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ORIGINAL RESEARCH ARTICLE

Chemical composition of soils on post-agricultural and forest sites before and after sawdust addition against the background of weather elements

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Abstract. We analysed changes in soil chemical properties (pH, C:N, N, P, K, Ca, Na) inside two forest areas chosen for renewal (Lubartów A and B) and within one post-agricultural site (Świerczyna) designated for afforestation with Scots pine. The experimental plots were located in areas known as persistent cockchafer grub spots. The Lubartów A site was not fenced and showed signs of wild boar activity. Analyses were carried out in the autumn of 2011 and spring 2012, prior to pine sawdust application to the soil and before tree planting, respectively, and again one year later in May 2013. Precipitation as well as air and soil temperatures were recorded throughout the experimental period. We found that soil temperature and humidity, determined by changes in weather, differences in soil chemical properties between forest and agricultural sites as well as sawdust treatments differentially affected soil reaction, C:N ratios and nutrient content. In the unfenced area (Lubartów A), the content of nutrient forms available to plants decreased no more under sawdust treatment than under control conditions. In the remaining areas, sawdust treatment caused an increase or no change in soil concentrations of the investigated nutrients. Under suitable temperature and humidity conditions, sawdust can represent a significant source of energy-rich compounds promoting diversified edaphone activity, which appears to be the main reason for changes in soil nutrient content.

Key words: chemical composition, fallow soil, forest soil, sawdust, weather parameters

1. Introduction

Microorganisms, mainly soil fungi, bacteria and the animal microworld (mites, nematodes), contribute to the mineralisation of the organic matter in the soil-forming processes for which the availability of energy sources, temperature and water is essential. Roots and, specifically, their wood containing cellulose, lignin, xylan, phenolic, terpene and other compounds as well as the metabolites of the microorganisms colonising them are, *inter alia*, such energy sources in the forest soil. The microbiological degradation of root wood contributes to results in humus formation (Lopez et al. 2006). Without inquiring into the nature of these complex biochemical processes described by, *inter alia*, Kowaliński and Gonet (1999), attention should be drawn to the availability of different types of ecological niches (sources of nutrients) in the forest soil for destruents. Their activity, associated with the implementation of their specific life processes, is used in environmental engineering to, *inter alia*, stimulate mycorrhiza formation (Różycki et al. 1986) during the remediation of the contaminated sites (Speir et al. 1992; Bielińska et al. 2009) or restoration of the structures of the forest environment, for example in former farmlands (Kwaśna et al. 2000). In such processes, sawdust

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from coniferous trees (Sierota, Kwaśna 1999) as well as wood chips or compost containing shoots and leaves (Siuta 2005; Oszako et al. 2005) are used.

The microbiological processes taking place in soils are determined by the elements of climate that is one of the most important soil-forming factors (Overby et al. 2003). It decides to a large extent the nature of rock weathering and influences the direction of soil-forming processes, determines temperature and water regimens that, in turn, affect the intensity of degradation and synthesis of mineral and organic compounds. Low soil temperatures in winter can also lead to changes in enzyme activity, denaturation of cellular structures or even the death of fungi and other organisms involved in soil formation processes, although it is not commonplace (Addy et al. 1994). The phenomena implicated by weather conditions, specifically its weather anomalies, alter the functioning of microorganisms and may result in the disappearance of individuals or whole populations, reducing the expected effect of their activity (Bardgett et al. 2008).

The way of land use (Thornley, Cannell 2000) is another important factor influencing the microbial processes in the soil. The soils of former farmlands (called post-agricultural land) differ from forest soils in many physicochemical and microbial properties, but primarily in the absence of tree root systems (as a food source for wood-decaying fungi) and the presence of the so-called ‘plough shoe’ impeding the proper development of root systems (Rykowski 1990). Although silvicultural operations in forestry tend to be less intense than in agriculture, their impact on the edaphon should not be ignored. The operation of clear-cutting changes, at least for some time, though most drastically, the soil conditions, including the edaphon activity. Its consequence is seen in the lack of litterfall (leaves, needles), disturbance in the growth of forest floor vegetation, reduction in the range of root system penetration and mycorrhizae, changes in water regimen and temperature as well as an increased infiltration of light accelerating the decomposition of the organic matter (Bekele et al. 2007).

The post-agricultural soils and clear-cut sites or cut patches in a forest stand are afforested or renewed relative to the type of the terrain. At the same time, such areas exposed to sunlight are favourable habitats for the development of cockchafers (Melolonthidae): egg deposition, a 4-year development cycle of grubs and, subsequently, the population growth of these insects (Malinowski 2007). The reduction of damage from grubs using non-chemical methods is one of the most important problems of integrated forest protection (Malinowski 2010). Sawdust application has long aroused interest both in view of the simplicity and availability of its acquisition as well as its physicochemical properties, allowing its easy penetration by fungi, bacteria or nematodes (Kwaśna et al. 2001). They give soil, especially the post-agricultural soil, a special structure, absorptivity and permanence in the environment. With the large energy resources contained in cellulose, lignin and xylan, the sawdust in the soil began to act as an elicitor of microbiological transformations used in many aspects. Sierota and Kwaśna (1998) demonstrated the possibility of applying conifer sawdust to post-agricultural soils as an energy source to increase the number of ubiquitous soil fungi of the genus *Trichoderma* colonising sawdust in the first place.

This was to ensure the inoculums of antagonistic fungi, effective against the pathogen *Heterobasidion annosum*, the main causal agent of tree dieback in former farmlands. Sawdust and wood residues were used both to accelerate the conversion of post-agricultural soils into forest soils (Olejarski et al. 2003) as well as to apply organic fertilisers to post-agricultural soils (Olejarski 2005). Sawdust is also used as a substrate to increase the yield of crop plants e.g. blueberries (Ochmian et al. 2007), oats, potatoes or wheat (Skowrońska 2007).

In the areas of persistent grub occurrence, sawdust was used as an elicitor of microbial processes in the soil. The rationale for doing so was to initiate or intensify the expected antifeedant or inhibitory reactions of soil bacteria and fungi to cockchafer larvae during the colonisation of roots and sawdust. The luring of insects by the carbon dioxide released during the decomposition of wood, a potent attractant for grubs, is also noteworthy (Galbreathab 1988; Weissteiner et al. 2012; Małecka et al. 2014). The presented results are part of the multifaceted research projects related to this issue.

The aim of the presented results was to determine the changes taking place in soil chemical composition one year after the application of pine sawdust to the forest soil in the cutting area and fallow post-agricultural soil, as well as after the planting of pine seedlings. These changes were discussed in relation to precipitation as well as air and soil temperature in the study period. The explanation of these relationships can help analyse changes in the activity of soil-colonising bacteria and fungi in the described areas also in the context of their impact on the number of grubs and the survival of seedlings (Małecka et al. 2014; Kubiak et al. in preparation; Kwaśna et al. in preparation).

2. Materials and methods

Selection of experimental sites and performance of the treatment

The experimental plots (sites) were located in the area of persistent grub occurrence indicated by Forest Protection Teams:

– The Lubartów Forest District (Lublin Regional Directorate of the State Forests), Jawidz Forest Sub-District, compartment 201c, a clear-cut area, fresh mixed deciduous forest habitat type (LMŚw) on brown rusty soil, developed from fluvioglacial sands, with grain size of loamy sand; unfenced site (Lubartów A; LA);

– The Lubartów Forest District, Jawidz Forest Sub-District, compartment 159a, a clear-cut area, fresh mixed deciduous forest habitat type (LMŚw) on brown rusty soil, developed from fluvioglacial sands, with the grain size of loamy sand, fenced site (Lubartów B; LB);

– The Świerczyna Forest District, (Szczecinek Regional Directorate of the State Forests), Laski Forest Sub-District, compartment 497f, fallow soil on post-agricultural land, podzolic rusty soil, developed from fluvioglacial sands, with the grain size of sand, fenced site (Świerczyna; SW).

In the autumn of 2011, three blocks of the future experimental plantation with a length of 40 m were set out on each site, and three strips of 1.2 m in width were selected for planting in each of them as different experimental variants (Fig. 1). In the spring of 2012, the following treatments were performed on the strips in each block:

– variant T1 – fresh pine sawdust was spread (0.3 m^3/row, 7.5 dm^3/running metre) on the soil surface in a strip of 40 cm in width and mixed with a soil cutter (Lubartów) or manually (Świerczyna) to a depth of about 30 cm;

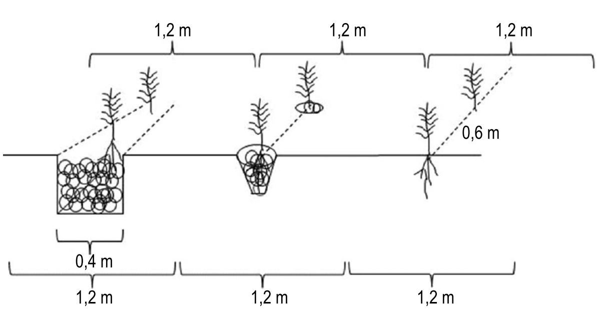

Figure 1. Layout of seedlings in variants T1, T2 and K in the experimental block

– variant T2 – sawdust was applied directly under the roots of pine seedlings during planting (0.3 dm^3 sawdust/seedling);

– variant K – control variant without sawdust application.

One-year-old Scots pine seedlings from local nurseries were planted in May 2012 at a spacing of 0.6 × 1.2 m immediately after sawdust application to the soil.

Meteorological conditions

The interpolated meteorological data from the nearest synoptic stations of the Institute of Meteorology and Water Management (IMGW) (Hydrometeorological Station (HMS) in Lublin and Chojnice, respectively) were used to assess the prevailing weather conditions in the experimental plots in the Lubartów and Świerczyna Forest Districts during the study period. The analysis took in the following meteorological parameters: monthly amount of precipitation, monthly average air temperature, minimum temperature at ground level and minimum temperature of the soil at a depth of 5 cm. The hydrothermal Sielianinov coefficient ($K = 10P/\Sigma t$) was calculated for the growing seasons from January 2011 to July 2013. The source data were taken from the generally available Bulletins of the National Hydrological and Meteorological Service.

Soil chemical analysis

Samples were taken when setting out experimental plots in September 2011 and May 2012 – before the treatment, and in May 2013 – after one year of plantation growth. Three soil samples were taken with a soil auger from a depth of 0–20 cm from each strip in variants T1 and K and from an area close to the roots in variant T2 to form a bulk sample. The study was performed in accordance with the methodology adopted in the international forest monitoring programme ICP Forests. Soil texture was determined using the pipette method according to ISO 11277, soil reaction (pH-H_2O and pH-KCl) by the potentiometric method according to ISO 103390: 1997, organic carbon content (%) by the elemental analysis according to BS ISO10694: 2002, total nitrogen content (%) by the elemental analysis according to PN-13878: 2002, the content of potassium, calcium, magnesium (mg/100g) in the extract of ammonium acetate according to the procedure PB-05 ed.2, and bioavailable phosphorus (P_2O_5) by the Egner-Riehm method converted to P (mg/100g). The analyses were performed in the

Laboratory of Forest Environment Chemistry of the Forestry Research Institute that has the accreditation certificate No. AB740 issued by the Polish Centre for Accreditation.

The two-way analysis of variance was applied and the *post-hoc* differences were assessed with Tukey's HSD test (Statgraphics™ Centurion programme) to evaluate the relationships between the treatment variant and the parameters of soil chemical elements in each of the sites, after the processing of the selected data (C%, N %, C:N ratio) in accordance with the formula by Bliss.

3. Results

Weather elements

Atmospheric precipitation

The summer preceding the period of sawdust application to the soil was wet, with precipitation in July amounting to approximately 165 mm in Lubartów and 125 mm in Świerczyna, the highest in entire 2011 (Fig. 2). In turn, the autumn of 2011 saw a drastic shortage of precipitation, which was the highest in September in Lubartów (5 mm). In the winter of 2011/2012, the amount of precipitation on both sites was similar to that in the spring of 2012; the exceptionally heavy rainfalls started from June 2012, especially on the Świerczyna site, where they exceeded 135 mm in July 2012. In turn, the precipitation in Lubartów in October abounded to 90 mm. The winter 2012/2013 in this region was quite snowy and together with the rainfalls from March to July (113 mm in June) supplemented the soil moisture deficit. In Świerczyna, in turn, the rainfall in March and April was light (about 20 mm), and only the rainfall of 70–80 mm in the period of May–July increased the soil moisture content.

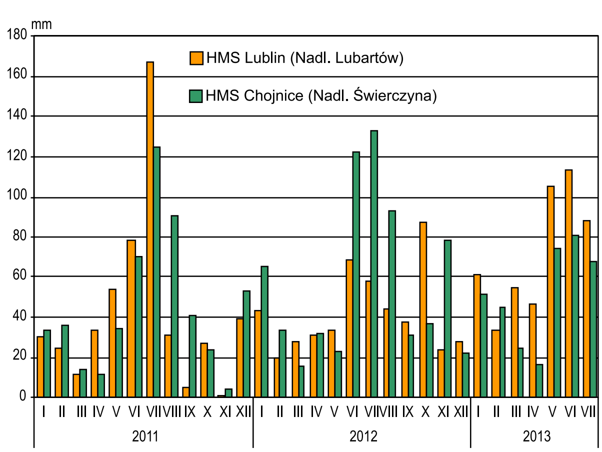

Figure 2. Atmospheric precipitation in 2011–2013 in the Lubartów and Świerczyna experimental plots (HMS – Hydrometeorological Station, Nadl. – Forest District)

Monthly mean air temperature

The lines describing the monthly mean air temperature in the two sites in 2011–2013 were similar, with larger fluctuations occurring only periodically (Fig. 3). In the summer of 2011, slightly higher mean air temperatures were recorded in Lubartów, while in the winter of 2012 (February), they were a few degrees lower than in Świerczyna. Beginning from April 2012, the temperatures in Lubartów remained higher than in the Świerczyna site and this state continued until September. The winter of 2012/2013 was rather mild for both sites, for example, the mean air temperature in February was below -2°C. The spring of 2013 was mild, with the average temperature in May amounting to 14–15°C in both sites, while the temperatures in June and July were higher than the average.

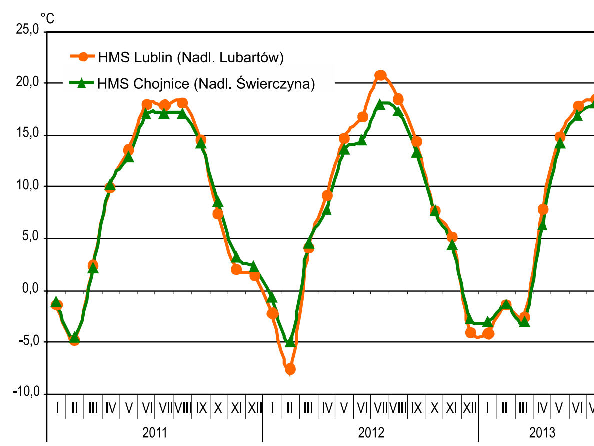

Figure 3. Monthly mean air temperature in 2011–2013 in the Lubartów and Świerczyna experimental plots (HMS – Hydrometeorological Station, Nadl. – Forest District)

Minimal ground temperature at a depth of 5 cm

The lowest minimum winter temperature at ground level in the subsequent years of observations was recorded in the Lubartów site in February 2011 and 2012, reaching almost -8.0°C (Fig. 4). The winter 2013 was milder; the ground temperature did not fall below -2.0°C. Soil minimum temperature in the growing season was similar on both sites, while in the summer months, it oscillated between 11.0 and 12.0°C.

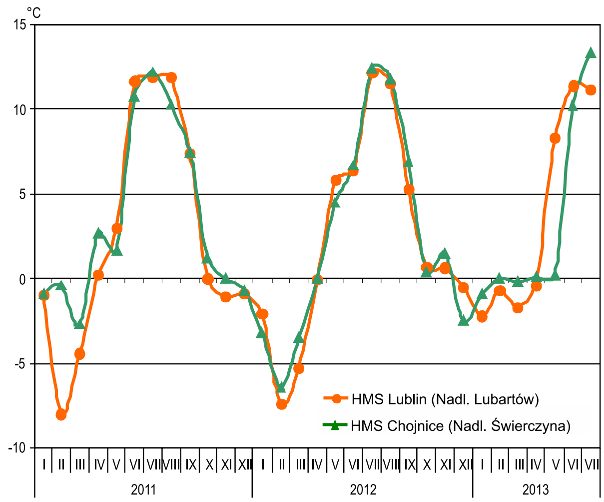

Figure 4. Minimal temperature at ground level at a depth of 5 cm in 2011–2013 in the Lubartów and Świerczyna experimental plots (HMS – Hydrometeorological Station, Nadl. – Forest District)

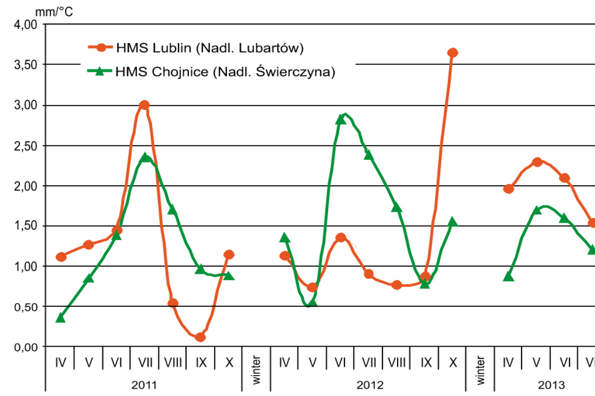

Figure 5. The values of the hydrothermal coefficient in individual months of the growing season 2011–2013 in the Lubartów and Świerczyna experimental plots (HMS – Hydrometeorological Station, Nadl. – Forest District)

Hydrothermal coefficient *K*

The values of hydrothermal coefficient *K* describing the relationship between air temperature and rainfall during the growing season reflect, in a synthetic way, changes in these meteorological elements of the weather. Only in the summer of 2011, the growth conditions in Lubartów were better than in Świerczyna to rapidly worsen from August (Fig. 5). The spring of (from May) 2012 was very conducive to plant growth on both sites. The situation improved in June and July, especially in Świerczyna when the coefficient reached 2.5–3.0 (long-term mean value of the coefficient for this site is 1.44). During this time, the growth conditions for plants on the Lubartów site might be described as unfavourable (drought, $K<1$). The weather conditions in September 2012 deteriorated in the Świerczyna site and the hydrothermal coefficient was 0.78, which was indicative of a very serious disturbance in plant growth by the end of the growing season. The weather conditions in the Lubartów site in September were similar. Surprisingly, the end of the growing season (October) in both sites saw an improvement in moisture conditions, especially in the Lubartów site, which was reflected in a very high hydrothermal coefficient $K = 3.7$. The spring and early summer of 2013 in this region were conducive to the development of plants, while the thermal and moisture conditions in the Świerczyna site were slightly worse.

Soil chemical parameters

The comparison of soil chemical properties in the same variants assessed in the autumn of 2011 and the spring of 2012 shows many significant changes both between the two sites and assessment dates (Table 1). They were particularly visible in the Lubartów A site where, in a few months, soil pH significantly increased from pH 4.53 to pH 4.91 (in Lubartów B from pH 4.52 to pH 4.68). In the spring of 2012 (before planting), a threefold increase in the magnesium content, a twofold increase in the calcium content and a significant increase in the content of potassium and phosphorus in the soil were recorded on the Lubartów A site. A twofold increase in the share of nitrogen with a slight increase in the share of carbon entailed changes in the value of C:N ratio; in the Lubartów A site, this ratio decreased from 27 in the autumn of 2011 to 14 in the spring of 2012 (in the Lubartów B site from 21 to 14, respectively). In turn, the content of the analysed elements in the soil in the Lubartów B site decreased (though not statistically significantly). The share of nitrogen and carbon in the soil also decreased. The value of C:N ratio in the studied sites at both soil analysis dates was higher in the soils on clear-cuts (Lubartów A and B) than in the fallow soils on post-agricultural land (Świerczyna).

The differences in the values of soil chemical properties on the Świerczyna site measured in the autumn of 2011 and spring of 2012 were not statistically significant. The analyses indicated a generally less acidic soil pH in the Świerczyna site compared with the Lubartów site. This was confirmed by a higher content of exchangeable

Table 1. Mean values of the examined soil properties, *F* values and significance p values in the Analysis of Variance (ANOVA) in the autumn of 2011 and spring of 2012, prior to sawdust application and planting (control variant).

Sites	Dates/ ANOVA	pH-H_2O	pH-KCl	Ca	Mg	K	P	N	C	C:N
				mg/100 g				%		
LA	autumn 2011	4.53	3.69	8.94	0.82	4.58	1.68	0.082	2.24	27.26
	spring 2012	4.91	3.85	19.77	2.93	7.24	2.46	0.163	2.31	14.25
	F	18.23	25.51	20.96	51.75	11.98	9.53	104.42	0.42	85.54
	p	**0.0130**	**0.0072**	**0.0102**	**0.0020**	**0.0258**	**0.0367**	**0.0005**	**0.5521**	**0.0008**
LB	autumn 2011	4.52	3.55	21.98	2.73	6.82	3.07	0.15	3.22	21.48
	spring 2012	4.68	3.80	9.01	1.34	4.09	1.03	0.09	1.28	14.56
	F	0.67	2.14	4.82	4.05	1.58	3.40	32.27	157.55	63.51
	p	0.4598	0.2171	0.0930	0.1144	0.2772	0.1388	**0.0047**	**0.0002**	**0.0013**
SW	autumn 2011	5.92	4.61	36.57	3.66	7.78	7.46	0.079	1.07	13.07
	spring 2012	5.97	4.55	31.11	4.02	9.06	4.65	0.097	1.03	10.56
	F	0.10	0.12	0.18	0.14	0.70	5.52	1.28	0.00	4.38
	p	0.7713	0.7483	0.6971	0.7250	0.4497	0.0786	0.3213	0.9640	0.1046

Bold letters indicate significant differences between the means ($p < 0.05$)

calcium in the soil exceeding the value of 30 mg/100 g in 2011 and 2012 compared with 19–20 mg/100 g in the Lubartów A and Lubartów B sites (Table 1).

The soil analysis after one year of the experiment showed some changes in the chemical properties of soils. Compared with the initial state (spring 2012), soil pH underwent a slight but statistically significant change; significant differences were also found in the content of individual elements (Table 2). The content of Ca, Mg, K and P ions (especially calcium) after one year of the experiment in the Lubartów A site was higher than in the control, and lower in the plots where sawdust had been applied. The content of magnesium, potassium and phosphorus in variants T1 and T2 was similar compared with the control.

The soil analysis after one year of the experiment showed a reduction in soil pH. The phosphorus content did not change much, and the application of sawdust in the T2 variant (spot application) resulted in a reduction of other elements in the treated plots. The plots without sawdust enrichment showed a lower content of these elements compared with the previous year (Table 2).

The content analysis of the examined elements in the control soil samples taken for testing from the Świerczyna site showed no significant changes in soil pH, element content and C:N ratio between the spring of 2012 and the spring of 2013 (Table 2). The application of sawdust to the soil in the T1 variant caused a significant increase in the amount of calcium compared with the control and its slight increase compared with T2 variant. No significant differences were found in the content of magnesium, potassium and phosphorus between the control soil (no sawdust application) and the soil before the treatment.

The assessment of differences in the content of carbon and nitrogen in the examined soils shows that, after one year of growth of pine seedlings, the share of calcium and, to a lesser extent, nitrogen decreased, except for the Lubartów B site in the control (K) and sawdust application variant (T2) (Table 2). The application of sawdust in variant T1 resulted in an increase in the carbon content in the soil in all sites, with the largest recorded in the Lubartów A site. The amount of carbon in the soil where sawdust was spot applied (variant T2) was always lower than in the control. In general, the share of carbon in the Lubartów A site was almost twofold higher than in the Lubartów B site and almost 2.5 times higher than in the post-agricultural soil of the Świerczyna site. The share of nitrogen in the soil was at a similar level in all study sites.

4. Discussion and conclusions

The decrease in the soil organic carbon (SOC) resources after clear-felling is mainly due to mixing ectohumus rich in organic matter and topsoil with deeper mineral layers (Nyland 2001; Yanai et al. 2003). In consequence, the destruction of soil increases microbial respiration (Besnard et al. 1996; Diochon et al. 2009) that, in the case of extremely unfavourable harvesting

Table 2. Mean values of the examined soil properties, *F* values and significance p values in the Analysis of Variance (ANOVA) in the spring of 2012 and the spring of 2013, after sawdust application and planting (treatment variants: K – control, without sawdust, T1 – sawdust mixed with soil in rows, T2 – sawdust applied under seedlings).

Sites	Dates/ANOVA	Treatment variant	$pH\text{-}H_2O$	pH-KCl	Ca	Mg	K	P	N	C	C:N
					mg/100 g				%		
LA	spring 2012	initial state	4.91 b	3.85 b	19.8 b	2.93 c	7.63 b	2.46 b	0.16 c	2.31 d	14.25 b
	spring 2013	K	4.84 b	4.80 d	50.0 a	5.79 d	14.69 c	5.36 c	0.12 b	1.64 b	13.30 a
		T1	4.70 a	3.70 a	17.0 b	2.22 b	4.04 a	1.23 a	0.15 c	2.11 c	14.10 b
		T2	5.00 c	4.00 c	12.0 c	1.53 a	3.76 a	1.69 a	0.10 a	1.36 a	13.20 a
	F		46.84	949.85	374.41	165.93	1570.75	87.6	55.47	171.91	21.36
	p		**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0004**
LB	spring 2012	initial state	4.68 a	3.8 a	9.1 bc	1.34 b	4.09 d	1.03 ab	0.09 b	1.28 b	14.56
	spring 2013	K	4.80 b	3.8 a	8.0 b	0.78 a	2.28 a	0.95 a	0.09 b	1.29 b	13.80
		T1	5.00 c	3.8 a	10.0 c	1.31 b	3.60 c	1.11 b	0.10 c	1.43 c	14.70
		T2	4.70 a	3.9 b	5.0 a	0.64 a	2.56 b	0.93 a	0.08 a	1.10 a	13.80
	F		177.33	42.86	27.34	64.84	331.53	11.50	28.95	31.26	2.68
	p		**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0028**	**0.0001**	**0.0001**	0.1181
SW	spring 2012	initial state	5.97 ab	4.54 a	31.1 ab	4.02	9.06	4.65	0.097	1.03	10.60
	spring 2013	K	5.80 a	4.40 a	25.0 a	3.16	6.07	4.68	0.092	0.95	10.40
		T1	6.20 b	4.90 b	47.0 b	4.32	7.65	4.44	0.092	0.99	10.80
		T2	6.10 b	4.70 ab	34.0 ab	3.40	5.02	3.77	0.085	0.90	10.70
	F		7.20	7.75	4.29	3.04	1.70	3.42	1.30	1.49	2.12
	p		**0.0116**	**0.0094**	**0.0443**	0.0929	0.2433	0.0728	0.3407	0.2901	0.1761

Bold letters indicate significant differences between the means ($p < 0.05$)

techniques, may lead to a loss of 20 ± 2.5 Mg C of SOC per hectare. Covington (1981) estimated that in the first 20 years after clear-cutting, the SOC resources rapidly decreased by 50% or even more. Zummo and Friedland (2011) demonstrated that differences in the soil carbon content due to the use of extremely favourable or unfavourable harvesting techniques may arrive at 25% of the total SOC pool. A similar effect (though lasting only for one year) of partial mixing of the upper soil horizons seems to be the result of wild boar rooting in the plantation on the Lubartów A site (fenced plantation).

The comparison of the initial organic carbon content with its amount in the soils of the control variants showed a rapid decomposition of organic matter in the two sites located in the clear-cut area (LA and LB). Between the spring of 2012 and the spring of 2013, the SOC content in the LA site decreased by as much as 29%. The mineralisation rate was also affected by weather conditions, especially by high air temperature in the summer. The decomposition of organic matter in the SW site (fallow soil on post-agricultural land) was much less intense, probably in the absence of fungi decomposing cellulose and lignin. This was also confirmed by a constant C:N ratio oscillating around 10, characteristic of agricultural soils. In the fallow soil, there was a balance between the amount of C supplied to the soil with plant residues and the loss of C through, first of all, the decomposition of the organic matter.

The increased edaphon activity (Yanai et al. 2003) under the clear-cut conditions results in an increase in the rate of mineralisation of the organic matter to simple inorganic compounds such as CO_2, NH_3, H_2O, NO_3-, SO_4^{2}- or HPO_4^{2}- ions. The rapidly reproducing edaphon uses soil nutrients to build its organisms, competing for them with higher plants. This phenomenon is known as biological sorption (immobilisation). A clear, gradual decrease in the pool of exchangeable and absorbable forms of nutrients was observed in the soils of the studied sites (LA and LB) located on clear-cuts. This was due to the uptake of these components primarily by the edaphon (Kubiak et al., in preparation) but also by higher plants mainly by the ectomycorrhizal mycelium (Smith, Read, 1997). In the post-agricultural soils (SW) where the mineralisation of organic matter by the edaphon was not so intense (Kubiak et al., in preparation), a decrease in the number of exchangeable and absorbable forms of nutrients in the soil was insignificant.

The additional amounts of nitrogen, phosphorus, potassium, calcium and magnesium were brought to the soil enriched with the organic matter in the form of conifer tree sawdust. As a result of microbial degradation of sawdust primarily by the copiothrophic bacteria and some fungi, the mineral forms of these nutrients were released (Kubiak et al., in preparation; Kwaśna et al., in preparation). They were consumed by the edaphon (secondary immobilisation) or remained in the soil in the exchangeable or absorbable forms. An increase, decrease or no change in the content of N, P, K, Ca, and Mg in the soils might be the net effect of the treatment.

Comparing the initial state of the soils *i.e.* without sawdust application (spring of 2012 and the spring of 2013 – control plot K), the content of exchangeable forms of calcium, magnesium, potassium and absorbable forms of phosphorus in the Lubartów A (fenced) site markedly increased. This was probably due to the activity of wild boars and their droppings. The spring of 2013 showed a decrease in the content of nutrients available for plants in the soil of LA site mixed with sawdust in comparison with the control soil. The rooting of wild boar, causing aeration of the soil, and the presence of their urea in the soil might have increased the content of cations in the tested compounds, including a twofold increase in the share of nitrogen (N%), even in the absence of sawdust in the control. In the same period, no increase in the nutrient content on the fenced LB and SW sites was recorded.

Irrespective of the study site, the nutrient content in the soil was higher in the T1 variants in which sawdust was used in rows at a dose of 0.3 m^3/row than in the T2 variants in which sawdust was applied directly under plant roots during planting at a dose of 0.3 dm^3 sawdust/plant. This was due to the higher edaphon activity in T2 variants (Kubiak et al., in preparation; Kwaśna et al., in preparation) determined by a large spot concentration of the organic matter, and hence the increased biological sorption of nutrients.

Through such elements as temperature, amount of precipitation and volume of evapotranspiration, climate exerts a strong influence on the activity of the edaphon, organic matter accumulation rate and other physicochemical properties of soils (Post et al. 1982; Andrews et al. 2000; Gulledge, Schimel 2000; Prichard et al. 2000; Wilcox *et al*. 2002). Short-term changes are, however, difficult for an explicit interpretation, while the results obtained during the two-year study are only signal information about the ongoing changes.

The results indicate that:

– the thermal and moisture conditions resulting from the weather conditions in the study period, differences in the chemical composition of forest and post-agricultural soils, as well as sawdust application affected, in different ways, changes in soil pH, the C:N ratio and the values of the examined chemical properties of soils;

– an increase in the content of the available forms of nutrients for plants was found in the soil on the unfenced site (Lubartów A), which is associated with wild boar rooting;

– the application of sawdust to the soil resulted in an increase or no change in the content of the tested elements, depending on the way it had been placed under the plant;

– changes in the soil nutrient content can be explained primarily by the increased activity of bacteria and fungi for which sawdust, at the appropriate temperature and moisture conditions, is an important source of energetic compounds (unpublished results) and therefore can be considered as an elicitor.

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