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BIOMASS AND SELECTED MORPHOLOGICAL TRAITS OF FINE ROOTS IN YOUNG PINE STAND GROWING ON FORMERLY ARABLE LAND

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Abstract. The objective of the study was to estimate biomass and selected morphological traits of fine roots (diameter ≤ 2 mm) in 26-year-old Scots pine stand originating from afforestation and growing as the first forest generation on formerly arable land. The stand is located about 30 km north-east from Poznań (western Poland) in the Murowana Goślina Experimental Forest Division, which belongs to Poznań University of Life Sciences. 20 sample trees were selected. Within a distance of 30 cm from each tree intact soil cores were sampled from 3 depths in the soil: 0–20, 21–40 and 41–60 cm. The total number of samples was 120. All roots were separated from the soil, scanned, dried to constant mass and weighed. Fine root biomass and morphological traits (such as: length, surface area, volume and number of root tips) decreased with soil depth. The only exception was diameter, which increased with soil depth.

Key words: fine roots, biomass, morphological traits, *Pinus sylvestris*, formerly arable land

INTRODUCTION

Fine roots play a major physiological role in life of trees. They are responsible for water and nutrient absorption from soil solution. Many studies indicate that in case of trees fine roots have usually diameter equal or smaller than 2 mm (Fogel, 1983; Eissenstat, 1992; 1997; Jackson et al., 1997; Pregitzer et al., 2002). The knowledge of their biomass and morphological traits is crucial if we want to understand the functioning of single trees as well as whole forest ecosystems. Especially when it comes to wide spread and common species in Poland and Europe such as Scots pine (*Pinus sylvestris* L.).

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The share of pine forests in Poland exceeds 67% of total forest area (Puchniarski, 2008). It is a species of great ecological, silvicultural and economical importance in Poland and other European countries (Bernadzki, 1996; Białobok et al., 1993; Ilmurzyński and Włoczewski, 2003; Jaworski, 2011; Murat, 2005; Puchniarski, 2008; Szymański, 1996). Scots pine as a pioneer tree species is used in afforestation of formerly arable lands. Thereby it plays an important role in formation of forest ecosystems in places, which for years have been intensively utilized and cultivated (Puchniarski, 2000; Skolud, 2006; Skolud, 2008; Sobczak, 1990; Strzelecki and Sobczak, 1972; Zając and Gil, 2003). Stands planted as the first generation of forest on abandoned farmlands are transitional associations and from silvicultural point of view they are treated as pioneer crops (Gorzelak, 1996). The knowledge of processes and mechanisms taking place in these temporary ecosystems is crucial if we want to understand their functioning and make responsible economic decisions in the future.

The main objective of the study was to estimate biomass and selected morphological traits of fine roots (diameter ≤2 mm) in 26-years-old Scots pine stand originating from afforestation and growing as the first forest generation on formerly arable land.

MATERIAL AND METHODS

Field site

The stand is located in the Puszcza Zielonka forest complex, about 30 km north-east from Poznań. Administratively it belongs to the Murowana Goślina Experimental Forest Division. Table 1 presents the most important informations about the stand and the site (Plan urządzania..., n.d.).

Climate of this part of Poland is transitional between maritime and continental. Average precipitation for the Puszcza Zielonka forest complex is about 531 mm/year, mean annual temperature is about 8.7°C and the length of vegetation season is 200 days (Grajewski, 2011; 2013).

Intact soil cores

Fieldwork took place in July of 2012. At first 20 sample trees were selected and marked permanently with paint. Then within the distance of 30 cm from each selected tree 6 intact soil cores were sampled. Soil cores were excavated with the steel sampler (Photo 1) from 3 depths in the soil: 0–20 cm (2 cores), 21–40 cm (2 cores) and 41–60 cm (2 cores). Photograph 2 shows the sampling scheme.

Soil sampler was inserted in the soil with 4 kg sledgehammer at specified depth. Then it was lifted up by handles located in the upper part of the device. Soil was removed from the sampler with special stick and small rubber hammer. The volume of the soil sampled (the cylinder with the height of 20 cm and radius of 2.5 cm) is constant and equals 0.000393 m^3. The total number of sampled soil cores was 120. After excavation

Table 1. Characteristics of the stand and site conditions
Tabela 1. Charakterystyka drzewostanu i warunków siedliskowych

Geographical coordinates Współrzędne geograficzne	52°32’52.9”N, 17°06’13.3”E
Forest Division Nadleśnictwo	Zielonka
Forest District Leśnictwo	Stęszewko
Compartment Oddział	40
Subcompartment Pododdział	z
Surface area Powierzchnia	0.4 ha
Tree species Gatunek drzewa	Scots pine (*Pinus sylvestris* L.) sosna zwyczajna (*Pinus sylvestris* L.)
Stand age* Wiek drzewostanu*	28 years 28 lat
Stand origin Pochodzenie drzewostanu	artificial regeneration (afforestation) odnowienie sztuczne (zalesienie)
Average DBH Przeciętna pierśnica	14 cm
Average height Przeciętna wysokość	12 m
Index of stocking Zadrzewienie	1
Stand density Zwarcie drzewostanu	medium umiarkowane
Stand quality Jakość drzewostanu	23
Site index Bonitacja	IA
Forest site type Typ siedliskowy lasu	coniferous mixed mesic forest bór mieszany świeży
Soil type Typ gleby	rigosols rigosole
Soil cover Pokrywa gleby	litter ścioła

*The stand age in 2014. The research was conducted in 2012, when the stand was 26-years-old.
*Wiek drzewostanu w 2014 roku. Badania przeprowadzono w 2012 roku, gdy drzewostan był w wieku 26 lat.

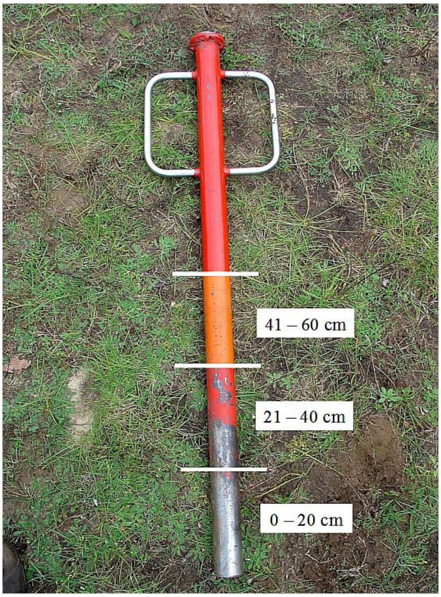

Photo 1. Soil sampler
Fot. 1. Próbnik glebowy

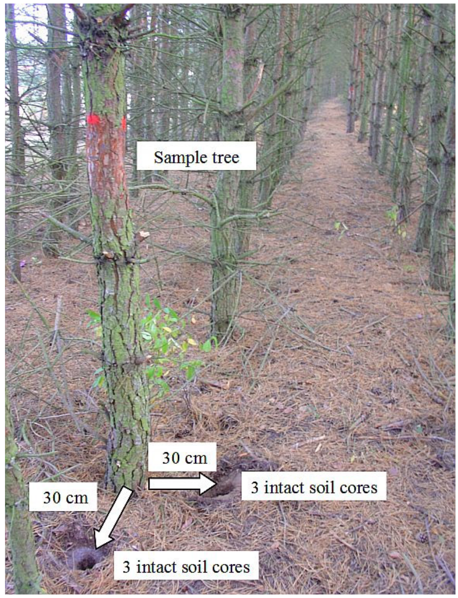

Photo 2. Sampling scheme
Fot. 2. Schemat pobierania prób

they were put into marked plastic bags and later transported to the laboratory and placed in the refrigerator (4°C).

Lab procedures

Soil from the samples was sieved and Scots pine fine roots (with diameter ≤2 mm) were sorted by hand with forceps and separated from other plants roots (mostly herbaceous). Afterwards all pine roots were scanned in order to determine various morphological traits, such as length (cm), surface area (cm^2), volume (cm^3), diameter (mm) and number of root tips. Scans were taken with Epson Perfection 1260 scanner and later analysed with WinRhizo 2002a Reg (Règent Instruments Inc.) software. All roots were dried to constant mass for at least 72 h in 65°C (Pol-Eko Aparatura drier, model SLN53STD) and weighed (Sartorius scale, model ED423S-OCE with the accuracy up to 0.001 g) in order to determine their biomass.

Statistical analyses

All graphs and basic calculations were made with the use of Microsoft Excel 2013. Statistical analyses (ANOVA) were made with the use of Statistica 12 (StatSoft).

Units calculations

Biomass of roots was calculated and exhibited in kilograms of dry mass per hectare (kg/ha). Morphological traits of roots were calculated (except diameter) and exhibited as:
- length – meters per square meter of soil, m/m^2,
- surface area – square meters per square meter of soil, m^2/m^2,
- volume – cubic centimeters per square meter of soil, cm^3/m^2,
- root tips – number of root tips per square meter of soil, number/m^2.

RESULTS

Biomass. Fine root biomass decreased with soil depth (F = 107.8, p < 0.001; Fig. 1, 2, Table 2).
Morphological traits. Fine root length, surface area, volume and number of root tips decreased with soil depth (F = 175.47, p < 0.001; F = 187.42, p < 0.001; F = 155.59, p < 0.001; F = 95.03, p < 0.001, respectively; Fig. 3–6, Table 2). The only trait that increased with soil depth was fine root diameter (F = 14.69, p < 0.001; Fig. 7, Table 2).

Table 2. Means, standard errors and coefficients of variation of fine root biomass and morphological traits by depth
Tabela 2. Średnie, błędy standardowe i współczynniki zmienności biomasy oraz parametrów morfologicznych drobnych korzeni na poszczególnych głębokościach

Statistics Statystyki	Mean Średnia	*SE*	*CV* %	Mean Średnia	*SE*	*CV* %	Mean Średnia	*SE*	*CV* %
	0–20 cm			21–40 cm			41–60 cm		
Biomass, kg/ha Biomasa, kg/ha	2 234.24	113.55	32	841.08	74.80	57	495.03	71.45	91
Length, m/m^2 Długość, m/m^2	2 291.97	112.63	31	530.81	31.74	38	346.57	48.80	89
Surface area, m^2/m^2 Powierzchnia, m^2/m^2	4.57	0.21	29	1.27	0.08	38	0.79	0.10	83
Diameter, mm Średnica, mm	0.63	0.01	11	0.77	0.02	13	0.75	0.02	18
Volume, cm^3/m^2 Objętość, cm^3/m^2	736.18	34.46	30	246.75	16.94	43	148.08	19.41	83
Root tips, number/m^2 Zakończenia korzeni szt./m^2	715 560	45 173	40	197 148	12 888	41	132 875	20 388	97

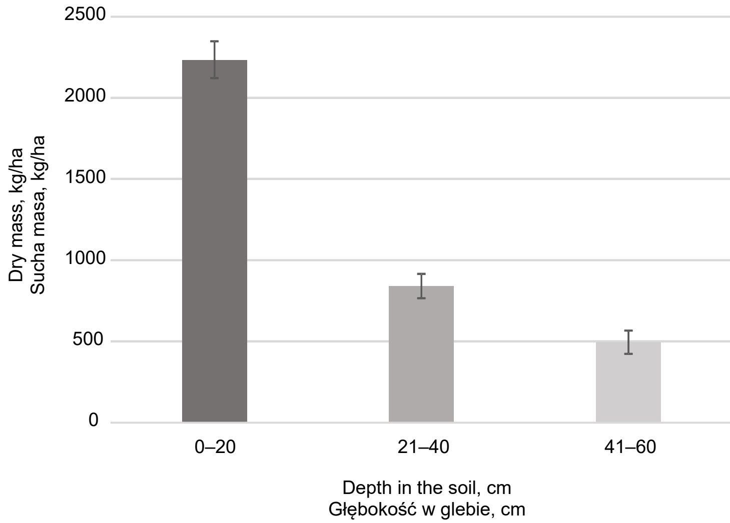

Fig. 1. Fine root biomass at given depths in the soil
Rys. 1. Biomasa drobnych korzeni na poszczególnych głębokościach w glebie

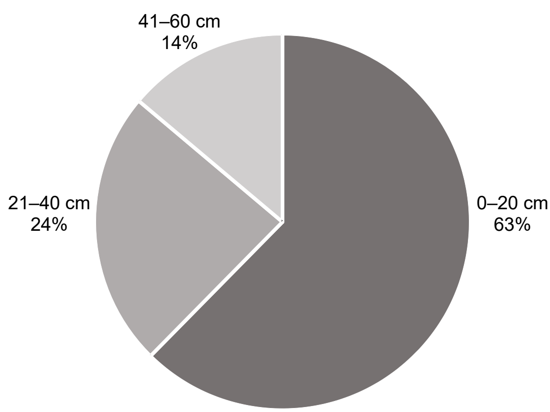

Fig. 2. Percentage share of fine root biomass at given depths
Rys. 2. Procentowy udział biomasy drobnych korzeni na poszczególnych głębokościach

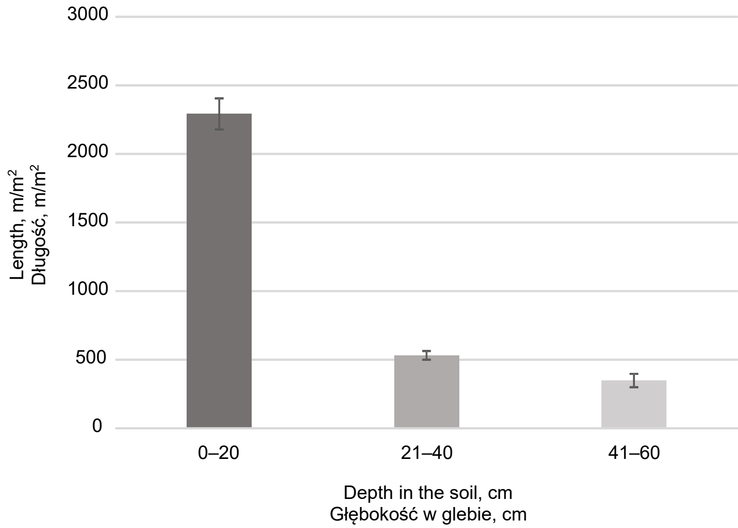

Fig. 3. Fine root length at given depths in the soil
Rys. 3. Długość drobnych korzeni na poszczególnych głębokościach w glebie

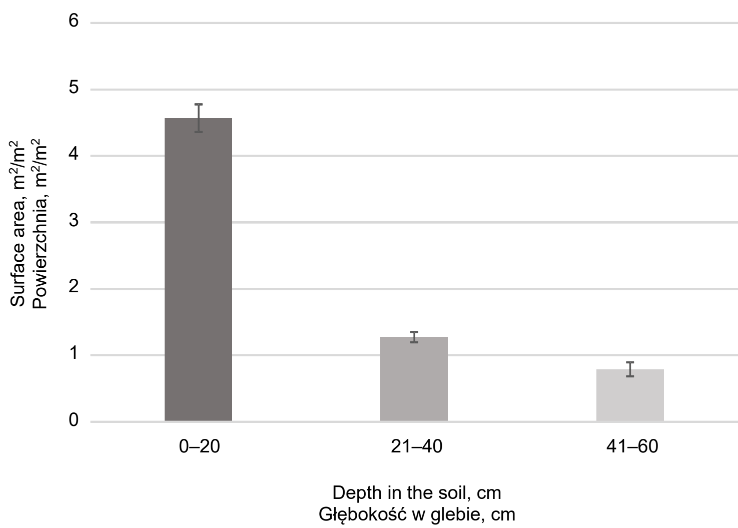

Fig. 4. Fine root surface area at given depths in the soil
Rys. 4. Powierzchnia drobnych korzeni na poszczególnych głębokościach w glebie

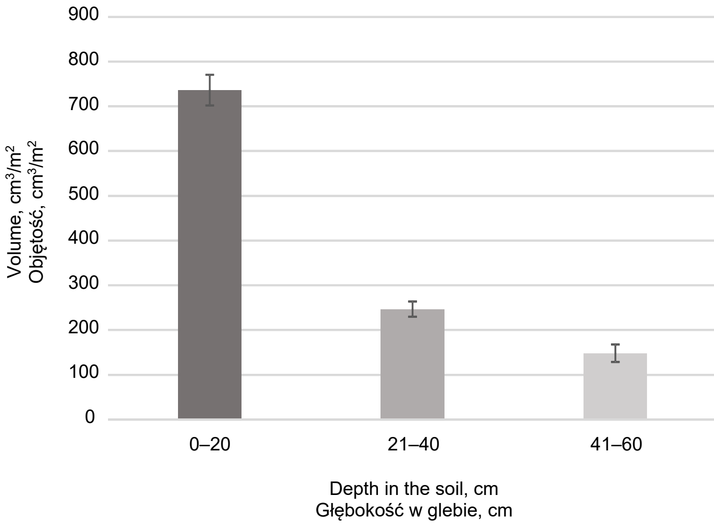

Fig. 5. Fine root volume at given depths in the soil
Rys. 5. Objętość drobnych korzeni na poszczególnych głębokościach w glebie

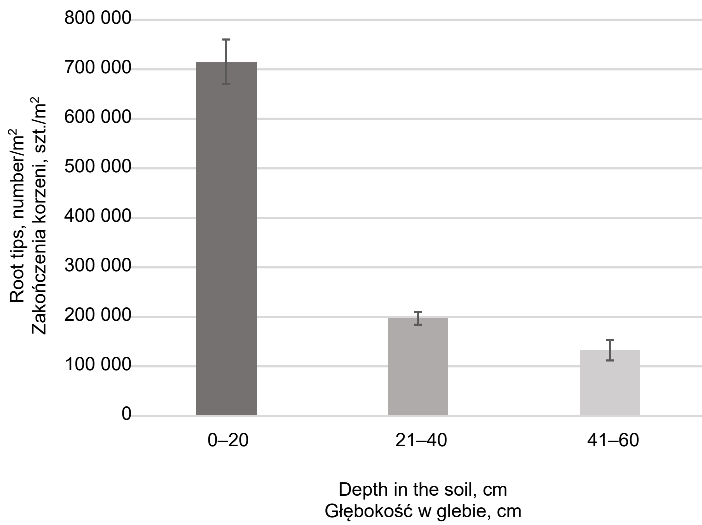

Fig. 6. Number of root tips at given depths in the soil
Rys. 6. Liczba zakończeń korzeni na poszczególnych głębokościach w glebie

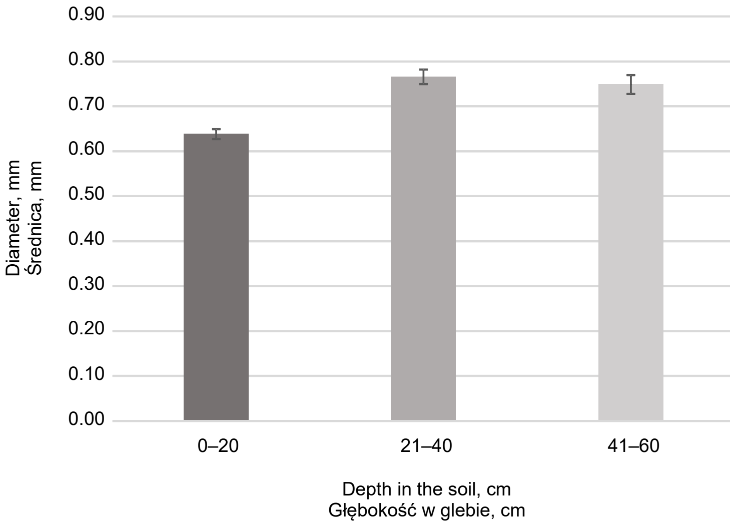

Fig. 7. Fine root diameter at given depths in the soil
Rys. 7. Średnica drobnych korzeni na poszczególnych głębokościach w glebie

DISCUSSION AND CONCLUSIONS

The tree root system can be divided into two separate types of roots when it comes to their function. First type are so called coarse structural roots, which are mainly responsible for mechanical anchorage of a tree in the soil (Persson, 2002; Stokes, 2002). The second type of roots are so called fine roots. Their main function is water and nutrient absorption from the soil solution (Fogel, 1983; Eissenstat, 1992; 1997; Jackson et al., 1997; Pregitzer et al., 2002). Generally in most terrestrial ecosystems fine root biomass decreases with soil depth (Jackson et al., 1997). The largest absorptive fine root biomass occurs in the upper soil horizons (Persson, 1983; Makkonen and Helmisaari, 1999). For Scots pine and other pine species the high concentration of roots in favorable soil locations represents a strategy for maximizing water and nutrient gain for a given carbon investment (Eissenstat and Van Rees, 1994). In our study we've confirmed this relationship. The Scots pine stand grows on relatively poor and exploited soil, which is mainly caused by many years of various agricultural operations (e.g. plowing, fertilization etc.). This means that the main water supply for fine roots during the vegetation season is rainfall. The other source of nutrients for fine roots in this synanthropic ecosystem is the humus layer. In case of pine stand it's mostly consisted of dead needles and branches. The main group of saprophytes here are different fungi species (Klasyfikacja gleb..., 2000). The humus layer, even in nutrient poor acidic soils, plays an important role in energy and matter cycling (Weiner, 1999). Meaningful part in this process belongs to fine roots. In our study we showed that not only biomass, but also several morphological traits of fine roots decreased with soil depth. In the upper soil horizons fine roots had the largest length, surface area, volume and number of tips. The only morphological trait that increased with the depth in the soil was fine root diameter. Similar findings were published by Roberts (1976), who studied root distribution and growth in mature Scots pine stand. As it was mentioned above, the finest of roots dominate in the upper soil horizons. They are usually small in diameter and relatively young. Deeper soil horizons are dominated by older and larger roots, which main function is not water and nutrient absorption, but their transport or storage.

The management of forest stands growing on abandoned farmlands is one of the most important goals of Polish and European forestry (Puchniarski, 2000; Skolud, 2006; 2008; Sobczak, 1990; Strzelecki and Sobczak, 1972; Zając and Gil, 2003). In recent years the surface area of formerly arable lands in Poland and Europe has significantly increased. It is due to changes in global and local economics, politics and environmental protection policies (Hatna and Bakker, 2011). Very important issue here is how do we understand our goals in that field. We obviously cannot think of the forest (wherever it grows) as the "timber factory". Forest, even one of the simple structure described in this paper, is a complex ecosystem, which has to be managed in a balanced way. To make proper economic and environmental decisions we have to understand the mechanisms of forest ecosystem functioning (Gorzelak, 1996). Fine roots of small diameters play here an important ecological role.

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BIOMASA I WYBRANE PARAMETRY MORFOLOGICZNE DROBNYCH KORZENI W MŁODYM DRZEWOSTANIE SOSNOWYM ROSNĄCYM NA GRUNCIE POROLNYM

Streszczenie. Celem badań było określenie biomasy i wybranych parametrów morfologicznych drobnych korzeni (o średnicy ≤2 mm) w 26-letnim drzewostanie sosnowym sztucznego pochodzenia, będącym pierwszym pokoleniem lasu rosnącym na gruncie porolnym. Jest on położony w odległości około 30 km w kierunku północno-wschodnim od Poznania, na terenie Leśnego Zakładu Doświadczalnego Murowana Goślina Uniwersytetu Przyrodniczego w Poznaniu. W drzewostanie wyznaczono 20 drzew próbnych. Następnie w odległości 30 cm od każdego drzewa pobrano po dwie próby glebowo-korzeniowe z trzech głębokości: 0–20, 21–40 i 41–60 cm. Ich łączna liczba wyniosła 120. Wszystkie korzenie z prób po oddzieleniu od gleby zostały zeskanowane, wysuszone do stałej masy i zważone. Biomasa oraz cechy morfologiczne drobnych korzeni (takie jak: długość, powierzchnia, objętość i liczba zakończeń korzeni) malały wraz ze wzrostem głębokości. Jedyną cechą morfologiczną wykazującą wzrost wraz z głębokością była średnica korzeni.

Słowa kluczowe: drobne korzenie, biomasa, parametry morfologiczne, *Pinus sylvestris*, grunt porolny

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