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Arbuscular fungi and mycorrhizae in agricultural soils of the Western Pomerania
II. Distribution of arbuscular fungi

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This part of the two-part paper of arbuscular mycorrhizal fungi (AMF) of the phylum Glomeromycota of agricultural soils of the Western Pomerania, north-western Poland, presents the distribution of 26 species of these fungi in both the sites considered in this study and cultivated soils of other regions of Poland and the world investigated previously. The fungi were isolated from both field-collected rhizosphere soil and root mixtures and trap cultures established from each field sample and seeded with three species of plant hosts. Among the fungal species characterized, 18 are of the genus *Glomus*, one each of the genera *Archaeospora*, *Entrophospora* and *Paraglomus*, and three and two of the genera *Acaulospora* and *Scutellospora*, respectively.

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

INTRODUCTION

This paper continues the presentation of arbuscular mycorrhizal fungi (AMF) of the phylum Glomeromycota found in agricultural soils of the Western Pomerania, north-western Poland (N52°37'E14°34'-N53°54'E14°22' x N53°17'E16°42'-N54°33'E16°40'), in the years 1998-2000. In the first part of the paper (Iwaniuk and Błaszkowski 2004), the general occurrence of spores of AMF in both field-collected rhizosphere soil and root samples and trap cultures established from each field sample and seeded with three plant host species were described. The frequency of occurrence and the dominance of the arbuscular fungal species revealed, as well as the abundance of spores and the species richness of these fungi among roots of the plant families and species examined were also characterized. Additionally, the level of mycorrhizal colonization of selected plant species cultivated in the field and the correlations between soil chemical properties and the occurrence of spores and species of the AMF revealed were showed. Finally, the species composition of

the AMF found by the authors of this paper and that revealed by Błaszkowski (1993a) in the years 1985-1990 was compared.

The aim of this paper is to present the distribution of the arbuscular fungal species found in agricultural soils of the Western Pomerania (Iwaniuk and Błaszkowski 2004) as well as in cultivated sites of other regions of both Poland and the world examined previously.

MATERIALS AND METHODS

The study area, its climatic conditions, the methods of collection of rhizosphere soil and root mixtures, establishment of trap and one-species cultures, as well as the methods of isolation and identification of the spores of AMF recovered were presented in the first part of this paper (Iwaniuk and Błaszkowski 2004). Additionally, the terminology of spore structure, the classification of AMF, as well as the statistical terms used here are as those characterized previously.

Color microphotographs of spores and mycorrhizae of the AM fungal species presented below can be viewed at the URL http://www.agro.ar.szczecin.pl/~jblaszkowski/.

RESULTS

The data of the origin of the arbuscular fungal species characterized below were presented in the first part of the paper (Iwaniuk and Błaszkowski 2004). Briefly, the fungi were isolated from 162 mixtures of rhizosphere soil and roots coming from under 10 plant species cultivated in 109 localities of the Western Pomerania in the years 1998-2000. Most soil and root samples represented the family Poaceae (121 samples). The plant species most frequently sampled was *Triticum aestivum* L.

During the three-year study, a total of 25707 spores of AMF were isolated, of which 7453 came from field-collected samples 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 isolated, 26 species were identified, including 18 species of the genus *Glomus*, one each of the genera *Archaeospora*, *Entrophospora* and *Paraglomus*, and three and two of the genera *Acaulospora* and *Scutellospora*, respectively.

Distribution of arbuscular mycorrhizal fungi in agricultural soils of the Western Pomerania

The data of records made in other regions of Poland and the world regard only collections coming from cultivated sites.

Abbreviations:

n – number of soil and root samples coming from under plants growing in the field in which a given fungal species was found,

nPl - number of trap cultures with spores of a given fungal species, when the plant host was *Plantago lanceolata*,

nSv - number of trap cultures with spores of a given fungal species, when the plant host was *Sorgum vulgare*,

nZm - number of trap cultures with spores of a given fungal species, when the plant host was *Zea mays*.

The numbers that follow are those of sites presented in Table 1 and Fig. 1, as well as those mentioned in the list of sites showed in Table 2 (Iwaniuk and Błaszkowski 2004).

Acaulospora capsicula Błaszk.

n=0; nPl=0; nSv=1; nZn=0: 119Sv.

Spores of *Ac. capsicula* were found only in one trap culture with the rhizosphere soil and roots of *T. aestivum* cultivated in Wardyń.

General distribution. Błaszkowski (1993a) revealed *Ac. capsicula* in five cultivated sites of Poland. *Acaulospora colossica* Schultz et al. described from spores found in the USA (Schultz et al. 1999) probably is synonymous with *Ac. capsicula*.

Acaulospora paulinae Błaszk.

n=4; nPl=0; nSv=1: 1, 1Sv, 5, 136, 140.

As the results of isolation of spores from both the field and trap culture samples showed, in the cultivated sites of the Western Pomerania, *Ac. paulinae* occurred infrequently and was hosted by *Beta vulgare*, *Brassica oleracea*, *Secale cereale* and *T. aestivum*.

General distribution. *Acaulospora paulinae* has been described from spores isolated from under *Lupinus luteus* L. (Błaszkowski 1988). 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, USA.

Remarks. *Acaulospora paulinae* probably is widely distributed both in Poland and the other regions of the world, although it occurs rather infrequently.

Acaulospora thomii Błaszk.

n=1; nPl=0; nSv=1: 78Sv, 136.

Acaulospora thomii occurred only in two cultivated sites of the Western Pomerania where the plant host grown was *S. cereale*.

General distribution. *Acaulospora thomii* has been described based on spores isolated from among roots of *T. aestivum* growing in Bolesławiec (Błaszkowski 1988). This paper is the second report of the occurrence of this fungus in Poland.

Acaulospora thomii has recently been revealed in Switzerland (Dr. Fritz Oehl, Botanisches Institut, Universität Basel, pers. inf.).

Archaeospora trappei Ames et Linderman

n=0; nPl=4; nSv=4; nZn=6: 25Pl, 25Zn, 28Sv, 29Pl, 30Zn,31Zn,43Sv, 55Zn, 57Zn, 59Pl, 84Zn, 135Sv, 136Pl, 160Sv.

In the studies presented here, *Arch. trappei* was revealed only in trap cultures.

General distribution. *Archaeospora trappei* has been described from spores isolated from trap cultures with the rhizosphere soil and roots collected from under *Lilium longiflorum* Thunb. growing in California and Oregon (Ames and Linder-

man 1976). Additionally, this fungus has been found in cultivated soils of Florida (Schenck and Smith 1981; Schenck and Kinloch 1980), Kansas (Hetrick and Bloom 1983), Israel (Haas and Menge 1990), Australia (Abbott 1982), and among roots of different plants cultivated in Brazil and Japan (Morton and Redecker 2001).

Archaeospora trappei probably commonly occurs in both Poland and the world as the results of studies of trap cultures representing different cultivated and uncultivated plants growing in different regions of Europe (Błaszkowski, pers. observ.).

Remarks. The lack of findings of *Arch. trappei* in the field-collected samples may have resulted from either the omission of spores of this fungus or their absence at the time of collection of soil and root samples due to decomposition of spores by soil microorganisms or seasonal sporulation of the fungus. *Archaeospora trappei* produces small and colourless spores with one wall consisting of thin and delicate layers. Many soil microorganisms have been identified to parasite spores of AMF (Lee and Koske 1994). The seasonality of sporulation has been found in many species of AMF (e. g., Gemma et al. 1989).

Entrophospora infrequens (Hall) Ames et Schneider

n=3: 151Pl, 136Sv, 148Zn.

General distribution. *Entrophospora infrequens* has originally been described as *Gl. infrequens* Hall from spores discovered in New Zealand (Hall 1977). However, the description was incomplete. Following the finding of specimens representing all developmental stages of this fungus among roots of *Opium graveolens* L. cultivated in California, Ames and Schneider (1979) transferred *Gl. infrequens* to a newly erected genus, *Entrophospora* Ames et Schneider. *Entrophospora infrequens* has subsequently been found in many other cultivated sites of the USA (Hetrick and Bloom 1983; Pfleger and Stewart 1989; Schenck and Smith 1982; Stahl and Christensen 1982), Switzerland (Jansa et al. 2002), Finland (Vestberg 1995), and Australia (Hall and Abbott 1984). Błaszkowski (1993a) revealed *E. infrequens* only in four cultivated sites of Poland.

Glomus aggregatum Schenck et Smith emend. Koske

n=3; nPl=1; nSv=0; nZn=0: 9, 11, 44, 149Pl.

The studies of the authors of this paper showed that *Gl. aggregatum* co-occurred with *Be. vulgaris*, *F. vesca*, and *T. aestivum* growing in three localities of the Western Pomerania.

General distribution. *Glomus aggregatum* has originally been described based on spores recovered from among roots of *Citrus sinensis* x *Ponicirus trifoliata* cultivated in Florida (Schenck and Smith 1982). Błaszkowski (1993a) found spores of this fungus in 15 cultivated sites of Poland.

Remarks. *Glomus aggregatum* probably has a worldwide distribution, although Koske (1985) and Błaszkowski (1991) suggest this fungus to prefer sandy soils, especially sand dunes.

Glomus aggregatum distinguishes the formation of loose aggregates and extensive extraradical hyphae binding sand grains into aggregates. Hence, *Gl. aggregatum*

is considered to play a significant role in improving soil structure and counteracting their erosion (Błaszkowski 1991; Koske and Halvorson 1981).

Glomus caledonium Trappe et Gerd.

n=34: nPl=48; nSv=42; nZn=65: 1, 1Sv, 1Zn, 2Pl, 2Sv, 3Pl, 3Sv, 4, 4Sv, 4Zn, 5Sv, 5Zn, 7Pl, 7Zn, 8Sv, 8Zn, 9Zn, 10, 12Pl, 13Pl, 14Sv, 17Pl, 17Sv, 17Zn, 19Sv, 20, 20Pl, 22Sv, 24Pl, 24Sv, 24Zn, 25Sv, 26Pl, 26Sv, 26Zn, 27Sv, 27Zn, 29, 32, 33Pl, 34, 34Sv, 34Zn, 35Pl, 35Zn, 36Pl, 36Sv, 36Zn, 37Pl, 41, 41Zn, 43Pl, 43Sv, 44, 44Pl, 44Sv, 45Pl, 46, 46Pl, 46Sv, 46Zn, 47Pl, 48, 48Pl, 48Sv, 48Zn, 49, 49Zn, 51Sv, 52Pl, 52Sv, 52Zn, 53Zn, 54Pl, 54Zn, 55Pl, 56Zn, 57Pl, 60Zn, 61, 61Zn, 62, 62Sv, 64, 64Sv, 66Zn, 68Pl, 68Sv, 69Zn, 72Zn, 74Zn, 77, 78, 78Pl, 79Pl, 79Zn, 83Zn, 86Zn, 89Zn, 90, 90Pl, 90Sv, 92, 92Sv, 93, 93Zn, 96, 96Zn, 97, 98Zn, 99Sv, 100Zn, 101, 102Zn, 106, 106Sv, 107, 108Zn, 112Pl, 113, 113Pl, 115Sv, 115Zn, 117, 117Zn, 118Pl, 120Zn, 121, 121Zn, 122, 122Zn, 125Pl, 126Pl, 127Pl, 127Zn, 128, 128Sv, 129Pl, 129Zn, 130Pl, 130Sv, 130Zn, 131Pl, 132Pl, 133Pl, 133Zn, 134Sv, 135Pl, 135Zn, 136Sv, 137Pl, 137Zn, 138Zn, 142Pl, 143Zn, 144Sv, 144Zn, 145Sv, 145Zn, 146Zn, 147Pl, 147Zn, 148, 148Pl, 148Sv, 148Zn, 149Zn, 150Pl, 150Zn, 152Zn, 153Sv, 154, 154Pl, 154Zn, 155Pl, 155Zn, 156, 156Sv, 156Zn, 157Zn, 158Pl, 159, 159Pl, 159Zn, 160Pl, 160Zn, 161Pl, 162Pl, 162Zn.

Glomus caledonium was the forth most frequently found species of AMF in cultivated soils of the Western Pomerania examined in this study. The fungus was associated with all the plant species considered. Spores of this fungus were found in both poor sandy and fertile humus soils.

General distribution. *Glomus caledonium* is widely distributed in the world. This fungus has originally been described from spores coming from a meadow soil located in Scotland (Nicolson and Gerdemann 1968). Other reports of its findings in cultivated soils are, e. g., those from the USA (Gerdemann and Trappe 1974; Miller et al. 1985; Pfleger et al. 1989), Germany (Land and Schönbeck 1991), Finland (Vestberg 1995), New Zealand and Australia (Hall 1975; Hall and Abbott 1984), India (Selvaraj and Subramanian 1987), and Taiwan (Wu and Chen 1986).

Błaszkowski (1993a) found *Gl. caledonium* in 59 of the 173 soil samples collected from under plants cultivated in different regions of Poland where it ranked seventh in respect of the frequency of occurrence.

Glomus claroideum Schenck et Smith

n=19; nPl=54; nSv=47; nZn=79: 1, 1Pl, 1Zn, 3Pl, 4Sv, 4Zn, 5Pl, 5Sv, 5Zn, 6Pl, 6Sv, 6Zn, 7, 7Pl, 7Zn, 8Pl, 8Sv, 9Pl, 9Sv, 9Zn, 10, 10Zn, 11Pl, 11Sv, 12Pl, 13Pl, 12Zn, 13Zn, 14Pl, 14Sv, 14Zn, 15Pl, 15Zn, 17Pl, 17Sv, 17Zn, 18Pl, 18Sv, 18Zn, 20Sv, 20Zn, 21Sv, 22Pl, 23Pl, 23Zn, 24Pl, 24Sv, 24Zn, 25Pl, 25Sv, 25Zn, 26Pl, 26Sv, 26Zn, 27Pl, 27Sv, 27Zn, 28Zn, 30Sv, 30Zn, 31Pl, 31Sv, 32Pl, 32Zn, 33Pl, 34Pl, 34Sv, 34Zn, 35Pl, 35Sv, 35Zn, 36Pl, 36Sv, 36Zn, 37Pl, 37Sv, 40Pl, 42Sv, 42Zn, 43Sv, 43Zn, 44Sv, 45Sv, 46Pl, 46Sv, 46Zn, 47Pl, 47Sv, 47Zn, 48, 48Pl, 48Sv, 48Zn, 50Pl, 50Zn, 51Pl, 52Pl, 53Pl, 53Sv, 53Zn, 54Pl, 54Sv, 54Zn, 55Sv, 58Sv, 58Zn, 60Pl, 60Zn, 62, 62Zn, 63, 63Pl, 63Sv, 63Zn, 66Sv, 67Zn, 69Zn, 72, 73, 74, 75Zn, 76, 77, 79Sv, 81Zn, 86, 86Zn, 87Zn, 89Pl, 89Zn, 91Pl, 91Zn, 93, 94, 94Zn, 95Zn, 98Zn, 99Sv, 101, 102Zn, 103Zn, 105Pl, 105Zn, 109, 109Pl, 109Sv, 109Zn, 112Sv, 112Zn, 114Pl, 116Zn, 118Zn, 121Zn, 122Pl, 122Zn, 123, 123Pl, 123Zn, 124Sv, 124Zn, 125Sv, 125Zn, 128Pl, 129Pl, 129Zn, 130Pl, 130Sv, 130Zn, 131Zn, 132Zn, 135Pl, 138Zn, 139, 139Sv, 140Pl, 141Zn, 144Zn, 145Sv, 145Zn, 146Zn, 147Zn, 149Pl, 149Sv, 149Zn, 150Zn, 151Sv, 151Zn, 152Pl, 152Zn, 154Pl, 154Sv, 154Zn, 155Zn, 157Zn, 158Zn, 159, 159Pl.

The studies presented here showed that *Gl. claroideum* was the third most frequently occurring species in cultivated soils of the Western Pomerania. When spores recovered from both field samples and trap cultures were considered, this fungus

was the first among eudominants. *Glomus claroideum* co-occurred with all the plant species examined.

General distribution. *Glomus claroideum* has originally been described based on spores coming from under *Glycine max* (L.) Merr. cultivated in Florida (Schenck and Smith 1982). According to Walker and Vestberg (1998), this fungus is widely distributed in the northern Europe, whereas only two reports come from the southern hemisphere.

Remarks. *Glomus claroideum* is a species difficult to identify based on spores isolated from the field. The spores usually lack two outermost layers of their wall, which are exceptionally short-lived. Additionally, the innermost spore wall layer of this species usually tightly adheres to the penultimate laminate layer and, thereby, may be indistinguishable. *Glomus claroideum* has not earlier been found in cultivated soils of Poland. Using methods of molecular biology, Turnau et al. (2001) revealed *Gl. claroideum* in roots of *F. vesca* growing in highly Zn-contaminated heaps located near Chrzanów, southern Poland.

Glomus clarum Nicolson et Schenck

n=1: 24Pl.

Glomus clarum was revealed in only one trap culture representing *Z. mays* cultivated in Stary Chrapów.

General distribution. *Glomus clarum* has been described from spores isolated from the rhizosphere soil of *Paspalum notatum* Flugge cultivated in Florida (Nicolson and Schenck 1979).

This fungus also co-occurred with other plants cultivated in the USA (Hetrick and Bloom 1983; Miller et al. 1985; Schenck and Kinloch 1980), and South America (Schenck et al. 1984).

This paper is the first report of the occurrence of *Gl. clarum* in cultivated soils of Poland. In Poland, this fungus has earlier been found in maritime dunes (Błaszkowski 1994b) and inland dunes of the Błędowska Desert (Błaszkowski et al. 2002).

Glomus constrictum Trappe

n=43; nPl=35Sv; nSv=29; nZn=26: 1Pl, 1Zn, 2Sv, 4, 5, 5Sv, 7Zn, 15Pl, 16Pl, 21Pl, 22, 26Sv, 27Pl, 29, 29Sv, 32, 32Pl, 32Zn, 33Pl, 33Sv, 36Zn, 37Pl, 37Sv, 38Sv, 39Pl, 41, 42Zn, 43, 46Sv, 48Pl, 49Pl, 58, 61, 61Pl, 61Zn, 64Sv, 64Zn, 65Pl, 66Sv, 67, 67Pl, 67Sv, 70Pl, 70Zn, 71, 71Pl, 71Zn, 72, 72Pl, 72Zn, 73Pl, 74Zn, 76Sv, 76Zn, 77Zn, 78Sv, 79, 79Sv, 79Zn, 80, 80Sv, 81, 82, 83, 83Pl, 84Pl, 86, 86Sv, 88, 88Sv, 89Pl, 90, 90Zn, 93, 93Pl, 93Sv, 98, 98Sv, 99, 101, 102Zn, 103, 104, 106, 107, 107Sv, 107Zn, 108Pl, 109, 109Sv, 109Zn, 110, 111, 111Zn, 113Pl, 114, 114Sv, 117Zn, 118, 118Pl, 120, 120Zn, 122, 122Sv, 124, 124Pl, 124Sv, 124Zn, 125Zn, 127Pl, 127Zn, 128Pl, 129, 130, 130Pl, 131, 133Pl, 134Zn, 136Sv, 137, 139Sv, 141Pl, 144Pl, 148Zn, 149, 152, 152Sv, 155Pl, 156Sv, 157Pl, 158Pl, 162Sv.

Glomus constrictum occurred in almost 27% rhizosphere soil samples of the cultivated plants in the Western Pomerania and was more frequently found in field-collected samples than in trap cultures. This fungus was associated with all the plant species considered.

General distribution. The type of *Gl. constrictum* has been described based on spores isolated from under *Cocos nucifera* L. grown in Veracruz, Mexico (Trappe

1977). The fungus has also occurred in cultivated soils of, e. g., California (Menge et al. 1978; Trappe 1977), Florida (Nemec et al. 1981), Kansas (Hetrick and Bloom 1983), Canada (Dalpé et al. 1986), and India (Sulochama and Monoharachary 1989).

In Błaszkowski's (1993a) studies, *Gl. constrictum* was the third fungus in respect of the frequency of occurrence in cultivated soils of Poland.

Glomus deserticola Trappe, Bloss et Menge

n=124; nPl=78; nSv=77; nZn=66: 1, 2, 3, 3Zn, 4, 5, 6, 6Sv, 6Zn, 7, 8, 8Pl, 8Sv, 8Zn, 9, 10, 11, 12, 12Pl, 12Zn, 15, 16, 17, 19, 19Pl, 19Sv, 21, 22, 23, 25, 26, 27, 28, 29, 29Zn, 30, 30Zn, 31, 31Pl, 31Sv, 31Zn, 32, 32Pl, 32Sv, 32Zn, 33, 33Zn, 34, 35, 36, 37, 37Sv, 38, 38Pl, 39, 41, 42, 43, 44, 44Pl, 44Sv, 45, 45Pl, 45Sv, 45Zn, 46, 47, 49, 49Pl, 50, 50Pl, 50Sv, 51, 51Sv, 51Zn, 52, 55, 55Pl, 55Zn, 56, 58, 59, 60, 61, 61Pl, 63, 63Sv, 64, 64Pl, 64Zn, 65Pl, 65Zn, 66, 66Pl, 68Pl, 68Zn, 69, 69Sv, 70, 70Pl, 70Zn, 71Pl, 71Sv, 71Zn, 72, 72Sv, 73Zn, 74, 74Pl, 74Sv, 74Zn, 75Pl, 75Sv, 76, 76Sv, 76Zn, 77Sv, 77Zn, 78, 78Pl, 80, 80Pl, 80Zn, 81Zn, 83, 83Pl, 83Sv, 83Zn, 84, 84Pl, 84Sv, 84Zn, 85Pl, 85Sv, 85Zn, 86Sv, 86Zn, 87, 87Pl, 87Sv, 87Zn, 88, 88Pl, 88Sv, 88Zn, 89, 89Sv, 89Zn, 90, 90Pl, 90Sv, 90Zn, 91, 91Pl, 91Sv, 91Zn, 92Zn, 93, 93Sv, 94, 94Pl, 94Sv, 94Zn, 95Pl, 95Sv, 95Zn, 97Sv, 98Sv, 99Sv, 102Zn, 103, 104Pl, 104Sv, 104Zn, 105, 105Pl, 106, 106Pl, 106Sv, 107, 107Pl, 107Sv, 108, 108Pl, 108Sv, 108Zn, 109, 109Pl, 110, 110Pl, 110Sv, 110Zn, 111, 111Pl, 111Sv, 111Zn, 112, 112Pl, 112Sv, 112Zn, 113, 113Pl, 113Sv, 113Zn, 114, 114Pl, 114Sv, 114Zn, 115, 115Pl, 115Sv, 116, 116Pl, 117Pl, 118, 118Pl, 118Sv, 118Zn, 119, 119Pl, 119Sv, 119Zn, 120, 120Sv, 120Zn, 121, 121Pl, 121Sv, 122, 122Pl, 122Sv, 122Zn, 123, 123Pl, 123Sv, 124, 124Pl, 124Zn, 125, 125Pl, 125Sv, 125Zn, 126, 126Pl, 126Sv, 126Zn, 127, 127Pl, 127Sv, 128, 128Sv, 129Pl, 129Sv, 130, 131, 132Zn, 133, 133Sv, 134, 134Pl, 134Sv, 134Zn, 135, 135Pl, 135Sv, 136, 136Sv, 137Zn, 138, 138Pl, 138Sv, 138Zn, 139, 139Pl, 140, 140Pl, 140Sv, 140Zn, 141, 141Pl, 141Sv, 142, 142Pl, 142Sv, 142Zn, 143, 143Pl, 143Zn, 144, 144Pl, 145, 145Pl, 145Zn, 146, 146Pl, 146Sv, 147, 147Pl, 147Zn, 148Pl, 148Sv, 149, 150, 150Pl, 150Sv, 151, 151Pl, 151Sv, 152, 152Pl, 152Sv, 153, 153Sv, 153Zn, 154, 154Pl, 154Sv, 154Zn, 155, 155Pl, 155Sv, 155Zn, 156, 156Pl, 156Sv, 156Zn, 157, 157Pl, 157Sv, 157Zn, 158, 158Pl, 158Sv, 159, 159Pl, 159Sv, 159Zn, 160, 160Pl, 160Sv, 161, 161Sv, 161Zn, 162.

Glomus deserticola was the species of AMF most frequently found in cultivated soils of the Western Pomerania. The fungus was associated with all the plant species examined.

General distribution. *Glomus deserticola* has been described using spores recovered from different plant species colonizing the deserts in California, Arizona, and Texas (Trappe et al. 1984). There is lack of information of the occurrence of this fungus in cultivated soils located outside Poland. In Błaszkowski's (1993a) studies, *Gl. deserticola* was the second species in respect of the frequency of occurrence in cultivated soils of Poland.

Glomus dominikii Błaszk.

n=49; nPl=35; nSv=34; nZn=31: 32, 32Sv, 44, 55Zn, 56, 62, 62Pl, 62Sv, 62Zn, 63, 67, 68, 68Pl, 68Sv, 68Zn, 70Zn, 71, 72Zn, 73, 74Sv, 75Pl, 75Sv, 77, 78Pl, 78Sv, 78Zn, 79, 79Pl, 79Sv, 79Zn, 80, 80Pl, 80Sv, 80Zn, 83, 83Pl, 84, 84Pl, 84Zn, 87, 87Pl, 87Sv, 87Zn, 88Pl, 90, 91Sv, 92, 92Sv, 93, 96Zn, 97, 97Sv, 97Zn, 98Sv, 99Pl, 99Zn, 102Pl, 107, 107Pl, 111, 111Pl, 112, 112Pl, 112Sv, 114Sv, 115, 115Sv, 115Zn, 116, 116Pl, 116Sv, 116Zn, 117, 117Pl, 117Zn, 120, 120Pl, 120Sv, 120Zn, 121Sv, 122, 122Sv, 124, 124Zn, 125, 125Sv, 126, 126Pl, 127, 127Pl, 127Sv, 127Zn, 129, 129Sv, 131, 132, 132Pl, 132Sv, 132Zn, 134, 134Pl, 134Sv, 134Zn, 135, 135Pl, 135Sv, 135Zn, 136, 136Pl, 136Sv, 136Zn, 138Pl, 139, 139Pl, 139Sv, 139Zn, 140, 140Pl, 140Sv, 140Zn, 141Zn, 143Pl, 143Sv, 145, 146, 146Pl, 146Zn, 147, 149, 149Pl, 150, 150Pl, 150Sv, 150Zn, 151, 153, 153Pl, 153Zn, 155Zn, 156Pl, 157Zn, 159Pl, 162Pl.

In cultivated soils of the Western Pomerania, *Gl. dominikii* ranked fifth among the most frequently occurring fungi and was one of the eudominants. Of the ten

plant species considered, this fungus was not found to occur among roots of *Br. oleracea* and *F. vesca*.

General distribution. According to Błaszkowski (1993a), *Gl. dominikii* occurs in the whole Poland. However, the occurrence of this fungus is irregular and it seems to prefer cultivated sites. Jansa et al. (2002) suggested that sporulation of some species of AMF of cultivated soils activates agrochemical practices. Apart from Poland, this fungus has also been found in cultivated soils of Germany and Great Britain (Walker, pers. inf.).

Glomus etunicatum Becker et Gerd.

n=0; nPl=2; nSv=1; nZn=1: 5Pl, 22Pl, 39Zn, 127Sv.

The presence of *Gl. etunicatum* in cultivated soils of the Western Pomerania indicated only four trap cultures representing *Br. oleracea*, *Be. vulgaris*, *T. aestivum*, and *Z. mays*.

General distribution. *Glomus etunicatum* has originally been described based on spores isolated from the root zone of *Andropogon scoparius* Michx. and *Z. mays* cultivated in Illinois (Becker and Gerdemann 1977). Later, this fungus has been encountered in agricultural soils of Florida (Medina et al. 1988), California (Nemec et al. 1981), Kansas, Wisconsin, and Minnesota (Hetrick and Bloom 1983; Koske and Tews 1987; Pfleger and Steward 1989), as well as in orchards with *Malus domestica* Borkh. located in 18 states of the USA (Miller et al. 1985).

Remarks. According to Błaszkowski (1993a), *Gl. etunicatum* probably commonly occurs in different regions of Poland and is adapted to a wide range of plant hosts and soil conditions.

Glomus fasciculatum (Thaxter) Gerd. et Trappe emend. Walker et Koske

n=6; nPl=3; nSv=4; nZn=4: 2, 3Sv, 4Pl, 11, 12Zn, 25Sv, 29, 52, 63Sv, 74, 86, 91Sv, 93Zn, 98Zn, 111Pl, 148Zn, 149Pl.

Glomus fasciculatum was found in 17 of the 162 soil and root samples of 6 of the 10 plant species considered in this study. Spores of this fungus occurred in samples coming from both the field and trap cultures with all the plant hosts used.

General distribution. *Glomus fasciculatum* has for the first time been found on sphagnum moss in Canada (Thaxter 1922). Among roots of cultivated plants, the fungus has been found in, e. g., California and Florida (Menge et al. 1978; Schenck and Smith 1981), Germany (Land and Schönbeck 1991), India (Selvaraj and Subramanian 1979), Taiwan (Wu and Chen 1986), New Zealand (Crush 1973), and Australia (Hayman and Stovold 1979).

In Błaszkowski's (1993a) studies, *Gl. fasciculatum* was the sixth species in respect of the frequency of occurrence and the third among the eudominants of AMF of cultivated soils of Poland.

Glomus fuegianum (Spegazzini) Trappe et Gerd.

n=1; nPl=0; nSv=0; nZn=0: 39.

In studies of the authors of this study, *Gl. fuegianum* was recovered only from under *Be. vulgaris* cultivated in Stare Czarnowo.

General distribution. *Glomus fuegianum* has originally been discovered in Argentina (Thaxter 1922). There is no other literature report of the occurrence of this fungal species in cultivated soils.

Błaszkowski (1998a, 2003) found *Gl. fuegianum* in three soil and root samples collected under *Juniperus communis* L. growing in inland dunes of the Kampinos National Park.

Glomus geosporum (Nicol. et Gerd.) Walker

n=3; nPl=5; nSv=5; nZn=7: 7Zn, 9Pl, 16Pl, 16Zn, 17Sv, 20Zn, 22, 23Sv, 31Zn, 32Sv, 33Pl, 38, 39Pl, 40Sv, 50, 55Zn, 59Pl, 61Zn, 65Sv, 104Zn.

Glomus geosporum was found in 20 cultivated sites of the Western Pomerania. Of the ten plant species considered, this fungus was not revealed to occur in the root zone of *A. sativa*, *H.* vulgare, and *S. cereale*.

General distribution. *Glomus geosporum* has originally been described based on spores recovered from the rhizosphere soil of *H. vulgare* cultivated in Scotland (Nicolson and Gerdemann 1968). Later, it has been found among roots of, e. g., *Festuca* spp. cultivated in the western states of the USA and Canada (Molina and Trappe 1978), in cultivated soils of Florida (Schenck and Smith 1981), and orchards with *M. domestica* located in 18 states of the USA (Miller et al. 1985).

Błaszkowski (1993a) found *Gl. geosporum* to be the fifth species in respect of the frequency of occurrence and the third one among the dominating AMF in cultivated soils of Poland.

Glomus intraradices Schenck et Smith

n=0; nPl=0; nSv=1; nZn=1: 9Sv, 85Zn.

In the studies presented here, spores of *Gl. intraradices* were isolated from only two trap cultures representing *A. sativa* and *F. vesca* cultivated in Witnica and Kołbacz, respectively.

General distribution. *Glomus intraradices* has been described from spores isolated from under *P. notatum* cultivated in Florida (Schenck and Smith 1982), where it has been one of the arbuscular fungi most frequently found in agricultural sites (Schenck and Smith 1981, 1982). This fungus has also been recorded in cultivated soils of Kentucky (An et al. 1983), Finland (Williams et al. 1992), France (Gianinazzi-Pearson et al. 1985), and Germany (Land and Schönbeck 1991).

Glomus intraradices was not so far reported from cultivated soils of Poland. Using methods of molecular biology, Turnau et al. (2001) revealed *Gl. intraradices* in roots of *F. vesca* growing in a highly Zn-contaminated heaps located near Chrzanów.

Glomus laccatum Błaszk.

n=0; nPl=4; nSv=4; nZn=10: 19Sv, 20Zn, 31Zn, 33Zn, 34Pl, 39Zn, 40Sv, 46Sv, 46Zn, 48Zn, 52Zn, 53Pl, 53Zn, 54Sv, 129Zn, 131Pl, 136Pl, 146Sv.

In the Western Pomerania, *Gl. laccatum* was revealed only in 18 trap cultures representing six plant species cultivated in nine localities.

General distribution. No literature data exists of the occurrence of *Gl. laccatum* in cultivated soils. However, the results of both this study and those of trap cultures containing soils of different uncultivated areas (Tadych and Błaszkowski 2000; Błaszkowski 2003) indicated that *Gl. laccatum* is rather a frequently occurring arbuscular fungus in Poland.

Remarks. *Glomus laccatum* produces small and colourless spores with a delicate wall. Hence, the infrequent finding of this species in soil samples collected from the field probably resulted from the same reasons making difficulties to reveal, e. g., *Arch. trappei* (see above).

Glomus macrocarpum Tul. et Tul.

n=8; nPl=0; nSv=0; nZn=0: 9, 41, 71, 115, 125, 133, 143, 155.

In the studies discussed here, spores of *Gl. macrocarpum* were found in eight soil and root samples coming only from the field. The species occurred among roots of 6 of the 10 plant species investigated.

General distribution. *Glomus macrocarpum* has for the fist time been found in the East of the North America (Thaxter 1922). In cultivated sites, this fungus has been recorded in, e. g., many states of the USA (Hetrick and Bloom 1983; Nemec et al. 1981; Molina et al. 1978; Pfleger and Steward 1989), Grad Britain (Godfrey 1957), and Australia (Hall and Abbott 1984).

Błaszkowski (1993a, b) found spores of this fungus in 43 of the 173 rhizosphere soil samples of cultivated plants of Poland examined.

Remarks. There is no literature report of sporulation of *Gl. macrocarpum* in pot cultures.

Glomus microcarpum Tul. et Tul.

n=1; nPl=0; nSv=0; nZn=0: 140.

Sporocarps with spores of *Gl. microcarpum* were recovered only from under *T. aestivum* cultivated in Kanin.

General distribution. *Glomus microcarpum* has been described using specimens collected near Paris (Tulasne and Tulasne 1845). In cultivated sites, this fungus was present in, e. g., California (Nemec et al. 1981), Wyoming (Stahl and Christensen 1982), Kansas (Hetrick and Bloom 1983), Kentucky (An et al. 1993), Canada (Molina et al. 1978), and Australia (Hayman and Stovold 1979).

Błaszkowski (1993a, b) found *Gl. microcarpum* to occur in 11 of the 173 samples of cultivated soils examined.

Glomus mosseae (Nicol. et Gerd.) Gerd. et Trappe

n=61; nPl=88; nSv=98; nZn=108: 1, 1Pl, 1Sv, 1Zn, 2Pl, 2Zn, 3, 3Pl, 3Zn, 4Sv, 5Sv, 5Zn, 6Pl, 6Sv, 6Zn, 7Pl, 8Pl, 8Zn, 9Pl, 9Sv, 10Zn, 11Sv, 12Sv, 13, 13Pl, 13Zn, 14Pl, 14Sv, 14Zn, 15Pl, 15Sv, 15Zn, 16Pl, 16Sv, 16Zn, 17Pl, 17Sv, 18Pl, 18Sv, 18Zn, 19, 19Pl, 20, 20Pl, 20Sv, 20Zn, 21, 21Pl, 21Sv, 21Zn, 22, 22Sv, 22Zn, 23, 23Pl, 23Sv, 23Zn, 24, 24Pl, 24Sv, 24Zn, 26, 27Pl, 27Sv, 28, 28Pl, 28Sv, 28Zn, 29, 29Pl, 29Zn, 30, 30Pl, 30Sv, 30Zn, 31Pl, 32Pl, 34Pl, 34Sv, 35Zn, 36Sv, 36Zn, 37Sv, 37Zn, 38Sv, 38Zn, 39Zn, 40Pl, 40Sv, 40Zn, 41, 41Pl, 41Sv, 41Zn, 42Sv, 43Pl, 43Sv, 44Pl, 44Sv, 45Pl, 45Sv, 45Zn, 46, 46Pl, 46Zn, 47, 47Zn, 48, 48Pl, 48Sv, 48Zn, 49Sv, 50Pl, 50Sv, 51Sv, 52Pl, 52Sv, 52Zn, 54Pl, 54Sv, 54Zn, 55Pl, 55Sv, 56Pl, 56Sv, 56Zn, 57Sv, 57Zn, 58Pl, 59Sv, 60, 60Pl, 60Sv, 61, 61Sv, 63Zn, 64, 64Zn, 65Zn, 66Pl, 66Sv, 66Zn, 67, 68, 68Sv, 68Zn, 69, 70, 70Pl, 70Zn, 73, 73Pl, 73Zn, 74Pl, 75, 75Zn, 76, 76Pl, 77, 77Sv, 78, 78Zn, 79, 79Sv, 79Zn, 81Zn, 83, 83Sv, 83Zn, 85Zn, 88, 89Zn, 90, 90Sv, 90Zn, 91, 91Sv, 91Zn, 92Sv, 93, 93Sv, 94Sv, 95, 95Zn, 96Pl, 96Zn, 97, 97Zn, 98, 99Pl, 100Zn, 101, 101Zn, 102, 102Sv, 103, 104Sv, 104Zn, 105, 105Sv, 105Zn, 106, 106Pl, 106Sv, 106Zn, 107Pl, 107Zn, 108Pl, 108Sv, 108Zn, 109Sv, 109Zn, 110, 110Zn, 111Sv, 111Zn, 112Pl, 112Zn, 113, 113Pl, 113Sv, 113Zn, 114, 114Pl, 114Sv, 114Zn, 115Pl, 115Zn, 116Pl, 116Sv, 117, 117Pl, 117Sv, 117Zn, 118Pl, 118Zn, 119Pl, 119Sv, 119Zn, 120, 120Pl, 120Sv, 120Zn, 121, 121Pl, 121Sv, 121Zn, 122, 122Sv, 122Zn, 123, 123Sv, 123Zn, 124Pl, 124Sv, 124Zn, 125Pl, 125Zn, 126, 126Pl, 126Zn, 127Pl, 127Sv, 127Zn, 128, 128Pl, 128Sv, 128Zn, 129, 130Pl, 130Sv, 130Zn, 131Pl, 131Sv, 131Zn, 132Pl, 132Sv, 132Zn, 133Pl, 134Pl, 134Sv, 134Zn, 135Pl, 135Sv, 135Zn, 136Sv, 137Sv, 137Zn, 138Pl, 138Sv, 138Zn, 139Pl, 139Sv, 139Zn, 140, 140Sv, 141Pl, 141Zn, 142Pl, 142Sv, 143Pl, 143Sv, 143Zn, 144, 144Sv, 144Zn, 145, 145Pl, 145Sv, 145Zn, 146Pl, 146Sv, 146Zn, 147Pl, 147Sv, 147Zn, 148, 148Pl, 148Sv, 148Zn, 149, 149Zn, 150Pl, 150Sv, 150Zn, 151Sv, 151Zn, 152Pl, 152Sv, 152Zn, 153Pl, 153Sv, 153Zn, 154Pl, 154Zn, 155Zn, 156Sv, 156Zn, 158Pl, 158Sv, 158Zn, 159, 159Pl, 159Sv, 159Zn, 160Pl, 160Sv, 160Zn, 161, 161Pl, 161Sv, 161Zn, 162Pl, 162Sv, 162Zn.

In the cultivated soils of the Western Pomerania, *Gl. mosseae* ranked second in respect of the frequency of occurrence and one of the dominants among the species of AMF revealed. It accompanied all the cultivated plant species compared.

General distribution. The holotype of *Gl. mosseae* comes from under *T. aestivum* cultivated in Scotland (Nicolson and Gerdemann 1968). *Glomus mosseae* is one of the species of AMF most frequently listed in the literature. In cultivated sites, spores of this fungus have been found in, e. g., many states of the USA (An et al. 1993; Nemec et al. 1981; Schenck and Smith 1981; Stahl and Christensen 1982; Hetrick and Bloom 1983; Miller et al. 1985), Canada (Hamel et al. 1994; Talukdar and Germida 1993), France (Gianinazzi-Pearson et al. 1985), Germany (Land and Schönbeck 1991), Finland (Vestberg 1995), India (Sulochama and Monoharachary 1989), and Australia (Hayman and Stovold 1979).

Błaszkowski's (1993a) studies showed that *Gl. mosseae* was the species most frequently occurring and the second among the eudominants in cultivated sites of Poland.

Glomus spurcum Pfeiffer et al. emend. Kennedy et al.

n=0; nPl=1; nSv=0; nZn=2: 10Zn, 29Pl, 37Zn.

Only three trap cultures representing *Be. vulgare* and *T. aestivum* revealed *Gl. spurcum* in three cultivated sites of the Western Pomerania.

General distribution. *Glomus spurcum* has originally been described from spores isolated from a greenhouse bed of sand used for propagation of various ornamental plants cultivated in Arizona (Pfeiffer et al. 1996).

The only literature report of the presence of *Gl. spurcum* among roots of agricultural plants is that of Błaszkowski et al. (2003).

Glomus verruculosum Błaszk.

n=0; nPl=0; nSv=0; nZn=1: 3Zn.

Spores of *Gl. verruculosum* were revealed only in one trap culture containing a mixture of rhizosphere soil and roots of *Be. vulgare* cultivated in Stare Czarnowo.

General distribution. *Glomus verruculosum* has been described based on spores isolated from under *Glyceria aquatica* (L.) Wahlb. growing at the sandy bank of the Odra river in Szczecin (Błaszkowski and Tadych 1997).

This paper is the first report of the occurrence of *Gl. verruculosum* in a cultivated site.

Paraglomus occultum Walker

n=0; nPl=1; nSv=2; nZn1: 28Sv, 32Zn, 48Sv, 146Pl.

The presence of *P. occultum* in cultivated soils of the Western Pomerania confirmed only four trap cultures with soil and root mixtures taken from under *Be. vulgare*, *T. aestivum*, and *Z. mays*.

General distribution. The holotype of *P. occultum* comes from spore populations recovered from the rhizosphere soils of *Populus* spp. and associated grasses growing in a nursery in Iowa, USA (Walker 1982). Subsequently, the fungus has sporadically been revealed among roots of *M. domestica* cultivated in 18 states of the USA (Miller et al. 1985), as well as *Glyci. max* and *Z. mays* produced in Pennsylvania (Douds et al. 1993).

Błaszkowski (1993a) isolated spores of *P. occultum* from 10 samples of cultivated soils of Poland.

Scutellospora dipurpurescens Morton et Koske

n=15; nPl=7; nSv=7; nZn=1: 14Sv, 19, 30, 32, 56Pl, 63, 68, 71, 71Pl, 71Zn, 76Sv, 79, 80, 80Pl, 80Sv, 88, 102Sv, 107, 113, 119, 122Pl, 124Pl, 130Sv, 136, 141Pl, 143, 143Sv, 150Sv, 158, 159Pl.

Scutellospora dipurpurescens was revealed in 30 sites, in which six plant species were cultivated. This fungus markedly more frequently sporulated in the field conditions than in trap cultures. The lack of or low sporulation of *Scu. dipurpuresens* in trap cultures probably resulted from (1) the exclusion or suppression of the fungus 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 fungus (Brundrett et al. 1999a, b; Jansa et al. 2002).

General distribution. The type of *Scu. dipurpurescens* comes from a natural site of West Virginia, where it has also been revealed in cultivated soils (Morton and Koske 1988).

According to Błaszkowski (1993a, 1994a), *Scu. dipurpurescens* is widely distributed in Poland, although it prefers uncultivated sites. This fungus is the most frequently occurring member of the genus *Scutellospora* in Poland.

Remarks. Despite the lack of literature reports, *Scu. dipurpurescens* probably is widely distributed in the world. A large part of reports of the finding of *Scu. calospora* (Nicol. et Gerd.) Walker et Sanders probably regards *Scu. dipurpurescens*.

The two species are indistinguishable under a dissecting microscope and difficult to recognize when examined under a compound microscope.

Scutellospora pellucida (Nicol. et Schenck) Walker et Sanders

n=2; nPl=0; nSv=0; nZn=0: 76, 79.

In the studies presented here, spores of *Scu. pellucida* occurred only in two field-collected samples collected under *S. cereale* and *T. aestivum* cultivated in Kierzkowo and Derczewo, respectively.

General distribution. *Scutellospora pellucida* has originally been described from spores recovered from under *Glyci. max* grown in Florida (Nicolson and Schenck 1979), where the fungus has also been found among roots of other cultivated plant species (Schenck and Kinloch 1980). Additionally, *Scu. pellucida* has been encountered in the root zone of *T. aestivum* cultivated in Kansas (Hetrick and Bloom 1983), sporadically under *M. domestica* growing in orchards of 18 states of the USA (Miller et al. 1985), in many cultivated sites of the Central and South America (Sieverding 1989), and in Japan (Saito and Vargas 1991).

In Poland, Błaszkowski (1993a) found *Scu. pellucida* in five cultivated sites.

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Grzyby i mikoryzy arbuskularne gleb rolniczych województwa zachodniopomorskiego II. Rozmieszczenie grzybów arbuskularnych

Streszczenie

Niniejsza, druga część artykułu o arbuskularnych grzybach mikoryzowych z gromady Glomeromycota gleb rolniczych województwa zachodniopomorskiego przedstawia rozmieszczenie 26 gatunków tych grzybów w zarówno stanowiskach uwzględnionych w niniejszym studium, jak i glebach uprawnych innych regionów Polski i świata zbadanych wcześniej. Grzyby te wyizolowano z mieszanin gleby ryzosferowej i korzeni zebranych z pola oraz kultur pułapkowych założonych z części każdej próby polowej i obsianych trzema gatunkami roślin gospodarzy. Wśród scharakteryzowanych gatunków, 18 pochodzi z rodzaju *Glomus*, po jednym z rodzajów *Archaeospora*, *Entrophospora* i *Paraglomus*, oraz trzy i dwa z rodzajów odpowiednio *Acaulospora* i *Scutellospora*.