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SOIL PROPERTIES AND DENDROLOGICAL PARAMETERS OF TREES AFTER 20-YEAR REFORESTATION IN THE POST FIRE AREA POTRZEBOWICE (MIDDLE POLAND)

Summary

The paper presents results of the research on the assessment of technical parameters of forest stands on a post-fire area which has been reclaimed for 20 years, based on various methods of soil preparation. An attempt was made to determine the potential influence of soil properties on them. The following variants were tested: digging furrows with a forest plough, shallow tillage with a disc plough, dimples dug with a shovel, natural succession, forest complex intact by fire (zero area). Planting was done with: Quercus rubra, Pinus sylvestris, Betula pendula, Quercus petraea, Larix decidua, Alnus incana. The examined area is dominated by Brunic arenosols and podzols. The following technical parameters were determined: height, diameter at breast height (DBH), relascopic number of trees and forest cover. Such properties were marked as: texture, solid phase density, soil density, porosity, moisture, pH, hydrolytic acidity, cation exchange capacity, the content of exchangeable cations and available forms, organic carbon and total nitrogen content. No relations were observed between the variations of soil properties and technical parameters of the investigated forest stands. It suggests that soil preparation methods were the most important factor which influenced the examined parameters. According to the obtained results, planting into dimples is a good method for post-fire soil preparation. It is difficult to determine unambiguously which reclamation method is the best for a post-fire area in order to obtain better technical parameters, however, the observations may be helpful in determining more effective ways of post-fire forest stands' reconstruction.
***Key words**: reforestation, post fire area, soil properties, technical parameters of forest*

WŁAŚCIWOŚCI GLEB ORAZ PARAMETRY DENDROLOGICZNE DRZEW PO DWUDZIESTOLETNIEJ REFORESTACJI POŻARZYSKA POTRZEBOWICE (ŚRODKOWA POLSKA)

Streszczenie

Praca zawiera wyniki badań dotyczące właściwości gleb na pożarzysku restytuowanym od 20. lat, w oparciu o różne sposoby przygotowania gleby oraz odmienne nasadzenia. Scharakteryzowano również podstawowe parametry dendrologiczne drzew, stanowiących odnowienia na poszczególnych – w różny sposób przygotowanych – płaszczyznach. Testowano następujące warianty: wyoranie bruzd pługiem dwuodkładnicowym, płytka orka pługiem talerzowym, jamki wykopane łopatą, sukcesja naturalna, kompleks leśny nienaruszony przez pożar (powierzchnia zerowa). Do nasadzeń użyto: Quercus rubra, Pinus sylvestris, Betula pendula, Quercus petraea, Larix decidua, Alnus incana. Określono następujące parametry techniczne: wysokość, pierśnicę, relaskopową liczbę drzew, zadrzewienie. Na badanym obszarze dominującymi typami gleb były gleby rdzawe oraz bielice. Oznaczono takie właściwości gleby, jak: skład granulometryczny, gęstość fazy stałej, gęstość gleby, porowatość, wilgotność, odczyn, kwasowość hydrolityczną, kationową pojemność sorpcyjną, zawartość wymiennych oraz przyswajalnych form, węgiel organiczny, azot ogólny. W odniesieniu do gleb siedliska leśnego, nienaruszonego przez pożar, w glebach reforestowanego obszaru, wystąpiło znaczne zmniejszenie się zawartości węgla organicznego oraz wzrost zawartości azotu ogólnego. Zawężeniu uległ stosunek C:N; nieznacznie podniosło się pH. Większość kationów wymiennych uległa wymyciu. Właściwości fizyczne gleb poszczególnych płaszczyzn badawczych były zróżnicowane w bardzo małym stopniu. Przeprowadzone badania wskazują, że dość dobrym sposobem przygotowania gleby popożarowej jest nasadzenie w jamki. Na obecnym etapie badań trudno jest jednoznacznie określić wybór najlepszej metody rekultywacji pożarzyska w celu osiągania lepszych parametrów technicznych, jednakże dokonane obserwacje mogą być pomocne w typowaniu efektywniejszych metod odbudowy drzewostanów dotkniętych klęską pożaru.
***Słowa kluczowe**: reforestacja, pożarzysko, właściwości gleby, parametry dendrologiczne*

1. Introduction

Research carried out in forest areas which were devastated by fire usually leads to effective reconstruction of forest stands. Better height gain is obtained, having prepared the soil for tillage first than when the soil has not been prepared [19]. What is also important, this is the method of soils' recovery [9]. When treated with fire, soil also undergoes drastic changes. It is both its physical [1, 13, 16, 25] and chemical properties that change [2, 3, 15]. In the paper, basic properties of soils occurring on the plots restituted in different ways have been characterized also the basic dendrological parameters of trees, constituting the beginning of the developing tree stands. The assessment of chosen habitat components after 20-year post fire area reclamation was presented.

2. Object

The research was carried out in an experimental area established in *Potrzebowice* Forest Division in 114 d section (currently 114 g sector) by the Department of Sylviculture at the Agriculture University in Poznan, Poland [5]. Before the fire, the area was covered with a 60-year old forest stand. Three reclaimed plots (A, B, C) were selected for the research, of 150x20 m, with six plots each as well as the plot of natural succession and plot zero. Plots varied in terms of soil preparation methods:

- plot A: digging furrows with a forest plough, with a countersink up to the depth of 35-40 cm with 1.5 m gaps;
- plot B: shallow tillage with a disk plough up to the depth of 30 cm; as a result, all the remains of the organic horizon were completely removed and the horizon was evenly mixed with the mineral layer;
- plot C: furrows dug with a spade (excluded from mechanic tillage);
- plot of natural succession (NS): logging waste (tops, branches), including trunks, left on the logging site without grinding; on this site all the trees were from natural sewing [19];
- plot zero (F): forest complex intact by fire, covered with *Pinus sylvestris* planted with a tree planting bar; the age of the forest stand – 20 years (fresh forest).

Planting was done with: *Quercus rubra*, *Pinus sylvestris*, *Betula pendula*, *Quercus petraea*, *Larix decidua*, *Alnus incana*. The investigated area is predominantly covered with Brunic Arenosols (in Polish: gleby rdzawe) and Podzols (in Polish: gleby bielicowe) [12].

3. Methods

The study plots (18) were located at the intersection of two diagonals, within each location (3 plots x 6 locations). In the plot of natural succession, five research areas were randomized. Technical parameters were determined with standard methods used in sylviculture, i.e. relascopic number of trees [4], height of trees of minimal and maximal diameter at breast height (DBH), DBH for all the trees [11]. The obtained results allowed for the calculation of forest cover.

Average soil samples were collected from each area within the depth of 0-20 cm. The following soil parameters were determined: texture – with Bouyoucos' method in Pruszyński's modification [20], soil phase density – with a picnometric method [23], soil density – with Nitzsch's vessels of 100 cm^3 capacity, porosity – calculated on the basis of density's denotations, moisture – by gravimetric method, pH – potentionometrically, hydrolytic acidity (H) and sorption cation capacity (CEC, TEB) – with Kappen's method, the content of exchangeable and available forms of macroelements – with Egner-Riehm's and Schachtschabel's methods [18], total carbon and nitrogen – with Vario Max analyser. The results are average values from five replications.

4. Results and discussion

4.1. Impact of reclamation on soil properties

The content of clay in all soils in the researched areas allowed for their classification to a texture subgroup of loose sand. Therefore, texture could not be a differentiation factor (Table 1).

Porosity is one of the physical properties that best reflects changes in the ways of soil preparation. Porosities of all reclamation plots were slightly (about 1-3%v) higher than found at zero plot. The highest porosity (49.66%v) was found in the variant with deep tillage; slightly lower in other variants of reclamation. Deep tillage, i.e. fracturing lower horizons, had a better influence on roots penetration. Mixing the top horizon while disking did not result in the growth of porosity when compared to the plot of natural succession. It was more difficult to observe any influence of porosity on the investigated technical parameters (Table 1).

Table 1. Basic physical properties of investigated soils
Tab. 1. Podstawowe właściwości badanych gleb

Plot	Clay content [%]	Moisture [$m^3 \cdot m^{-3}$]	Specific density [$Mg \cdot m^{-3}$]	Bulk density [$Mg \cdot m^3$]	Porosity [%]
I	1.5	0.0457	2.65	1.34	49.66
II	2.0	0.0418	2.65	1.39	47.75
III	2.3	0.0412	2.65	1.37	48.25
NS	2.0	0.0436	2.65	1.38	47.74
F	1.8	0.0379	2.65	1.41	46.70

Source: own study / Źródło: opracowanie własne

According to Imeson et al. [10], a direct effect of fires on physical properties may be the creation of a discreet and continuous water-repellent front parallel to the surface that decreases soil permeability. Such statement was confirmed also by Everett et al. [7]. Deep tillage had a positive effect on soil's moisture through easier infiltration of precipitation waters into deeper horizons. From the point of view of restoration of soil's proper efficiency, it was a beneficial operation. Favourable moisture (4.36%v) was observed also in the plot of natural succession. It was a result of wood particles and post-fire remains having been left on the ground, which protected soil from extensive drying. Nevertheless, from a practical point of view, changes in moisture observed in various plots were very small (from 3,79 to 4,57%). Such little changeability of this property cannot be a factor which influences the differentiation of the investigated technical characteristics of the forest stands (Table 1).

The lowest density was observed in the soil from allotment I. Similarly to total porosity, which is correlated with this property, soil's density did not influence technical parameters (Table 1).

Forest fire causes the loss of soil organic matter. As a result of total fire a reduction or total removal of the forest floor occurs often [22]. The recovery of soil organic matter in the burnt areas starts with the natural or artificial reintroduction of vegetation [14]. The highest content of total carbon on the zero plot (12.3 $g \cdot kg^{-1}$) and natural succession plot (11.9 $g \cdot kg^{-1}$) may be explained with a balanced pace of humification and mineralization processes in the conditions which are as close as possible to the natural habitat. Soil preparation procedure which caused regular and strong mixing of organic matter and quartz maternity material (full tillage with a disc plough), led to significant carbon loss (8.2 $g \cdot kg^{-1}$) which was additionally intensified by initial strong aeration. However, from this point of view, a very low content of this element (7.5 $g \cdot kg^{-1}$) in the soil with combination with burrow planting and quite a high one – with furrows ploughed – is difficult to explain (Table 2).

The amount of nitrogen in the soil decreased along with the growth of soil's reclamation intensiveness. The highest contents of nitrogen were observed on succession plot (0.58 g·kg^{-1}) and zero plot (0.57 g·kg^{-1}), where the whole plant burnt mass was left (Table 2).

The relation of C:N, which reflects the scope of carbon and nitrogen transformations in the soil and directly characterises microbiological activity, was high. At a moderately strong differentiation in the content of these elements within a given combination, very similar texture and practically identical climate and weather conditions, the relation of C:N in the investigated soils was very aligned (from 18.53 to 22.50). The obtained values are more limited than the ones obtained in typical coniferous forests (21.4 – zero plot), which is an evidence for a constant process of this phytocenoses to balance (Table 2).

According to Certini [6], in post fire areas soils pH increases, although ephemerally, because of the release of the alkaline cations bound to the organic matter. Within all the investigated combinations, the observed differences in the values of soils reaction were minimal. From a practical point of view, the reaction was the same, characteristic for the discussed habitat (Table 2).

According to Khanna and Raison [17], in such soils calcium, magnesium and potassium increase often remarkably but ephemerally. It was not confirmed in soils of investigated area. In the investigated soils exchange cations appeared in small amounts. The ones which were leached primarily were calcium and magnesium. Moreover, the loss of potassium was also observed. In various combinations it was 2-3 times higher than in the control surface. Minimal, yet noticeable, decrease in the amount of sodium was observed. The highest and most balanced values of exchange cations filled the sorption complex of soils whose surface was the closest to natural conditions (Table 3).

Within the available mineral forms, a decrease in the content of available forms of potassium (around 30%) and – in a small extent – of phosphorus (around 2%) and magnesium (around 1%) took place. The exceptions were the surfaces of natural succession and planting into dimples, where slightly higher content of potassium and balanced content of magnesium when compared to other combinations, were observed (Table 3).

According to Sharpley [21] the peak of P bioavailability occurs around pH 6.5 and any fire-induced change in soil pH toward neutrality has a positive effect on its accessibility for forest plants. Data which were collected and analysed by Certini [6] indicate that exchange capacity decreases proportionally to the loss of organic matter and base saturation increases as a consequence of the prevailing release of bases from the combusting organic matter. It was not confirmed during investigations.

4.2. Dendrometry measurements

The species of measured trees differed partly from the ones which had been planted. All the surfaces were covered with *P. sylvestris* and *B. pendula*. Accompanying species were: *L. decidua* and *A. incana*. *A. incana* and *Q. rubra* - appeared on some surfaces, they did not meet yet the norms of a relascope. A total number of trees which were measured and included to next measurements was 302 units (Fig. 1). An average number of *P. sylvestris* in the research areas was 9-12 per a relascopic area. It is a similar value to the one from the area which was not damaged by fire – 12 units. In the area of natural succession, a number of 6 units of this species was marked. The number of *B. pendula* trees was between 3 and 7 units. In the area of deep tillage, a number of *L. decidua* was high – 9 units, moreover, it also appeared twice in 5 units. It was not included in the description of species in the areas of natural succession and zero area. *A. incana* in the number of 3 was only found in the area excluded from mechanical tillage (Fig. 2). Height of trees varied, depending on the method of soil's preparation. The most significant differences were observed in *B. pendula*- from 2.5 m to 15.5 m (on average 8.0 m), smaller - *P. sylvestris* - from 4.0 m to 11.0 m (on average 7.0 m). *P. sylvestris* and *L. decidua* achieved better parameters in the arras which had been less transformed by a man (Fig. 3).

Table 2. Basic chemical properties
Tab. 2. Podstawowe właściwości chemiczne

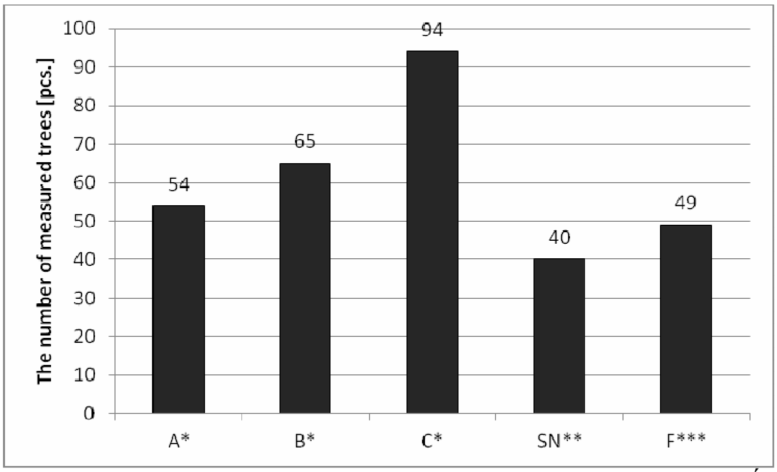
Plot	Total carbon [g·kg^{-1}]	Total nitrogen [g·kg^{-1}]	C:N	pH		H	TEB	CEC	BS [%]
				H_2O	KCl	[cmol$^{(+)}$·kg^{-1}]			
I	11.3	0.49	22.50	4.68	4.20	3.06	0.41	3.47	13.42
II	8.2	0.51	20.03	4.63	4.12	3.04	0.35	3.39	12.09
III	7.5	0.52	18.53	4.57	4.07	2.89	0.49	3.38	18.20
NS	11.9	0.58	20.63	4.61	4.10	3.18	0.50	3.67	17.77
F	12.3	0.57	21.40	4.68	4.09	3.36	0.49	3.85	15.68

Source: own study / Źródło: opracowanie własne

Table 3. Content of basic ions and available elements
Tab. 3. Zawartość kationów wymiennych

Plot	Basic ions				Available elements		
	Ca^{2+}	Mg^{2+}	K^+	Na^+	K	P	Mg
	[cmol$^{(+)}$·kg^{-1}]				[mg·kg^{-1}]		
I	0.14	0.05	0.05	0.18	6.80	9.06	0.63
II	0.07	0.05	0.06	0.18	6.01	10.59	0.64
III	0.17	0.05	0.07	0.23	6.55	9.17	0.64
NS	0.19	0.04	0.07	0.20	7.51	7.37	0.95
F	0.17	0.05	0.06	0.21	7.53	7.64	0.95

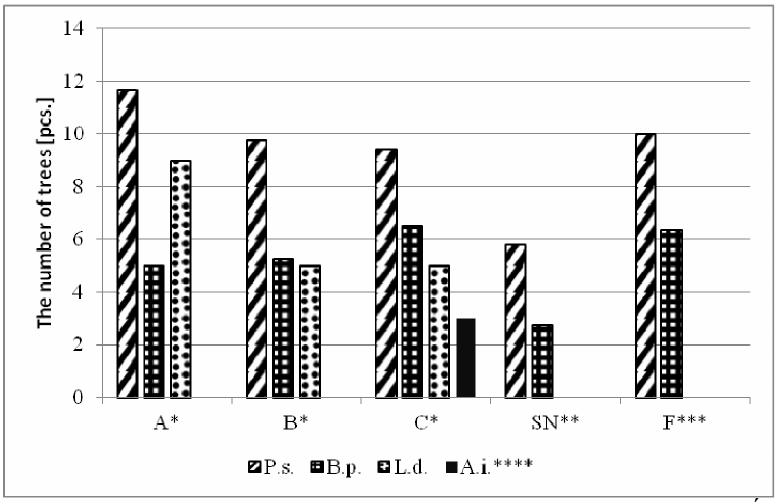
Source: own study / Źródło: opracowanie własne



Source: own study / Źródło: opracowanie własne

*Number of sample plots; **Natural succession; ***Forest (nill sample)

Fig. 1. The total number of trees
Rys. 1. Całkowita liczba pomierzonych drzew



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*Number of sample plots; **Natural succession; ***Forest; ****P.s. – *Pinus sivestris;* B.p. – *Betula pendula;* L.d. – *Larix deciduas;* A.i. . – *Alnus incana*

Fig. 2. Average number of trees on relascopic sample plots for individual species on investigated plots
Rys. 2. Średnia ilość drzew na relaskopowych powierzchniach próbnych dla poszczególnych gatunków na danych powierzchniach badawczych

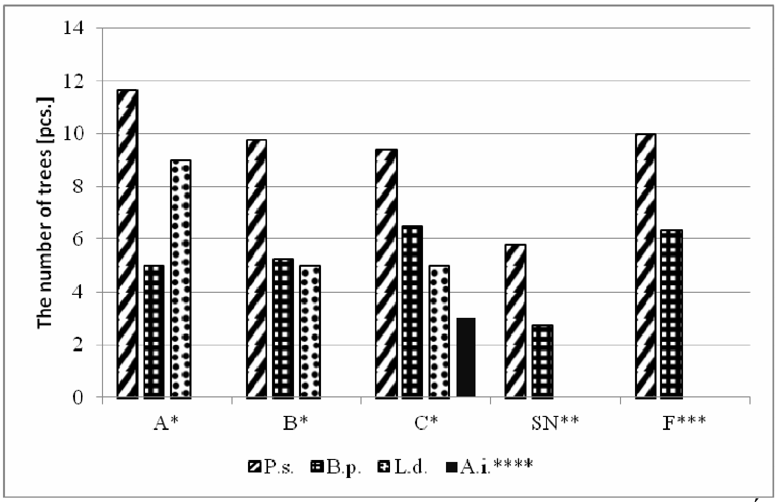

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Fig. 3. The average height of the trees on investigated plots
Rys. 3. Średnia wysokość drzew na badanych płaszczyznach

Average DBHs of all the trees oscillated between 37 and 121 mm. In the areas of natural succession and deep tillage at *P. sylvestris* similar values were marked. In the former case, it may be a result of a deeper and easier penetration of soil by roots in order to reach nutrition elements, in the latter – of smaller thickness and better accessibility of light. *L. decidua* reached its maximum in the first allotment; *B. pendula* – on the surface prepared with a disc plough (Fig. 4). The highest coefficient of forest cover in the reclaimed areas was marked on the surface of deep tillage – 0.8. Leaving soil in an intact state (planting in burrows) allowed for the development of forest cover of 0.7, which was satisfying. At a total exposure of soil cover (disc tillage) and exposing it to the influence of some unfavourable atmospheric conditions, forest cover was the least – of only 0.6. Natural recovery of at least 0.4 is a good result (Fig. 5).

5. Summary

Numbers which define technical parameters of the investigated forest stands vary on reclaimed surfaces in different ways which are, as it is visible in the defined values, on different stages of regradation. The sum of all the measured trees was the largest on a surface with planting in dimples. The number of species on each surface varied. Quite constant, and close to the average, values of this parameter were observed on the above mentioned surfaces. They were also covered with the trees of the most optimal average height – except *P. sylvestris.* The height of *P. sylvestris* fell along with the stage of the transformation of soil natural cover as a result of various means of soil preparation. Average values of DGH were strongly diverse. Their composition within various trees species and means of soil preparation showed no regularities. *P. sylvestris* DBH lowered and its height increased along with the growth of the number of trees.

A significant drop in the content of organic carbon and an increase in the content of total nitrogen were observed in the reclaimed soils. The relation of C:N dropped, pH grew slightly. Most of the exchange cations was washed out.

Physical properties of soils at various research horizons differed to a very little extent. No link between the changeability of soil properties and technical parameters of the investigated forest stands was observed, which suggests that the most important factor which influenced the researched parameters was the means of soil preparation.

According to the research, planting in dimples is a relatively good way of post-fire soil preparation. At a present stage of the research, it is difficult to unambiguously choose the best method of reclamation of a post-fire area in order to achieve better technical parameters. However, the conducted observations may be helpful in the selection of the most effective methods of the transformations of the forest stands which were damaged in fire.

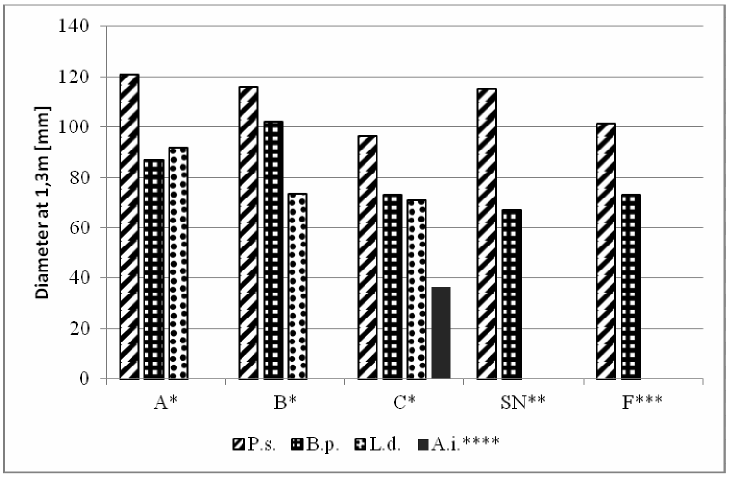

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Fig. 4. Average diameter of trees at a height of 1.3 m on investigated plots
Rys. 4. Średnia średnica drzew na wysokości 1,3 m na badanych płaszczyznach

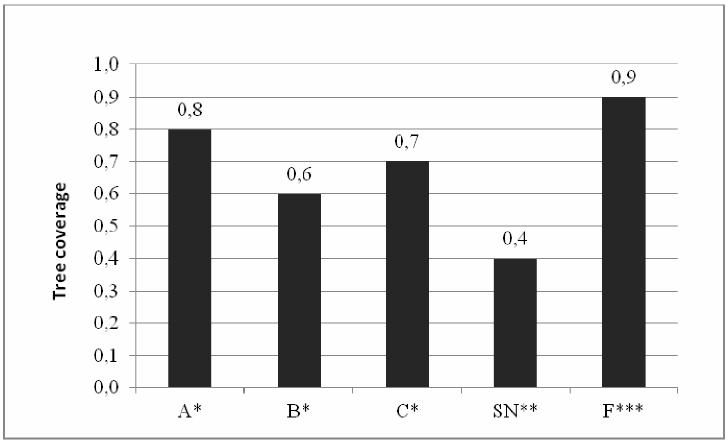

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Fig. 5. Size of the tree plantings on investigated plots
Rys. 5. Wielkość zadrzewienia na powierzchniach badawczych

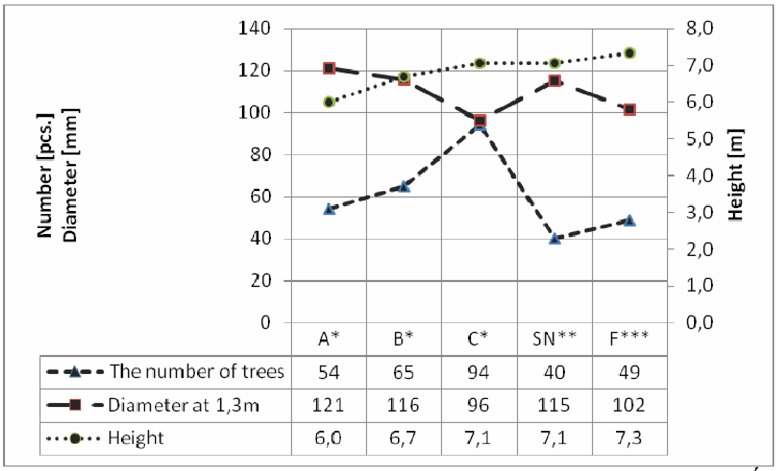

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Fig. 6. Parameters of *Pinus Silvestris*
Rys. 6. Parametry Pinus Silvestris

6. References

[1] Austin B.C., Basinger D.H.: Some effects of burning on forest soil of western Oregon and Washington. Journal of Forestry, 1955, 4, 275-280.

[2] Bar S., Vega J.A.: Effects of wild-fires on forest soil in the nortwest of Spain. Freiburger Waldshutz Abhandlungen, 1993, 4, 181-195.

[3] Barros N.F., Preira A.R., Barba A.M.D.E.: Liberation of mineral nutriens by burning. Revista Arvare, 1982, 6, 84-89.

[4] Btterlicht, W.: Die Winkelzä.blprobe. - Allg. Forst. und Eolzwirtsch. Zeitung, 1948, 59, 4-5.

[5] Ceitel J., Szymański S., Barzdajn W., Zientarski J.: Badanie różnych sposobów wprowadzania lasu na obszary drzewostanów zniszczonych przez pożar w Nadleśnictwie Potrzebowice. Sprawozdanie końcowe z tematu koordynowanego przez IBL z Warszawie (BLP – 669). Katedra Hodowli Lasu UP w Poznaniu, 1997.

[6] Certini E.: Effects of fire on properties of forest soils: a review. Oecologia, 2005, Vol. 143, 1, 1-10,

[7] Everett R.L., Java-Sharpe B.J., Scherer G.R., Wilt F.M., Ottmar R.D.: Co-occurrence of hydrophobicity and allelopathy in sand pits under burned slash. Soil Sci. Soc. Am. J., 1995, 59,1176-1183.

[8] FAO.: Guidelines for soil profile description. Land and water Development Division FAO, Rome, 2006.

[9] Hawryś Z., Zwoliński J., Kwapis Z., Małecka M.: Rozwój sosny zwyczajnej na terenie pożarzysk leśnych z 1992 roku w Nadleśnictwach Rudy Raciborskie i Potrzebowice. Leśne Prace Badawcze, 2004, 2, 7-20.

[10] Imeson A.C., Verstraten J.M., van Mulligen E.J., Sevink J: The effects of fire and water repellence on infiltration and runoff under Mediterranean type forest. Catena, 1992, 19, 45-361.

[11] Instrukcja urządzania lasu. Instrukcja sporządzania projektu planu urządzenia lasu dla nadleśnictwa, 2012, Cz. I: 28-93.

[12] IUSS Working Group WRB: World reference base for soil resources 2014, update 2015. International Soil Classification System for Naming Soil and Creating Legends for Soil Maps. Food and Agriculture Organization of the United Nations, Rome, 2015.

[13] Januszek K., Lasota J., Gruba P., Domicz D.: Właściwości fizyczno-chemiczne i biochemiczne gleb bielicowych sześć lat po pożarze całkowitym lasu. Acta Agraria, Seria Silvestrica, 2001,39, 47-61.

[14] Johnson D.W., Curtis P.S.: Effects of forest management on soil C and N storage: meta analysis. For. Ecol. Manage, 2001, 140, 227-238.

[15] Kaczmarek Z., Gajewski P., Mocek A.: Wpływ sposobu przygotowania gleby oraz nasadzeń sosną zwyczajną o olszą szarą na właściwości gleb zdegradowanych przez pożar. Roczniki Gleboznawcze, 2011, 57(2), 164-171.

[16] Kaczmarek Z., Michalik J., Spychalski W.: Wybrane właściwości chemiczne i zawartość rozpuszczalnych w wodzie składników w glebach leśnych pożarzyska Potrzebowice w zależności od sposobu rekultywacji. Roczniki Gleboznawcze, 2004, 55(2), 201-209,

[17] Khanna P.K., Raison R.J.: Effect of fire intensity on solution chemistry of surface soil under a Eucalyptus pauciflora forest. Aust. J. Soil Res., 1986, 24, 423-434.

[18] Mocek A., Drzymała S.: Geneza, analiza i klasyfikacja gleb. UP w Poznaniu, 2010.

[19] Olejarski J.: Wpływ zabiegów agrotechnicznych na niektóre właściwości gleb oraz stan upraw sosnowych na pożarzyskach wielkoobszarowych. Leśne Prace Badawcze, 2003, 2 (954), 47-77.

[20] Polski Komitet Normalizacyjny: Polska Norma PN-R-04032: Gleby i utwory mineralne. Pobieranie próbek i oznaczanie składu granulometrycznego, 1998.

[21] Sharpley A.: Phosphorous availability. In: Sumner ME (ed) Handbook of soil science. CRC, Boca Raton, Fla., 2000, 18-38.

[22] Simard D.G., Fyles J.W., Paré D., Nguyen T.: Impacts of clearcut harvesting and wildfire on soil nutrient status in the Quebec boreal forest. Can. J. Soil Sci., 2001, 81, 229-237.

[23] Soil Conservation Service. Soil Survey laboratory methods manual. Soil Survey Invest. Raport No. 42., U.S. Dept. Agric., Washington, DC., 1992, 105-195.

[24] Suchocka M.: Wpływ zmiany warunków siedliskowych na stan drzewostanu na terenach inwestycji. Człowiek i Środowisko, 2011, 35(1-2), 73-91.

[25] Tarrant R.F.: Changes in some physical properties after a preseribed burn in joung ponderosa pine. Journal of Forestry, 1956, 7, 439-445.

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