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THE INFLUENCE OF SOIL PREPARATION METHODS AND CUTTING RESIDUES MANAGEMENT ON BELOWGROUND BIOMASS OF 3-YEAR-OLD SCOTS PINE (*PINUS SYLVESTRIS* L.) SAPLINGS

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Abstract. This paper presents the results of studies on the influence of soil preparation methods and ways of utilization of logging residues on belowground biomass of 3-year--old Scots pine saplings, after artificial regeneration. Statistically significant correlations were detected between root biomass and soil preparation methods, while there was no significant impact of logging residues management. Furthermore, interaction of methods of soil preparation and various ways of logging residues management also did not affect the belowground biomass of the plants. The greatest biomass was detected on the area where the soil was prepared by ploughing furrows with the LPz-75 plough. On plots where the soil was prepared by scarifying with rotary tiller, the lowest values of belowground biomass were observed.

Key words: belowground biomass, soil preparation, cutting residues management

INTRODUCTION

The concept of biomass is defined as a measure of economic value of a given habitat or applied agrotechnical treatment. Volume and structure of biomass depends mostly on hereditary characteristics of a given species, but also on various external factors, such as: habitats quality, space available to the tree or presence of other plants [Ebiś 2001]. Consequently, the clear cut area should be immediately reforested to prevent habitats degradation and to obtain best economic effects.

In order to enable regeneration procedures, including soil cultivation, the area must be cleaned and cutting residues managed. By deciding the appropriate residue utilization method, not only economic but also ecological impact should be concerned [Gornowicz 2004]. Technologies of cutting residues utilization are divided into two categories. First category groups methods that are harmful for forest environment. Among these are:

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burning the residues or complete removal from the area. Second category includes methods friendly to environment, such as leaving twigs on surface or comminution and mixing with topsoil [Gornowicz 2005]. Research clearly showed, that on areas where cutting residues were chipped and mixed with topsoil, saplings were characterised by greatest height and lowest mortality [Marciniak 2005]. Unmanaged residues hinder the soil cultivation and may become a habitat for insect pests and fungal pathogens [Chlebowski 2000].

Proper site preparation on clear cut area is a key factor for natural or artificial regeneration. Appropriate soil cultivation treatments are necessary for success of reforestation and afforestation [Murat 2002]. Soil cultivation consists of three stages. First is to remove the living or dead soil cover. The next step is crushing and softening the soil, at least to the depth of trees root system. Beneficial effect of this treatment is increase in soils water absorption and capillary seeping action. Finally, mixing humus layer with mineral soil uniforms the particle distribution, which allows for more effective use of nutrients contained in humus [Murat 2005].

Methods of site preparation should be chosen in a way, that minimally interferes and disturbs natural soil processes, thus ensuring success in plantation establishment [Zasady... 2003].

The aim of the study was to analyse the influence of two factors: soil preparation method and cutting residue management on biomass of belowground part of 3-year-old Scots pine saplings.

MATERIALS AND METHODS

The experimental area was located in the Forest District Bierzwnik, forestry range Chojnowo, sub-compartment 84 g. To create an experimental area a clear cut was carried out (belt clear cut – Ib). The 100-year-old stand was characterised by the following parameters: mean height 23 m, mean breast height diameter 37 cm, moderate closure, site index II on fresh coniferous site. The rectangular area, measuring 60 × 180 m, was divided into 27 sample plots of 20 × 20 m. Plots were grouped into three blocks, which represent three measuring repetitions – 9 plots each. Blocks, in turn, were divider into three belts measuring 60 × 20 m, with 3 plots on each belt.

Within each belt, running across the blocks, one of the following methods of cutting residues management was randomly employed:

- complete removal (picking up and carrying outside the plot)
- leaving twigs and removing thicker branches
- comminution of all residues.

Parallel to the longer side of the block, 3 belts running along the block were selected. On each, the soil was prepared by:

- ploughing ridges
- scarifying with rotary tiller
- ploughing with double mouldboard plough LPz-75.

On Figure 1 schematic layout of plots from which samples were taken, within the research area is shown: Methods of cutting residues management: 1 – complete removal, 2 – leaving twigs and removing thicker branches, 3 – comminution of all residues.

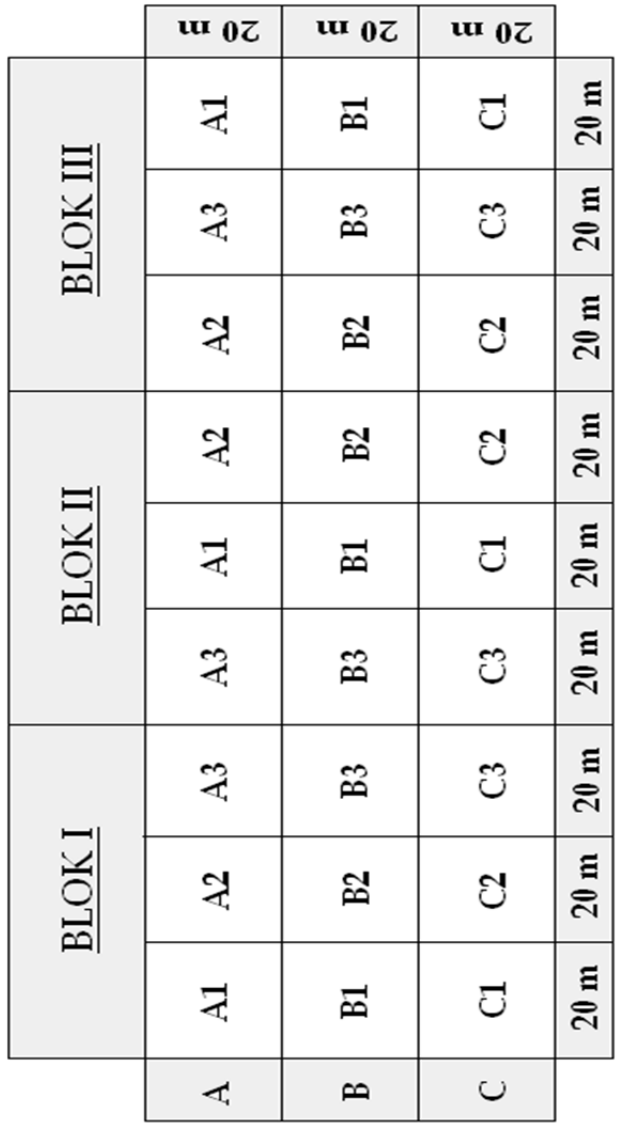

Fig. 1. The layout of sample plots on research area
Rys. 1. Schemat rozmieszczenia działek na powierzchni badawczej

Methods of soil preparation: A – ploughing ridges, B – scarifying with rotary tiller, C – ploughing with LPz-75 plough.

By regeneration planting, the following spacing was used:

1.7 × 0.65 m → ploughing ridges
1.2 × 0.65 m → scarifying with rotary tiller
1.5 × 0.60 m → ploughing with LPz-75 plough.

To determine the belowground biomass of sample trees, 10 saplings were randomly selected on each plot, which were later dug out (total of 270 specimens). Root biomass was then weighted to the nearest 0.1 g. Statistical analysis of the belowground biomass of 3-year-old Scots pine saplings, depending on soil preparation method and cutting residues management, was performed. The statistical characteristics of the results included the following elements:

- number (N)
- range of variation (min – max)
- calculating of arithmetic mean
- standard deviation
- determination of the variation coefficient (V%).

Basing on the abovementioned data, a two-way analysis of variance was performed. The purpose was to determine the influence of various methods of regeneration area management on belowground biomass. Separately analysed were: the influence of soil preparation method, cutting residues management and combination of these two factors. The level of statistical significance $\alpha = 0.05$ was assumed. Whenever two-way analysis of variance showed statistically significant effect ($p < \alpha = 0.05$), Duncan test was performed to determine the differences between the researched groups more accurately.

RESULTS

Belowground biomass of sample trees

Table 1 presents the basic statistical characteristics describing belowground biomass of sample trees. Arithmetic mean ranged between 16.3 g by scarifying with rotary tiller and leaving twigs (2B) and 53.4 g by ploughing ridges and comminution of residues (3A). Analysis of variance coefficients showed relatively small variability of root biomass on plots where ridges were ploughed and twigs left (2A – 51.23%). In turn, the greatest differences were found on plots where soil was scarified with rotary tiller and twigs left (2B – 78.54%).

Analysis of variance of the influence of soil preparation methods and cutting residues management on belowground biomass of 3-year-old Scots pine trees, showed statistically significant differences in case of soil preparation. Value – p is below assumed significance level $\alpha = 0.05$ ($p = 0.000041$). Error in claiming, that cutting residues management has an impact on belowground biomass is calculated as 10.67%. Furthermore, the combination of both soil preparation method and cutting residues management showed no influence on belowground biomass (p – 0.773912). To determine which of the mean values differ significantly, Duncan test was performed (Table 2). The comparison between mean biomass of belowground biomass of sample trees using Duncan test showed the existence of five groups of mean values: 32.16-44.93 g (group I); 36.41-53.35 g (group II); 16.34-32.16 g (group III); 20.71-36.41 g (group IV) and 22.75-39.40 g (group V). Statistically significant differences were found between variants A3 and C2, B3, B1, B2; A2 and B3, B1, B2; C3 and B3, B1, B2; A1 and B1, B2; C1 and C2. As a consequence of this, a group with higher values of belowground biomass can be distinguished, where soil was prepared by ploughing ridges and ploughing furrows with LPz-75. The highest value in this group was found in variant 3A,

Table 1. Statistical characteristic of belowground biomass of sample trees on 3-year-old Scots pine cultivation depending on soil preparation method

Tabela 1. Charakterystyka statystyczna biomasy frakcji podziemnej drzew próbnych 3-letniej uprawy sosnowej w zależności od sposobu przygotowania powierzchni zrębowej

Variant Wariant	Number of trees Liczba sadzonek *N*	Mean Średnia g	MIN Minimum	MAX Maximum	Standard deviation Odchylenie standardowe	V%
1A	30	39.4	12.1	100.2	23.6	59.99
1B	30	20.7	4.9	79.5	15.7	75.68
1C	30	36.4	7.9	92.3	22.5	61.82
2A	30	44.9	13.1	101.4	23.0	51.23
2B	30	16.3	3.9	71.1	12.8	78.54
2C	30	32.2	6.6	89.5	19.9	61.76
3A	30	53.4	15.1	103.2	26.5	49.64
3B	30	22.8	4.5	60.4	11.8	51.87
3C	30	44.2	15.3	117.2	23.2	52.43

Table 2. Results of Duncan test of influence of soil preparation method on belowground biomass of 3-year-old Scots pine saplings

Tabela 2. Wyniki testu Duncana wpływu sposobu przygotowania powierzchni zrębowej na biomasę frakcji podziemnej drzew próbnych 3-letniej uprawy sosnowej

Number of subclass Numer podklasy	Duncan test, variable – root mass Homogenous groups, alfa = 0.05000 Error: intergroup MS = 84.849, *df* = 18.000 Test Duncana; zmienna – masa korzenia Grupy jednorodne, alfa = 0,05000 Błąd: MS międzygrupowe = 84,849, *df* = 18,000							
	utilization utylizacja	soil preparation przygotowanie gleby	mean root mass średnia masa korzenia	I	II	III	IV	V
1	2	3	4	5	6	7	8	9
5	2 – leaving pozostawienie	B – rotary tiller frez leśny	16.34			****		
2	1 – removal uprzątnięcie	B – rotary tiller frez leśny	20.71			****	****	
8	3 – comminution rozdrobnienie	B – rotary tiller frez leśny	22.75			****	****	****
6	2 – leaving pozostawienie	C – plough LPZ-75 pług LPZ-75	32.16	****		****	****	****

Table 2 – cont. / Tabela 2 – cd.

1	2	3	4	5	6	7	8	9
3	1 – removal uprzątnięcie	C – plough LPZ-75 pług LPZ-75	36.41	****	****		****	****
1	1 – removal uprzątnięcie	A – ridges wałki	39.40	****	****			****
9	3 – comminution rozdrobnienie	C – plough LPZ-75 pług LPZ-75	44.16	****	****			
4	2 – leaving pozostawienie	A – ridges wałki	44.93	****	****			
7	3 – comminution rozdrobnienie	A – ridges wałki	53.35		****			

where ploughing ridges and comminution of cutting residues were employed. On the other hand, a group with lower belowground biomass is on the plots, where soil was prepared by scarifying with rotary tiller. The lowest value in this group was recorded in variant 2B, where soil was scarified with rotary tiller and cutting residues comminuted – 16.34 g.

Belowground biomass per 1 ha

Table 3 presents statistical interpretation of data describing belowground biomass of 3-year-old Scots pine saplings depending on soil preparation method. The average value per 1 ha ranged from 77.9 kg by scarifying with rotary tiller and leaving twigs (2B) to 312.9 kg by ploughing furrows with LPz-75 and comminution of branches (3C). At the same time, this variant was characterised by lowest variability (13.47%). The greatest variability was found in variant, where soil was scarified with rotary tiller and all cutting residues comminuted (3B – 65.79%).

As a result of analysis of variance, significant correlation between various soil preparation methods and belowground biomass of 3-year-old Scots pine trees was found ($p = 0.000015$). Analysing various variants of cutting residues management, a value – p was obtained, that was above the level of statistical significance $\alpha = 0.05$ ($p = 0.585593$). Interaction of both factors (soil preparation and cutting residues management) had no significant influence on belowground biomass of the trees ($p = 0.951487$). The Duncan test was performed, in order to find which of the mean values of root biomass differ significantly (Table 4).

The following analysis of multiple comparisons of mean values clearly showed the existence of two homogenous groups with different belowground biomass (group I and II). On plots assigned to group II, root biomass of 3-year-old Scots pines per 1 ha was the highest, ranging from 247.54 to 312.94 kg. In this group, soil was prepared by ploughing furrows with LPz-75 plough and cutting residues were managed by: complete removal (1C), leaving twigs and utilizing thick branches (2C) and comminution of all the residues (3C). In plots from group I mean belowground biomass ranged from 77.92 to 105.44 kg and soil was prepared by ploughing ridges and scarifying with rotary tiller, while all the methods of cutting residues management were employed. Between average values from groups I and II highly significant differences were found – the highest value (312.94 kg) was over four times greater then the lowest (77.92 kg).

Table 3. Statistical characteristic of belowground biomass of 3-year-old Scots pine saplings depending on soil preparation method per 1 ha

Tabela 3. Charakterystyka statystyczna biomasy frakcji podziemnej 3-letnich sosen w zależności od sposobu przygotowania powierzchni zrębowej w przeliczeniu na 1 ha

Variant Wariant	Mean Średnia kg/ha	MIN Minimum	MAX Maximum	Standard deviation Odchylenie standardowe	V%
1A	86.4	34.3	129.0	48.1	55.64
1B	89.8	34.3	134.2	50.8	56.64
1C	263.6	180.4	397.2	116.8	44.31
2A	90.5	57.0	113.7	29.7	32.82
2B	77.9	41.1	133.9	49.3	63.25
2C	247.5	131.9	311.9	100.4	40.55
3A	94.4	53.8	140.4	43.6	46.15
3B	105.4	36.9	175.6	69.4	65.79
3C	312.9	252.0	353.7	53.7	17.17

Table 4. Results of Duncan test of influence of soil preparation method on belowground biomass of 3-year-old Scots pine saplings per 1 ha

Tabela 4. Wyniki testu Duncana wpływu sposobu przygotowania powierzchni zrębowej na biomasę całej frakcji podziemnej 3-letnich sosen, w przeliczeniu na 1 ha

Number of subclass Numer podklasy	Duncan test; variable – root biomass Homogenous groups, alfa = 0.05000 Error: intergroup MS = 4615E6, *df* = 18.000 Test Duncana; zmienna – masa korzenia Grupy jednorodne, alfa = 0,05000 Błąd: MS międzygrupowe = 4615E6, *df* = 18,000				
	utilization utylizacja	soil preparation przygotowanie gleby	mean root mass średnia masa korzenia	I	II
1	2	3	4	5	6
5	2 – leaving pozostawienie	B – rotary tiller frez leśny	77 917.0	****	
1	1 – removal uprzątnięcie	A – ridges wałki	86 433.0	****	
2	1 – removal uprzątnięcie	B – rotary tiller frez leśny	89 769.0	****	
4	2 – leaving pozostawienie	A – ridges wałki	90 494.6	****	
7	3 – comminution rozdrobnienie	A – ridges wałki	94 401.0	****	

Table 4 – cont. / Table 4 – cd.

1	2	3	4	5	6
8	3 – comminution rozdrobnienie	B – rotary tiller frez leśny	105 440.1	****	
6	2 – leaving pozostawienie	C – plough LPZ-75 pług LPZ-75	247 540.4		****
3	1 – removal uprzątnięcie	C – plough LPZ-75 pług LPZ-75	263 641.5		****
9	3 – comminution rozdrobnienie	C – plough LPZ-75 pług LPZ-75	312 937.2		****

CONCLUSIONS

Significant influence of all three researched soil preparation methods (ploughing ridges, scarifying with rotary tiller and ploughing furrows with LPz-75 plough) on belowground biomass of 3-year-old Scots pine trees was found. The most beneficial was ploughing furrows with LPz-75 plough (variant 3C – 312.937 kg/ha).

No significant correlation between root biomass and researched cutting residues management methods (complete removal, leaving twigs and utilizing thick branches and comminution of all the residues) was found.

Interaction of soil preparation methods and cutting residues management methods, had no significant influence on belowground biomass.

In spite of lack of statistically significant influence of cutting residues management on root biomass, slightly higher values were observed on plots where all residues were comminuted, comparing to other two methods: complete removal and leaving twigs.

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WPŁYW METOD PRZYGOTOWANIA GLEBY ORAZ SPOSOBÓW UTYLIZACJI POZOSTAŁOŚCI ZRĘBOWYCH NA BIOMASĘ FRAKCJI PODZIEMNEJ SADZONEK 3-LETNIEJ UPRAWY SOSNOWEJ

Streszczenie. W pracy zaprezentowano wyniki badań nad wpływem metod przygotowania gleby oraz sposobów utylizacji pozostałości zrębowych na biomasę części podziemnej sadzonek 3-letniej uprawy sosnowej, która została założona sztucznie. Statystycznie istotne zależności wykryto pomiędzy biomasą korzeni a metodami przygotowania gleby, natomiast nie stwierdzono istotnego wpływu sposobów utylizacji pozostałości zrębowych. Ponadto interakcja metod przygotowania gleby i sposobów utylizacji pozostałości zrębowych również nie wpłynęła znacząco na biomasę części podziemnej. O największych wartościach biomasy możemy mówić w przypadku powierzchni, gdzie gleba została przygotowana poprzez naoranie wałków oraz orkę pługiem LPZ-75. Na działkach, gdzie zastosowano zdarcie pasów frezem leśnym zaobserwowano najmniejsze wartości biomasy korzeni.

Słowa kluczowe: biomasa części podziemnej, przygotowanie gleby, utylizacja pozostałości zrębowych

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