MYCORRHIZAL STATUS OF PLANTS IN TWO SUCCESSIONAL STAGES ON SPOIL HEAPS FROM FIRELOAM MINING IN LOWER SILESIA (SW POLAND)

DOROTA KASOWSKA

Department of Botany and Plant Physiology, University of Agriculture
Cybulskiego 32, 50-205 Wrocław, Poland
e-mail: dkas@ozi.ar.wroc.pl

(Received: April 26, 2001. Accepted: October 23, 2001)

ABSTRACT

The mycorrhizal status of two plant communities representing an initial stage (1-2 year-old) and a 8-9-year-old stage of succession on spoil heaps from fireloam mining in Lower Silesia, Poland, was determined. In the initial stage, the mycorrhizal structures were not observed in 39% of the investigated species; they were members of the Polygonaceae, Chenopodiaceae and Poaceae families. The relative cover of non-mycorrhizal plants exceeded 50% and the major role was played by the *Polygonum aviculare* population, which predominated the whole community. Mycorrhizal species (arbuscular mycorrhizae) contributed to 61% of the composition of the initial phytocoenosis. The most numerous taxa were those with 20-40% of the root length colonized, with a small number of arbuscules (0.2-3.1% of the root length containing arbuscules) and no vesicles. In the advanced stage of succession, mycorrhizal plants definitely dominated and the major role was played by the *Tussilago farfara* population. Compared with the initial stage, the later one also harboured more plants with mycorrhizas occupied >40% of the root length, as well as containing numerous arbuscules (>20% of the root length) and vesicles. The non-mycorrhizal species, i.e., *Equisetum arvense* and *Poa compressa*, represented 11% of the community composition and their relative cover amounted to 3%.

Despite the relatively frequent occurrence of the arbuscular mycorrhizae in the initial stage of succession, the qualitative properties of the colonization indicated a low effectiveness of symbiosis. This could be caused by the lack of adaptation of the fungal symbiont to the edaphic conditions which were changed after disturbance.

KEY WORDS: arbuscular mycorrhiza, mycorrhizal colonization, succession, mine spoil.

INTRODUCTION

Arbuscular mycorrhizae are commonly present in a wide range of different biotopes (Read et al. 1976; Trappe 1987). Only some habitats harbour plant communities with a high proportion of non-mycorrhizal plants. These mainly are very wet or arid, exceptionally rich in nutrients, and highly disturbed habitats, particularly those in the early stages of succession (Smith and Read 1997).

Investigations of the occurrence of arbuscular mycorrhizae in the early stages of colonization of disturbed areas carried out in different ecosystems has yielded contrasting results, and the role of the mycorrhizas in successional processes remains unclear. The classic theory of Janos (1980) assumes that the early successional stages are colonized by non-mycorrhizal or facultatively mycorrhizal plant species. Then, with elapsing time and with an influx of propagules of mycorrhizal fungi, the establishment of plants obligatively dependent on mycorrhiza becomes possible. These kinds of plants dominate in the later stages of the succession. This hypothesis was verified by Allen and

Allen (1990), who suggested that the mycorrhizal status of plants present in early seral stages depends on environmental conditions, i.e. the type of disturbance, nutrient availability and moisture of the habitat. However, in contradiction to the classical theories, some investigations indicate that the obligate mycorrhizal plants are present and also play an important role in the initial stages of succession. Koske and Polson (1984) as well as Gemma and Koske (1992) found arbuscular fungi and their mycorrhizae in the earliest stages of primary succession. These authors suggested that habitat stabilization and the subsequent development of communities were dependent on the presence of mycorrhizal associations.

The disturbed ecosystems which appear as a consequence of strip-mining are characterized by a high level of degradation, since the soil profile and the vegetation, as well as associated mycorrhizae are destroyed. This leads to the total elimination of or a substantial reduction in the viable inoculum capable of initiating mycorrhizal infection in plants colonizing the affected areas (Khan 1978; Miller 1979; Moorman and Reeves 1979; Allen and Allen 1980;

Jasper et al. 1992). This may influence the species composition of plant communities appearing in the early stages of succession, since the low infection potential of the soil may prevent the establishment of species dependent on mycorrhiza (Reeves et al. 1979; Janos 1980). Plants growing in mine spoils frequently become colonized (Daft and Nicolson 1974; Khan 1978; Miller 1979; Reeves et al. 1979; Allen and Allen 1980; Pendleton and Smith 1983; Pawłowska et al. 1996) and the intensity of colonization increases with the vegetation and soil development (Reeves et al. 1979; Allen and Allen 1980). The time in which mycorrhizal colonization reaches the level of that of non-disturbed areas depends on climatic conditions. In dry ecosystems, recovery to the state before disturbance is slow (Reeves et al. 1979; Allen and Allen 1980; Janos 1980), whilst in temperate situations this process is faster (Wamer 1983; Medve 1984).

The aim of the present investigations was to determine the mycorrhizal status of plants in the two stages of colonization of spoil heaps from a fireloam mine located in the Lower Silesia region (south-western Poland).

MATERIALS AND METHODS

Site description

The investigated spoil heaps are situated on the excavation of a fireloam strip-mine located close to the village of Jarosłów (59°59' N, 16°25' E) in the Lower Silesia region, Poland. They were created in the years 1986 and 1993 from the cap-rock of the fireloam deposits, composed of sands, gravel, Pleistocene and Miocene loams, as well as of clays and brown coal inserts (Kostecki 1961). These formed substrates, at the depth corresponding to the plant rooting zone, had the granulometrical composition of a sandy loam (Table 1). The soil forming process was weakly marked and the soil profiles were not differentiated into horizons. Some of the chemical properties of the soils are summarized in Table 1.

The vegetation of the spoil heaps has formed as a result of natural colonization and revegetation processes of the substrate composed of deeper geological layers, which were initially without plant cover. Therefore, this vegetation represented the early stages of the primary succession. The initial phytocoenosis (1-2nd year of the overgrowth), in which the major role was played by *Polygonum aviculare*, was mainly composed of ruderal species (Table 2). The following stage of succession (8-9-year-old) consisted of ruderal, grassland and sward vegetation; it was dominated by *Tussilago farfara* (Table 4).

Soil analysis

Samples for laboratory analysis were taken from the top layer, down to the plant rooting zone (0-25 cm). Soil gran-

TABLE 2. Absolute and relative cover of plant species recorded in the initial stage of succession (1-2-year-old) on spoil heaps from a fireloam mine in Lower Silesia. Species with an absolute cover <0.1% were omitted.

Species	Absolute cover %	Relative cover %
Non-mycorrhizal		
<i>Polygonum aviculare</i>	7.2	47.7
<i>Agrostis stolonifera</i> subsp. <i>stolonifera</i>	0.3	2.0
<i>Rumex crispus</i>	0.1	0.7
Mycorrhizal		
<i>Tussilago farfara</i>	3.1	20.5
<i>Cirsium arvense</i>	1.7	11.2
<i>Matricaria maritima</i> subsp. <i>inodora</i>	1.3	8.6
<i>Calamagrostis epigejos</i>	0.5	3.3
<i>Artemisia vulgaris</i>	0.3	2.0
<i>Senecio viscosus</i>	0.2	1.3
<i>Agropyron repens</i>	0.2	1.3
<i>Potentilla anserina</i>	0.1	0.7
<i>Lotus corniculatus</i>	0.1	0.7
Total	15.1	100

ulometrical composition was assessed by the Casagrande method with the Prószyński modification (Lityński et al. 1976). Soil pH was measured using a combination electrode (Lityński et al. 1976). Organic C was determined by the Tiurin method (Lityński et al. 1976). Total N and P were analyzed by colorimetric methods after digesting according to Nelson and Sommers (1980). Extractable P was measured by means of the Watanabe and Olsen method (1962).

Plant cover

The species composition of plant communities and the absolute cover of particular species were registered in the years 1994 and 1995 (in August), in 50 randomly selected square plots, each of an area of 1 m². The values of the absolute cover were estimated visually and expressed in percent (Pakarinen 1984). For each species, the average cover and the relative cover (as a percentage contribution to the total plant cover) were calculated.

Root sampling and mycorrhizal assessment

In the years 1994 and 1995 (in August), at least 5 individuals of each herbaceous species were excavated with an almost entire root system. The roots were rinsed with water and the fine lateral fragments were cut off and pooled. Samples were stored in 50% ethanol. Clearing and staining were carried out according to the modified Phillips and Hayman (1970) method. The root fragments were cleared in 10% KOH for 1 hour at 90°C. Strongly pigmented samples were bleached in an alkaline solution of H₂O₂. After rinsing with distilled water and acidification in diluted

TABLE 1. Chemical and physical properties of spoil heap substrates from a fireloam mine in Lower Silesia assessed at the plant rooting zone (0-25 cm depth).

Substrate	pH		C _{org.} %	N _{total} %	P _{total} g/kg	P _{extr.} mg/kg	Sand %	Silt %	Clay %
	H ₂ O	KCl							
1-2-year-old spoil heap	7.11	6.98	0.95	0.02	0.15	0.06	47	22	31
8-9-year-old spoil heap	6.14	5.82	3.40	0.09	0.15	0.08	52	16	32

TABLE 3. Mycorrhizal status of plants growing in the initial stage of succession (1-2-year-old) on spoil heaps from a fireloam mine in Lower Silesia. Species ordered by families. Values listed are means $\pm$ SE (n = 3) (A – arbuscules, V – vesicles, AC – arbuscular colonization, VC – vesicular col., HC – hyphal col.).

Family	Plant species	Mycorrhizal structure	Percentage of root length colonized		
			AC	VC	HC
Polygonaceae	<i>Polygonum aviculare</i> L.	absent			
	<i>Polygonum lapathifolium</i> L. subsp. <i>pallidum</i> (With.) Fr.	absent			
	<i>Rumex crispus</i> L.	absent			
Chenopodiaceae	<i>Chenopodium album</i> L.	absent			
Rosaceae	<i>Potentilla anserina</i> L.	VA	24.0 $\pm$ 4.4	22.9 $\pm$ 3.9	54.9 $\pm$ 1.9
Fabaceae	<i>Lotus corniculatus</i> L.	VA	62.7 $\pm$ 3.7	22.2 $\pm$ 5.1	81.8 $\pm$ 2.5
Apiaceae	<i>Pastinaca sativa</i> L.	A	27.3 $\pm$ 1.4	absent	50.1 $\pm$ 2.1
Asteraceae	<i>Achillea millefolium</i> L.	A	1.1 $\pm$ 0.2	absent	21.1 $\pm$ 3.6
	<i>Artemisia vulgaris</i> L.	A	1.3 $\pm$ 0.8	absent	37.2 $\pm$ 5.2
	<i>Cirsium arvense</i> (L.) Scop.	A	2.8 $\pm$ 1.2	absent	35.2 $\pm$ 2.6
	<i>Matricaria maritima</i> L., subsp. <i>inodora</i> (L.)	A	3.1 $\pm$ 1.7	absent	32.1 $\pm$ 4.2
	<i>Senecio viscosus</i> L.	A	16.9 $\pm$ 2.3	absent	40.5 $\pm$ 1.9
Poaceae	<i>Tussilago farfara</i> L.	A	0.4 $\pm$ 0.4	absent	30.5 $\pm$ 3.0
	<i>Agropyron repens</i> (L.) P. Beauv.	A	0.2 $\pm$ 0.2	absent	26.4 $\pm$ 5.8
	<i>Agrostis capillaris</i> L.	absent			
	<i>Agrostis stolonifera</i> L. subsp. <i>stolonifera</i>	absent			
	<i>Calamagrostis epigejos</i> (L.) Roth	A	0.2 $\pm$ 0.1	absent	12.4 $\pm$ 1.9
	<i>Lolium perenne</i> L.	absent			

HCl, the roots were stained with 0.05% trypan blue in lactoglycerole at room temperature for 48 hours.

The colonization of roots by mycorrhizal hyphae was examined using a dissecting microscope at magnification $\times$ 240 according to the method of McGonigle et al. (1990). 150 observations were made for each of three subsamples. The degree of root colonization was expressed as the percentage of root length containing arbuscules (AC – arbuscular colonization), vesicles (VC – vesicular colonization) and hyphae (HC – hyphal colonization).

TABLE 4. Absolute and relative cover of plant species recorded in the 8-9-year-old stage of succession on spoil heaps from a fireloam mine in Lower Silesia. Species with an absolute cover <0.1% were omitted.

Species	Absolute cover %	Relative cover %
Non-mycorrhizal		
<i>Poa compressa</i>	0.4	1.9
<i>Equisetum arvense</i>	0.2	1.0
Mycorrhizal		
<i>Tussilago farfara</i>	9.3	44.9
<i>Lotus corniculatus</i>	2.4	11.6
<i>Poa angustifolia</i>	2.2	10.6
<i>Trifolium arvense</i>	2.0	9.7
<i>Trifolium hybridum</i>	1.7	8.2
<i>Lolium perenne</i>	0.5	2.4
<i>Calamagrostis epigejos</i>	0.5	2.4
<i>Cirsium arvense</i>	0.5	2.4
<i>Vicia tetrasperma</i>	0.3	1.4
<i>Matricaria maritima</i> subsp. <i>inodora</i>	0.2	1.0
<i>Artemisia vulgaris</i>	0.2	1.0
<i>Carduus acanthoides</i>	0.1	0.5
<i>Agrostis capillaris</i>	0.1	0.5
<i>Taraxacum officinale</i>	0.1	0.5
Total	20.7	100

RESULTS

The total plant cover in the initial succession stage (1-2-year-old) amounted to approximately 15% (Table 2). In the composition of the investigated community 18 species were noted, including 7 taxa of non-mycorrhizal plants belonging to the families Polygonaceae, Chenopodiaceae and Poaceae (Table 3). The contribution of non-mycorrhizal species to the relative cover exceeded 50%. Among these plants, the main role was played by the *Polygonum aviculare* population, which dominated the whole community (Table 2).

Mycorrhizal plants of the initial succession stage comprised 61% of the recorded species and their contribution to the relative cover amounted to approximately 49% (Tables 2, 3). Species with the infection level of 20-40% of the hyphal colonization represented the most numerous group of 6 taxa, whose total contribution to the relative cover amounted to roughly 44%. In *Lotus corniculatus*, *Potentilla anserina*, *Pastinaca sativa* and *Senecio viscosus*, the root length containing hyphae exceeded 40%. However, the relative cover of that plant group was very small and amounted to 2.7%. Only for the 3 species with the highest hyphal colonization level, the abundance of arbuscules (AC), whose presence indicates functional symbiosis, did exceed 20%. For 7 mycorrhizal plants, the arbuscular colonization level was very low, ranging from 0.2 to 3.1%. Vesicles were only observed in *Lotus corniculatus* and *Potentilla anserina*.

In the advanced stage of succession (8-9-year-old), the total ground cover of the naturally developing plant community amounted to approximately 21% (Table 4). The number of the recorded species remained at the same level as in the initial stage, but the quantitative and qualitative composition of the two communities compared changed (Tables 3, 5). In the composition of the later phytocoenosis, none of the 5 non-mycorrhizal plants present in the initial stage was recorded. Mostly, they were members of the Polygonaceae and Chenopodiaceae. Mycorrhizae were not

TABLE 5. Mycorrhizal status of plants growing in the 8-9-year-old stage of succession on spoil heaps from a fireloam mine in Lower Silesia. Species ordered by families. Values listed are means $\pm$ SE (n = 3) (A – arbuscules, V – vesicles, AC – arbuscular colonization, VC – vesicular col., HC – hyphal col.).

Family	Plant species	Mycorrhizal structure	Percentage of root length colonized		
			AC	VC	HC
Equisetaceae	<i>Equisetum arvense</i> L.	absent			
Fabaceae	<i>Lotus corniculatus</i> L.	VA	63.5 $\pm$ 5.4	22.7 $\pm$ 1.4	84.2 $\pm$ 6.5
	<i>Trifolium arvense</i> L.	VA	48.4 $\pm$ 3.8	14.4 $\pm$ 1.2	72.4 $\pm$ 6.3
	<i>Trifolium hybridum</i> L.	VA	33.6 $\pm$ 3.0	22.2 $\pm$ 1.9	40.2 $\pm$ 3.6
	<i>Vicia tetrasperma</i> (L.) Schreb.	A	21.5 $\pm$ 1.4	absent	23.8 $\pm$ 2.1
	<i>Plantago lanceolata</i> L.	A	24.4 $\pm$ 1.7	absent	31.8 $\pm$ 2.9
Plantaginaceae	<i>Plantago lanceolata</i> L.	A	24.4 $\pm$ 1.7	absent	31.8 $\pm$ 2.9
Asteraceae	<i>Artemisia vulgaris</i> L.	VA	10.2 $\pm$ 0.9	3.6 $\pm$ 0.2	27.3 $\pm$ 2.5
	<i>Carduus acanthoides</i> L.	A	15.4 $\pm$ 1.3	absent	31.6 $\pm$ 2.8
	<i>Cirsium arvense</i> (L.) Scop.	VA	29.6 $\pm$ 2.6	8.4 $\pm$ 0.7	54.1 $\pm$ 4.7
	<i>Matricaria maritima</i> L., subsp. <i>inodora</i> (L.)	A	11.3 $\pm$ 0.8	absent	27.3 $\pm$ 2.4
	<i>Taraxacum officinale</i> F.H. Wigg.	VA	45.3 $\pm$ 3.6	12.0 $\pm$ 0.9	58.7 $\pm$ 5.1
Poaceae	<i>Tussilago farfara</i> L.	VA	20.0 $\pm$ 1.5	8.0 $\pm$ 0.3	33.8 $\pm$ 3.0
	<i>Agropyron repens</i> (L.) P. Beauv.	VA	5.6 $\pm$ 0.7	16.7 $\pm$ 1.0	42.0 $\pm$ 3.6
	<i>Agrostis capillaris</i> L.	A	22.0 $\pm$ 1.7	absent	32.9 $\pm$ 3.0
	<i>Calamagrostis epigejos</i> (L.) Roth	VA	18.2 $\pm$ 1.6	4.6 $\pm$ 0.3	26.9 $\pm$ 2.3
	<i>Lolium perenne</i> L.	VA	34.0 $\pm$ 3.1	3.8 $\pm$ 201	51.4 $\pm$ 4.8
	<i>Poa angustifolia</i> L.	A	34.7 $\pm$ 2.8	absent	34.9 $\pm$ 3.2
	<i>Poa compressa</i> L.	absent			

found in only *Equisetum arvense* and *Poa compressa*, which represented 11% of the community composition. The relative cover of the non-mycorrhizal plants clearly decreased compared with that of the initial stage and amounted to 3%.

Mycorrhizal species clearly dominated the 8-9-year-old stage of the spoil heaps revegetation. This group constituted 89% of the community composition and its relative cover amounted to roughly 97% (Tables 4, 5). Besides the mycorrhizal plants recorded already in the initial stage, new species with the arbuscular mycorrhizae entered into the composition of the later phytocoenosis. They were members of the Fabaceae, Asteraceae and Poaceae. The presence of mycorrhizal structures was also found in roots of *Agrostis capillaris* and *Lolium perenne*, which were non-mycorrhizal in the initial stage. The most numerous group was composed of species with the hyphal colonization level in the range of 20-40%, its relative cover amounted to 62%. The population of *Tussilago farfara*, belonging to this group, strongly dominated the whole community. Species with the HC exceeding 40% were numerously represented (7 taxa). The contribution of this group to the relative cover amounted to 35%. Compared with the mycorrhizal colonization of plants of the initial stage, the mycorrhizal hyphae in roots of plants of the advanced stage were also much frequently accompanied by numerous arbuscules (>20% of the root length occupied by arbuscules) and vesicles.

DISCUSSION

The vegetation of the spoil heaps from the fireloam mine was developing as a result of a spontaneous succession on a substrate of anthropogenic origin. The material used for the formation of heaps was initially without plant cover and soil horizons, which determined low concentrations of major nutrients. This created unfavourable conditions for revegetation, since nutrient stress is one of the main factors limiting plant establishment and development, as well as

inhibiting the successional dynamics on disturbed areas (Bradshaw 1983).

Changes of the floristic composition of plant communities proceeding in the course of succession are fastest in the earliest stages, whereas in the later stages the species exchange rate is lower (Grime 1979). Thus, the characteristic feature of the early succession stages is a non-stabilized species composition. In the investigated successional series, some differences in the floristic composition of the compared phytocoenoses occurred. They resulted from a retreat of typically non-mycorrhizal ruderals (i.e., the members of the Polygonaceae and Chenopodiaceae), which were present only in the initial stage, and from a settling of the mycorrhizal perennials (i.e., papilionaceous plants and sward of loamy soil species, for example *Poa angustifolia*, *P. compressa*) playing an increasing role in the following stage of succession. Ruderal species are the first colonizers of bare substrates in many disturbed ecosystems. However, their settling and creation of stable populations need a high nutrient availability. Therefore, it seems that in conditions of nutrient stress, which was found in the investigated spoil heaps, ruderal plants had no opportunities to achieve permanent success. According to Grime (1979), the biological characteristics of ruderal species predestine them for the colonization of heavily disturbed areas, but at the same time, these features make them sensitive to competition from plants entering the habitat after the decrease of the disturbance intensity. As soon as the influence of the disturbing factors are limited, the spread of mycorrhizal mycelium in the soil and host plant roots becomes possible. Presence of mycorrhizae may affect relations between coexisting species. According to Allen (1991), the mycorrhizae change the competitive outcomes between plants with a different mycorrhizal status by increasing the competitive ability of the species dependent on mycorrhizal fungi. The mycelium of arbuscular fungi developing in the soil may also have a direct antagonistic influence on the development of non-mycorrhizal plants, as indicated by the investigations of Allen et al. (1989) as well as Francis and Read (1994).

In the investigated succession series, together with the changes in the floristic composition of phytocoenoses compared, the mycorrhizal status of the community dominants changed. In the initial stage, the dominant species was *Polygonum aviculare*, for which no mycorrhiza was observed. In the following succession stage, *Tussilago farfara* with the arbuscular type of symbiosis played the major part in the community. A different mycorrhizal status of vegetation in the initial and later stages of succession has already been indicated in many investigations concerning both primary and secondary succession (Dominik 1951; Nicolson 1960; Reeves et al. 1979; Miller 1979). As is commonly regarded, the reason of the dominance of non-mycorrhizal species in the earliest phases of bare area colonization is the limited inoculum potential of the substrate (Miller 1979; Reeves et al. 1979; Allen 1991).

The contribution of the mycorrhizal plants to the initial community on the investigated spoil heaps seems to be high (61% of the noted species and 50% of the relative cover) in comparison with data for other phytocoenoses in the earliest succession stages. Dominik (1951), who investigated succession on coastal dunes, did not reveal any presence of endomycorrhiza in a foredune plant association. Only 1% of the mycorrhizal plant cover was found by Reeves et al. (1979) in a severely disturbed sagebrush community in semi-arid conditions. On the other hand, Medve (1984) observed the presence of arbuscular symbiosis in as many as 93% of species with 92% of the total cover in a *Solidago-Aster* community one year after its disturbance. The occurrence of mycorrhizal plants in the initial stage of succession on the spoil heaps from a fireloam mine probably resulted from the presence of arbuscular fungi propagules in the substrate. Is it commonly accepted that the source of the mycorrhizal infection could be spores, infected root fragments, as well as external hyphae growing in the soil. These elements may be spread by wind and water, as well as by invertebrates, birds and mammals (Koske and Gemma 1990; Friese and Allen 1993). The source of propagules are most frequently neighboring areas. The localization of the spoil heaps beneath a surrounding land certainly simplified and accelerated the migration of arbuscular mycorrhizal propagules.

In the advanced stage of succession, represented by a community dominated by *Tussilago farfara*, the group of mycorrhizal plants amounted to 89% of species composition and made up 97% of the relative cover. Similar contributions of the mycorrhizal plants to the community composition, equal to 85% and 94%, respectively, were found by Khan (1978) as well as Daft and Nicholson (1974) in early stages of succession on coal wastes. These values are also similar to the contribution of the mycorrhizal plants to the semi-natural grassland communities investigated by Read et al. (1976).

Many plant species growing in the initial stage of succession harboured mycorrhizae. However, compared with the mycorrhizal colonization coming from the advanced stage of spoil heap revegetation, that from the initial stage was characterized by a small number of arbuscules and a lack of vesicles. This may be important for the colonization effectiveness assessment, since the arbuscules are commonly regarded as sites for nutrient exchange between symbionts (especially as places for phosphorus transfer from the hyphae to the host plant). For that reason, a sparse

formation of these structures may suggest a malfunction of the symbiosis. A lower level of mycorrhizal colonization in disturbed areas, in comparison to the natural ecosystems or later successional stages, had already been revealed in many investigations (Allen and Allen 1980; Loree and Williams 1987; Pawłowska et al. 1996). However, only a small number of papers was concerned with the estimation of the qualitative characteristics of the infection. This problem had been indicated by Lovera and Cuenca (1996), who found a decreased number of arbuscules and vesicles in tropical savannas after a disturbance, despite a high infection frequency in early successional plant communities. It is known that the level and structure of colonization is determined by many factors, for example: genotype of plant and fungal symbiont, the type and density of inoculum, the level of vegetation development or availability of nutrients in soil (Smith and Read 1997). According to Morton (1988), the presence of vesicles is dependent on features of the fungal symbiont. Some arbuscular fungi do not produce any vesicles as a rule, whereas for others, (e.g. for species of *Glomus*), the creation of vesicles is determined by some favorable conditions dependent on the physiology of the host plant (Abbott and Robson 1979). An atypical picture of the mycorrhiza observed on the investigated spoil heaps in the initial stage of the succession could result from the presence in plant roots of an ineffectively functioning fungal symbiont. Its lower efficiency could be caused by a lack of adaptation to edaphic conditions changed by the disturbance. This seems to be probable in the face of the low species diversity of arbuscular fungi in the initial succession stages, which was revealed in some investigations (Nicolson and Johnston 1979; Allen et al. 1987), and of their physiological variety, which exhibits itself by the different reactions of species or isolates to the impact of abiotic factors (Brundrett 1991).

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STATUS MIKORYZOWY ROŚLIN DWÓCH STADIÓW SUKCESJI
NA ZWAŁOWISKACH NAKŁADU KOPALNI IŁÓW OGNIOTRWAŁYCH
NA DOLNYM ŚLĄSKU

STRESZCZENIE

Określono status mikoryzowy zbiorowisk roślinnych reprezentujących inicjalne (1-2 rok zarastania) i późniejsze (8-9-letnie) stadium sukcesji, przebiegającej na zwałowiskach nakładu kopalni iłów ogniotrwałych na Dolnym Śląsku. W stadium inicjalnym obecności mikoryzy nie stwierdzono u 39% odnotowanych gatunków; byli to przedstawiciele rodzin: Polygonaceae, Chenopodiaceae i Poaceae. Udział roślin niemikoryzowych w pokryciu powierzchni przekraczał 50%, w tym największą rolę odgrywała populacja *Polygonum aviculare*, dominująca w całym zbiorowisku. Gatunki mikoryzowe (mikoryzy arbuskularne) stanowiły 61% składu inicjalnego zbiorowiska. Najliczniej reprezentowane były taksony z kolonizacją zajmującą 20-40% długości korzeni, charakteryzującą się niewielką ilością arbuskul (0,2-3,1% długości korzeni z arbuskulami) oraz brakiem wezykul. W kolejnym stadium sukcesji, gatunki niemikoryzowe, tj.: *Equisetum arvense* i *Poa compressa*, stanowiły 11% składu zbiorowiska a ich udział w pokryciu powierzchni wynosił 3%. Zdecydowanie dominowały rośliny mikoryzowe, wśród których najważniejszą rolę odgrywała populacja *Tussilago farfara*. Częściej niż w stadium inicjalnym notowano gatunki z mikoryzami, które zajmowały >40% długości korzeni oraz zawierały liczne arbuskule (>20% długości korzeni) i wezykule. Mimo wysokiej frekwencji mikoryzowej w stadium inicjalnym, jakościowe cechy kolonizacji sugerują niską efektywność symbiozy, co może być spowodowane brakiem adaptacji grzybowego symbionta do zmienionych po zaburzeniu warunków glebowych.

SŁOWA KLUCZOWE: mikoryza arbuskularna, kolonizacja mikoryzowa, sukcesja, nieużytki kopalniane.