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INFLUENCE OF CUTTING RESIDUES MANAGEMENT METHOD AND SOIL CULTIVATION METHOD ON THE SURVIVAL RATE OF 3-YEAR-OLD SCOTS PINE (*PINUS SYLVESTRIS* L.) PLANTATION

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Abstract. This paper presents the results of studies on the influence of clear-cut site management on survival rate of 3-year-old Scots pine saplings, conducted in the Forest District Bierzwnik in September 2011. Statistical analysis showed, that only the soil cultivation method significantly influences the survival rate on the studied Scots pine plantation. No statistically significant influence of cutting residues management or combined methods of residues management and various variants of soil cultivation was found.

Key words: survival rate, soil preparation, cutting residues management

INTRODUCTION

The establishment success of forest plantations is one of the most important factors of proper forest management. In order to obtain the highest survival rate of plantation, especially with artificial regeneration, various methods and techniques of site preparation are employed.

One of the most common methods of forest utilisation in Poland is a clear-cut. This due to species distribution in Polish forests and a large share of poor habitats. To assure satisfactory regeneration success, the site must be adequately prepared. Cutting residues mustnot mechanically hinder the soil cultivation and should be a source of nutrients for young trees during earliest, most difficult, years of their life.

Before soil cultivation could start, the clear-cut area must be cleaned and cutting residues utilised. The method of utilisation must be chosen in a way, is least disturbing the process for forest environment while still being economically viable [Gornowicz 2004].

Two categories of cutting residues management technologies have been distinguished. First, consisting of methods that are harmful for the forest environment, like burning or complete removal from the area. Second, including technologies that are

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friendly for the environment, like leaving thin branches on site or comminution and mixing with topsoil [Gornowicz 2005].

Marciniak [2005] reports, that complete removal of cutting residues causes constant disruption in the process of renewing the topsoil. Any deficiency in topsoil increases nutrient leaching, the process in which nutrients are washed into the deeper layers of soil and become unavailable to trees.

In their study, Wojtkowiak et al. [2003], report that on clear-cut area where cutting residues were burnt, 5-12% of the surface was the degraded and for many years, despite fertilisation, on fire spots young saplings were continuously dying out.

The research, conducted at the Faculty of Forestry in Poznań has proved that the plantations have better height increment and best establishment success [Marciniak 2005] on areas where cutting residues were comminuted and mixed with topsoil.

Gornowicz [2005] reports, that on areas where cutting residues were mixed with topsoil, the amount of nutrients decreases faster, comparing to the areas where residues were left on the ground.

The proper soil cultivation is a basic condition for good establishment and correct development of reforestation and afforestation [Rudnicki 1954]. Although, in pro-ecological model of forest management soil cultivation is minimised, complete abandonment of this operation is impossible [Kocjan 2000]. Studies on the most beneficial way of soil preparation were conducted by the Reforestation Department of the Forest Research Institute. Conducted analyses showed that the best establishment success and height growth were found on spots where soil was cultivated by ploughing ridges with subsoiler. On contrary, the lowest values of these two factors were found on spots where no soil cultivation was employed.

THE AIM OF THE STUDY

The aim of the study was to analyse the influence of two factors: soil cultivation methods and cutting residues management on survival rate of 3-year-old Scots pine plantation.

MATERIAL AND METHODS

The experimental area was located in the Forest District Bierzwnik, sub-compartment 89g. The sub-compartment was of rectangular shape with arms 80 × 180 m (1.44 ha). The area was divided into 36 square plots (20 × 20 m, 400 m^2). All the area was planted with Scots pine saplings 1/0. The plots were grouped in three blocks, 12 plots each, in order to get the repetitions.

Each block was then divided into three belts, on which various methods of cutting residues management was used. These methods were: complete removal by carrying out of the area, utilising the bigger branches and leaving small, and comminution of all branches. Belts were laid out randomly.

Along the longer side of the research area, four belts were divided, that reflected various methods of soil cultivation. These methods were: ploughing ridges, scarifying with a rotary tiller and ploughing with a double mouldboard plough LPz-75. One of the

belts was left without cultivation as a control area. The aim was to detect the influence of soil cultivation method on establishment success. The layout of sample plots is pictured on Figure 1.

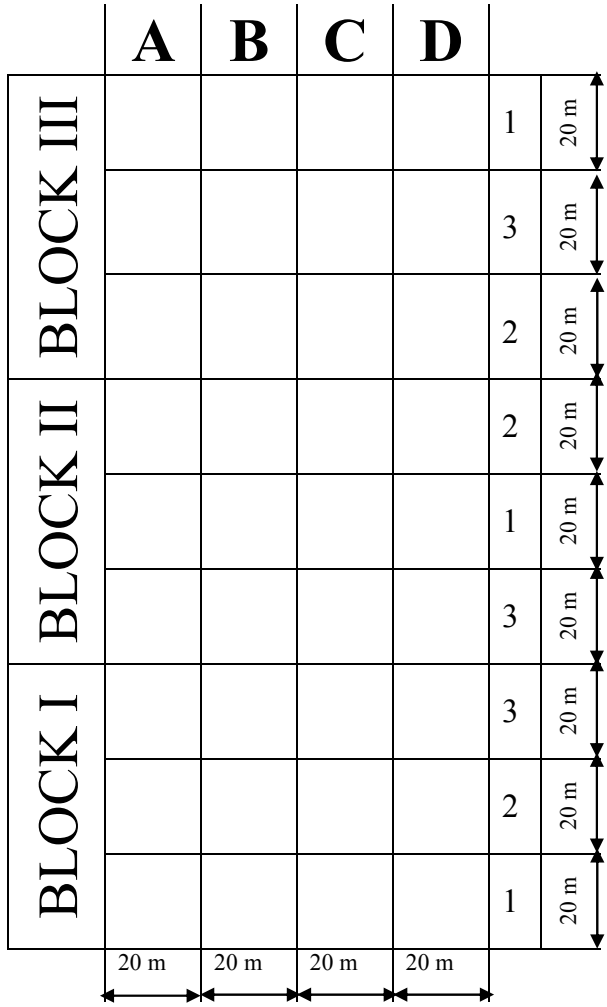

Fig. 1. The schematic layout of sample plots on the research area. Methods of cutting residues management: 1 – complete removal by carrying out of the area, 2 – utilising big branches and leasing small, 3 – comminution of all the residues. Methods of soil preparation: A – ploughing ridges, B – without soil preparation, C – sacrifying of belts with a rotary tiller, D – ploughing furrows with a double mouldboard plough LPz-75

Rys. 1. Schemat rozmieszczenia działek na powierzchni badawczej. Metody zagospodarowania pozostałości pozrębowych: 1 – całkowite uprzątnięcie poprzez wyniesienie poza uprawę, 2 – pozyskanie grubych gałęzi i pozostawienie cienkich, 3 – rozdrobnienie wszystkich gałęzi. Sposoby przygotowania gleby: A – naoranie wałków, B – bez przygotowania gleby, C – spulchnienie pasów pługiem leśnym, D – wyoranie bruzd pługiem dwuodkładnicowym LPz-75

On regeneration area, following spacing was used:
1.70 × 0.65 m – ploughing ridges
1.60 × 0.80 m – without soil cultivation
1.20 × 0.65 m – scarifying with a rotary tiller
1.50 m × 0.60 m – ploughing with a double mouldboard plough LPz-75.

During measurements, living and dead saplings were counted. Dead saplings and empty spaces on planting spot were considered a dead sapling.

On plots where ridges were ploughed and plots without cultivation saplings in 4 out of 11 rows were counted. Counted rows were: 3, 5, 7 and 9, which covered 36.4% of the area of sample plots. In case of other cultivation methods saplings were counted in 5 out of 13 rows (rows 3, 5, 7, 9, 12), which covered 38.5% of the area of sample plots. For each variant, edge rows were not counted, to avoid the influence of methods used on the next plot.

Collected data was then statistically analysed regarding the impact of soil cultivation method and cutting residues management on the survival rate of a 3-year-old Scots pine plantation.

A one-way analysis of variance was performed regarding the impact of soil cultivation method and cutting residues management on survival rate of Scots pine saplings. To determine the influence of combination of soil cultivation method and cutting residues management method, a two-way analysis of variance was performed.

Only three variants of soil cultivation methods were statistically analysed, as on plots without soil cultivation too low number of repetitions was found.

Duncan test was performed in order to more closely verify the statistically valid differences between homogenous groups.

RESULTS AND DISCUSSION

Comparison of average survival rate depending on the method of soil preparation

Comparison of average survival rates of 3-year-old Scots pine saplings depending on the soil cultivation method with various methods of cutting residues management. In Table 1, average survival rates on sample plots are shown, with the distinction on various soil cultivation and cutting residues management method.

The highest average survival rate was found in a variant where all the residues were comminuted, and the lowest on plots where big branches were utilised and small left on the ground. It is meaningful, that the change of soil preparation method had a significant influence on survival rate of the plants in all the researched variants. In only one variant – utilising of big branches and leaving small ones, two methods of soil cultivation give a similar result. These methods are ploughing ridges and scarifying with a rotary tiller.

Comparison of average survival rates of 3-year-old Scots pine saplings depending on the method of cutting residues management with various methods of soil cultivation. The highest survival rates characterised the plots prepared by using LPz-75 plough and the lowest rates were found on plots with ploughed ridges. In a variant where scarifying with a rotary tiller was employed, the biggest differences were found in establishment between various cutting residues management methods.

Table 1. Average survival rates of saplings on a 3-year-old Scots pine plantation, depending on the methods of cutting residues management and soil cultivation, %

Tabela 1. Średnia przeżywalność sadzonek w 3-letniej uprawie sosnowej w podziale na metody utylizacji pozostałości pozrębowych i sposoby przygotowania gleby, %

Method of soil preparation Sposób przygotowania gleby	Method of utilisation – Metoda utylizacji		
	complete removal of the cutting residues całkowite uprzątnięcie pozostałości pozrębowych	utilising of big branches and leaving small pozyskanie grubych gałęzi i pozostawienie drobnych	comminution of all the residues rozdrobnienie wszystkich gałęzi
Ploughing ridges Naoranie wałków	22.7	19.4	26.4
Scarifying of belts with a rotary tiller Spulchnienie pasów frezem leśnym	31.8	22.2	39.5
Ploughing furrows with LPz-75 Wyoranie bruzd pługiem LPz-75	65.5	66.4	63.7

Analysis of variance depending on soil cultivation and cutting residues management methods

As a result of a one-way analysis of variance depending on the method of cutting residues management, no significant differences between various methods of cutting residues management were found. The F value is lower than the critical value of F--Snedecor distribution on the assumed significance level 0.05. Calculated empirical value of a test statistic – *p*-value – equals **0.783669**.

In turn, a one-way analysis of variance of the influence of soil cultivation methods on the survival rate of a 3-year-old Scots pine plantation proved, that all the researched soil cultivation methods differ significantly between each other.

As a result of a two-way analysis of variance of the influence of cutting residues management methods with various methods of soil cultivation on establishment success of a 3-year-old Scots pine plantation, the following *p*-values were obtained: for ploughing ridges **0.261238**, for scarifying with a rotary tiller **0.205078**, for ploughing furrows with LPz-75 plough **0.828138**. All the *p*-values are higher than the assumed significance level (0.05), which proves the lack of statistically significant differences between methods of cutting residues management with various methods of soil cultivation.

The conducted two-way analysis of variance of the influence of the method of soil cultivation with various methods of cutting residues management showed, that the *p*-value in all the analysed cases is lower than the assumed significance level (0.05). For the variant with complete removal of cutting residues the *p*-value was **0.003843**, for utilising big branches and leaving small **0.002189** and for comminution of all branches **0.015092**.

In the research of Gornowicz et al. [2007] also the significant influence of soil cultivation method on height of a 5-year-old Scots pine plantation was found.

In Table 2 the results of analysis of variance with multiple classification are shown. This method was applied in order to detect the influence of combination of soil cultivation methods and cutting residues management on survival rate of 3-year-old Scots pine

Table 2. Analysis of the influence of the combination of various methods of soil preparation and cutting residues management methods on establishment success of a 3-year-old Scots pine plantation

Tabela 2. Analiza wariancji wpływu połączenia sposobów przygotowania gleby z metodami utylizacji pozostałości zrębowych na udatność 3-letniej uprawy sosnowej

Effect Efekt	df	SS	MS	F	*p*-value Wartość *p*
Free term Wyraz wolny	1	40 081.93	40 081.93	827.3962	0.000000
Method of soil preparation Sposób przygotowania gleby	2	3 314.56	1 657.28	34.2107	0.000001
Method of cutting residues management Metoda utylizacji pozostałości pozrębowych	2	98.26	49.13	1.0142	0.382507
Method of soil preparation × the method of cutting residues management (interaction) Sposób przygotowania gleby × metoda utylizacji pozostałości pozrębowych (interakcja)	4	114.40	28.60	0.5904	0.673916
Error Błąd	18	871.98	48.44		
Total Ogół	26	4 399.21			

saplings. The values shown in the table are the result of conversion of establishment success from percentage to angular values.

For combined methods of cutting residues management and soil preparation, the value of F statistic does not exceed the critical level of F-Snedecor distribution and *p*-values are above the assumed significance level (0.05). These results allow to state, that the combination of both methods of site preparation does not influence, in statistically significant way, the survival rate of saplings on the researched area.

The conducted analysis of variance showed some statistically significant differences between the influence of the methods of soil preparation on the survival rate of the plants. In order to research more accurately the detected differences between homogenous groups, the Duncan test was performed. The results are shown in Tables 3, 4 and 5.

The conducted comparison of the average values of survival rates in variant with complete removal of cutting residues, using the Duncan test, detected the statistically significant differences between ploughing furrows with LPz-75 Plough and the two other soil cultivation methods. On the other hand, in case of ploughing ridges and scarifying with a rotary tiller, no significant differences were detected (Table 3).

For the variant with utilisation of big branches and leaving small, no significant differences were found for ploughing ridges and scarifying with a rotary tiller. Statistically significant differences were detected in case of ploughing furrows with LPz-75 plough (Table 4).

The Duncan test, applied on plots where all the residues were comminuted, showed no significant differences in cases of ploughing ridges and scarifying with a rotary tiller. Significant differences were found in case of ploughing furrows with LPz-75 (Table 5).

Table 3. Results of the Duncan test of the influence of the soil preparation methods on establishment success of a 3-year-old Scots pine plantation in the variant with complete removal of cutting residues

Tabela 3. Wyniki testu Duncana wpływu sposobów przygotowania gleby na udatność 3-letniej uprawy sosnowej w wariancie uprzątnięcie pozostałości

Number of sub-class Numer podklasy	Method of soil cultivation Sposób przygotowania gleby	Establishment success (angular value) Average Udatność (wartość kątowa) Średnie	1	2
1	ploughing ridges naoranie wałków	28.19975	****	
4	scarifying with a rotary tiller spulchnienie pasów frezem leśnym	33.42506	****	
7	ploughing furrows with LPz-75 wyoranie bruzd pługiem LPz-75	54.11332		****

Table 4. Results of the Duncan test of the influence of various soil preparation methods on survival rate of a 3-year-old Scots pine plantation in the variant with utilisation of big branches and leaving small

Tabela 4. Wyniki testu Duncana wpływu sposobów przygotowania gleby na udatność 3-letniej uprawy sosnowej w wariancie pozyskanie grubych gałęzi i pozostawienie drobnych

Number of sub-class Numer podklasy	Method of soil cultivation Sposób przygotowania gleby	Establishment success (angular value) Average Udatność (wartość kątowa) Średnie	1	2
2	ploughing ridges naoranie wałków	26.04613	****	
5	scarifying with a rotary tiller spulchnienie pasów frezem leśnym	27.80243	****	
8	ploughing furrows with LPz-75 wyoranie bruzd pługiem LPz-75	54.65660		****

Table 5. Results of the Duncan test of the influence of the method of soil preparation on establishment success of a 3-year-old Scots pine plantation in the variant with comminution of all the residues

Tabela 5. Wyniki testu Duncana wpływu sposobów przygotowania gleby na udatność 3-letniej uprawy sosnowej w wariancie rozdrobnienie wszystkich gałęzi

Number of sub-class Numer podklasy	Method of soil cultivation Sposób przygotowania gleby	Establishment success (angular value) Average Udatność (wartość kątowa) Średnie	1	2
3	ploughing ridges naoranie wałków	30.92214	****	
6	scarifying with a rotary tiller spulchnienie pasów frezem leśnym	38.53477	****	
9	ploughing furrows with LPz-75 wyoranie bruzd pługiem LPz-75	53.06455		****

CONCLUSIONS

The research showed, that different methods of soil preparation on researched area have a statistically significant influence on the establishment of plantation.

The best establishment success was found on the area prepared by ploughing furrows with LPz-75. The survival rate on plots where this method was employed was twice as big as on the other plots.

Similar and very low establishment success was found on plots where soil was cultivated by ploughing ridges or scarifying with a rotary tiller.

The conducted analysis of variance showed no statistically significant differences in the influence of researched methods of cutting residues management on survival rate of saplings on a 3-year-old Scots pine plantation.

Combined methods of cutting residues management and soil cultivation (interaction) show no significant influence on the survival rate of saplings on the researched plantation.

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WPŁYW SPOSOBU ZAGOSPODAROWANIA POZOSTAŁOŚCI ZRĘBOWYCH I PRZYGOTOWANIA GLEBY NA PRZEŻYWALNOŚĆ 3-LETNIEJ UPRAWY SOSNOWEJ

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Słowa kluczowe: przeżywalność, przygotowanie gleby, utylizacja pozostałości zrębowych

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