum*, *Gl. microcarpum*, and *Scu. pellucida* in trap cultures, species found to occur in the field (Tab. 7), probably were (1) the exclusion or suppression of these fungi by species more competitive or faster adapting to the conditions of trap cultures and (2) the incompatability of the under- and above-ground conditions, as well as the plant hosts of these cultures with the ecological requirements of the four fungal species (Brundrett et al. 1999a, b; Jansa et al. 2002).

Many previous studies (e. g., Błaszkowski 1993; Gerdemann 1968; Harley and Harley 1987, 1990) showed that cultivated plant species of the families *Brassicaceae* and *Chenopodiceae* generally do not form mycorrhizae with fungi of the phylum Glomeromycota. However, recent investigations proved that mycorrhizae of same species of AMF do not react with the commonly used stains (Morton and Redecker 2001) and one of the methods enabling to reveal an existence of a mycorrhizal association is culturing of soil-root mixtures in trap cultures to initiate sporulation of species of AMF not producing spores in the field conditions (Stütz and Morton 1996). This method used in the studies discussed here indicated among others that *Br. napus* and *Br. oleracea* hosted abundant and diverse populations of AMF in trap cultures, despite the field-collected rhizosphere soils of members of the family *Brassicaceae* contained the lowest number of spores of these fungi (Tab. 4).

The species most frequently occurring and predominating in the spore populations of AMF associated with plants cultivated in the Western Pomerania, i. e., *Gl. caledonium*, *Gl. claroideum*, *Gl. desertiola*, *Gl. dominikii*, and *Gl. mosseae* (Tabs 7 and 8), have many times been found in cultivated soils of the other regions of the world (Błaszkowski 1993; Boddington and Dodd 2000; Jansa et al. 2002; Morton, Bentivenga and Bever 1994; Talukdar and Germida 1993; Vestberg 1995).

Stahl and Christensen (1991) suggested that a wide distribution of some species of AMF results from their genetical adaptation to different environmental conditions that leads to differentiation of genetically

distinct populations. Hence, the marked tolerance of the species mentioned above to agricultural and chemical practices applied in the Western Pomerania probably is stable. The evidence of it also is that the fungi belonged to the taxa most frequently revealed in both the field-collected samples and trap cultures.

Spore abundance. The average total spore abundance of AMF in the field-collected samples was 44±78.3 and ranged from 0 to 511 in 100 g dry soil. In trap cultures, the average total spore abundance was highly depended on the plant host used (Tabs 9, 10). It always was higher when the plant hosts were *Z. mays* and *P. lanceolata* than *S. vulgare*.

In the field, most spores hosted plants of the families Rosaceae and Chenopodiaceae, and least members of the family Brassicaceae (Tab. 9). In trap cultures, most spores were generally also found when the cultures contained soil-root mixtures coming from under plants of the Rosaceae (Tab. 9).

The plant species growing in the field and harbouring most spores of AMF was *F. vesca* (115.7 in 100 dry soil; Tab. 10). Numerous spore populations of these fungi were also isolated from samples collected under *Be. vulgaris*, *S. cereale*, and *H. sativum*.

In trap cultures, most spores were revealed following the cultivation of soil-root mixtures coming from under *F. vesca* (152.7 in 50 g dry soil; Tab. 10). Relatively abundant spore populations also came from cultures representing *Br. oleraceae* and *Z. mays*.

The average total abundance of spores of AMF isolated from the field samples by the authors of this paper is within the lower range of abundances determined in most agricultural sites examined to date (Hayman 1978; Hayman and Stovold 1979; Jakobsen and Nielsen 1983; Kianmehr 1981; Schenck and Kinloch 1980; Stahl and Christensen 1982). In contrast, in Błaszkowski's (1993) studies, the average total spore abundance of these fungi in cultivated soils of the former 11 provinces of Poland was almost two times higher than that found in this study. Apart from agricultural sites, Błaszkowski (1993) also examined soils of home gardens and nurseries with perennial shrubs and trees, whose soils generally are infrequently fertilized. Perennial plants have usually hosted more abundant spore populations of AMF than annual plants (Błaszkowski 1993; Johnson 1977; Hetrick and Bloom 1983; Kormarnik 1985). High rates of fertilizers usually suppress the activity of AMF (Hayman 1970; Kruckelmann 1975).

The finding of the highest number of spores in both field-collected samples and trap cultures representing the family Rosaceae (Tab. 9) supports many literature reports of an exceptionally stable and effective preservation of symbiosis of plants of this family with AMF (Harley and Harley 1987, 1990).

The presence of spores of AMF in both the field samples and trap cultures representing the families Brassicaceae and Chenopodiaceae (Table 9) contradicts many previous literature data that plants of these families are immune to AMF (Gerdemann 1968; Harley and Harley 1987; 1990; Landwehr et al. 2002). Recently, arbuscular mycorrhizae have been revealed in, e. g., *Biscutella laevigata* L. (Brassicaceae; Orłowska et al. 2002), many species of the genus *Thlaspi* (Brassicaceae; Regvar et al. 2002), and species of the family Chenopodiaceae (Sengupta and Chaudhuri 2002).

Species richness. The average total species richness of AMF in the field-collected samples was 2.3±1.3 and ranged from 0 to 5 in 100 g dry soil. In trap cultures, the average total species richness of these fungi was highest when their plant host was *Z. mays*), and the lowest number of species was trapped by *S. vulgare*.

In the field samples, the average species richness in 100 g dry soil coming from the plant families compared was similar and ranged from 2.0 (Rosaceae) to 2.9 (Brassicaceae; Tab. 9).

Cultivation of the soil-root mixtures in trap cultures showed that most fungal species were harboured by plants of the families Rosaceae and Poaceae (Tab. 9).

In the field, the plant species associated with the highest number of species of AMF were *H. vulgare* (3.1), *Br. napus* (3.1), and S. *cereale* (2.8; Tab. 10).

Considering the results of studies of trap cultures, most species of AMF co-occurred with *H. vulgare* (3.3), *A. sativa* (3.1), and *F. vesca* (3.0; Tab. 10). Relatively high number of species of these fungi also hosted *Br. oleraceae* (2.8), *T. aestivum* (2.5), and *Z. mays* (2.7).

Thus, the examination of the field samples and those from trap cultures indicated that the plant species harbouring most species of AMF in agricultural sites of the Western Pomerania were *H. sativum* (3.3), *Br. napus* (3.1), *A. sativa* (3.1), and *F. vesca* (3.0; Tab. 10).

Both the average total and the range of species richness of AMF found in this study (Tabs 9 and 10) are similar to those determined in agricultural sites of other regions of the world (Abbott and Robson 1977; Berch, Gamiet and Deom 1988; Stahl and Christensen 1982; Taludgar and Germida 1993). Somewhat higher average number of species of cultivated sites of Poland revealed by Błaszkowski (1993) probably resulted from the same reasons discussed in the section "Spore abundance".

Arbuscular mycorrhizae

The occurrence of arbuscular mycorrhizae in agricultural plants of the Western Pomerania was determined based on 67 root samples of eight species belonging to three plant families. Most root samples came from under plants of the Poaceae. The

Table 11

The percent of root length with arbuscules, vesicles, and intraradical hyphae of arbuscular fungi in selected species of plants cultivated in the Western Pomerania

Plant species	n	Arbuscule	Vesicle	Intraradical hyphae
		av.±S.D.	av.±S.D.	av.±S.D.
Avena sativa	13	6.0±4.0	7.0±8.0	46.00±23.00
Beta vulgaris	2	0.0	2.0±2.0	21.0±28.0
Brassica napus	9	3.0±4.0	2.0±4.0	23.0±13.0
Hordeum vulgare	8	4.0±4.0	4.0±2.0	31.0±12.0
Secale cereale	13	3.0±3.0	5.0±6.0	31.0±16.0
Triticum aestivum	17	5.0±2.0	3.0±3.0	28.0±14.0
XTriticosecale	4	5.0±3.0	5.0±3.0	34.0±10.0
Zea mays	1	4.00	5.00	41.00

n - number of root samples examined
S.D. – standard deviation

plant species most frequently examined were *T. aestivum*, *S. cereale*, and *A. sativa* (Tab. 11).

Arbuscules. The percent of root length with arbuscules was highest in *A. sativa*, followed by *T. aestivum* and *XTriticosecale* (Tab. 11). No arbuscules were found in roots of *Be. vulgaris*.

Vesicles. The occurrence of vesicles was highest in roots of *A. sativa*, then in *S. cereale*, *XTriticosecale*, and *Z. mays* (Tab. 11).

Intraradical hyphae. The percent of root length with intraradical hyphae was highest in *A. sativa* and *Z. mays* (Tab. 11).

According to Sanders et al. (1977), as low as 10% level of root colonization by AMF significantly increased the amount of absorbed phosphorous from the soil. Volkmar and Woodbury (1989) found that 2-7% colonization of roots by AMF increased up to 25% the weight of shoots of *H. vulgare*.

Arbuscules are indicators of functional mycorrhizae (Smith and Read 1997). Hence, their lack in roots of *Be. vulgaris* examined in this study (Tab. 11) suggests that the mycorrhizae revealed were inactive. However, only two root samples came from under *Be. vulgaris*, and numerous spores of AMF found in both the field samples and trap cultures representing this plant species (Tabs 4, 6, 10) indicated the *Be. vulgaris* mycorrhizae to be effective.

The amount of literature data of the common occurrence of arbuscular mycorrhizae in plants of the family Chenopodiaceae increases (Landwehr et al. 2002).

Physical and chemical properties of soils of the area investigated. The physical and chemical properties of the soils sampled in the Western Pomerania were determined based on 73 soil samples.

The mechanical composition of the soil samples investigated was typical of the cultivated soils of the Western Pomerania (Koźmiński and Michalska 2001). Most samples represented medium sand and slightly loamy sand, and least light loam.

pH of the soils examined ranged from 4.5 to 8.0. The ranges of the contents of organic carbon (%), phosphorous, potassium (mg per 100 g of soil), and total nitrogen (%) were 0.33-2.41, 0.04-26.62, 3.32-36.71, and 0.05-0.32, respectively.

Analysis of correlation. The analysis of linear correlation showed the significance of correlation's between the total spore abundance of AMF and (1) the species richness of these fungi ($r=0.58$, $p<0.05$), (2) the abundance of spores of the genus *Glomus* ($r=0.75$, $p<0.05$) and *Scutellospora* ($r=0.36$, $p<0.05$), (3) the abundance of spores of *Gl. caledonium* ($r=0.51$, $p<0.05$), *Gl. claroideum* ($r=0.57$, $p<0.05$), *Gl. constrictum* ($r=0.66$, $p<0.05$), *Gl. deserticola* ($r=0.62$, $p<0.05$), *Gl. dominikii* ($r=0.46$, $p<0.05$), and *Scu. dipurpurescens* ($r=0.34$, $p<0.05$).

Soil pH correlated with (1) the total abundance of spores ($r=0.31$, $p<0.05$), (2) the total species richness ($r=0.28$, $p<0.05$), (3) the abundance of spores of the genus *Glomus* ($r=0.40$, $p<0.05$), (4) the frequency of occurrence of spores of the genus *Glomus* ($r=0.40$, $p<0.05$), *Gl. constrictum* ($r=0.30$, $p<0.05$), and *Gl. deserticola* ($r=0.27$, $p<0.05$).

The content of organic C was associated with the occurrence of *Gl. constrictum* ($r=0.34$, $p<0.05$).

The content of soil phosphorous correlated with (1) the total species richness of AMF ($r=0.26$, $p<0.05$), (2) the frequency of occurrence of spores of the genera

Glomus (r=0.53, P<0.05) and *Scutellospora* (r=0.35, p<0.05), (3) the amount of spores of *Gl. caledonium* (r=0.28, p<0.05), *Gl. claroideum* (r=0.59, p<0.05), *Gl. constrictum* (r=0.56, p<0.05), and *Gl. deserticola* (r=0.42, p<0.05).

The content of potassium correlated positively with the amount of spores of *Gl. claroideum* (r=0.51, p<0.05) and the frequency of occurrence of *Gl. constrictum*

Table 12

The similarity of the species composition of arbuscular mycorrhizal fungi revealed in the cultivated sites of the Western Pomerania and the Szczecin Province

Western Pomerania (this paper)		Szczecin Province (Błaszkowski 1993)	
Number of soil and root samples	162		88
Number of sites sampled	109		34
Number of plant species sampled	10		23
	Fungal species		
+	*Acaulospora capsicula*	-	
-	*Acaulospora lacunosa*	+	
+	*Acaulospora paulinae*	+	
-	*Acaulospora mellea*	+	
+	*Acaulospora thomii*	-	
+	*Archaeospora trappei*	-	
+	*Entrophospora infrequens*	+	
-	*Gigaspora gigantea*	+	
+	*Glomus aggregatum*	+	
+	*Glomus caledonium*	+	
+	*Glomus claroideum*	-	
+	*Glomus clarum*	-	
+	*Glomus constrictum*	+	
+	*Glomus deserticola*	+	
+	*Glomus dominikii*	+	
+	*Glomus etunicatum*	+	
+	*Glomus fasciculatum*	+	
+	*Glomus fuegianum*	+	
+	*Glomus geosporum*	+	
-	*Glomus heterosporum*	+	
+	*Glomus intraradices*	-	
+	*Glomus laccatum*	-	
+	*Glomus macrocarpum*	+	
+	*Glomus microcarpum*	+	
+	*Glomus mosseae*	+	
+	*Glomus spurcum*	-	
+	*Glomus verruculosum*	-	
-	*Glomus tenue*	+	
+	*Paraglomus occultum*	+	
+	*Scutellospora dipurpurescens*	+	
+	*Scutellospora pellucida*	+	

($r=0.40$, $p<0.05$) and *Gl. deserticola* ($r=0.34$, $p<0.05$), but negatively with the frequency of occurrence of *Gl. dominikii* ($r=-0.26$, $p<0.05$).

The total level mycorrhizal colonization of the plant species considered did not correlate with either any of the properties regarding the occurrence of spores and species of the AMF revealed or the chemical properties of the soil samples examined.

The results of the analysis of correlation indicated that the soil chemical properties most influencing the occurrence of AMF in agricultural soils of the Western Pomerania are pH and the content of phosphorous. The concentration of phosphorous in both the soil and plant is the main factor modifying the activity of AMF (Smith and Read 1997). Germination of spores of AMF highly depends on soil pH (Green et al. 1976).

Comparison of the species composition of arbuscular mycorrhizal fungi of agricultural sites of the Western Pomerania and the Szczecin Province

The similarity of the species composition of the spore populations of AMF revealed in this study and that found by Błaszkowski (1993) in the years 1985-1990 was 67% (Tab. 12). In the study discussed here, 26 fungal species were identified, and Błaszkowski (1993) revealed 22. The number of common species was 16.

Although the numbers of soil-root samples, sites, and plant species examined by the authors of this paper were almost two and over three times higher, and over 2 times lower, respectively, than those considered by Błaszkowski (1993) and Błaszkowski (1993) did not use trap cultures, the high similarity of the species composition of the populations of AMF revealed in both studies indicate that (1) the occurrence of most taxa of AMF in agricultural soils of the Western Pomerania is uniform and does not change with time, (2) the communities of these fungi are stable, despite the arduousness resulting from the influence of the agro-technical and chemical practices applied, and (3) the species diversity of the cultivated plants, when considered in a long period of time, does not influence the species composition of populations of AMF.

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Grzyby i mikoryzy arbuskularne gleb rolniczych województwa zachodniopomorskiego Część I. Występowanie grzybów i mikoryz arbuskularnych

Streszczenie

Niniejszy artykuł przedstawia wyniki trzyletnich badań występowania arbuskularnych grzybów mikoryzowych i mikoryz arbuskularnych (Glomeromycota) w glebach rolniczych województwa zachodniopomorskiego. Występowanie tych grzybów określono na podstawie prób gleby i korzeni zebranych zarówno z pola, jak i kultur pułapkowych.