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IMPACT OF FOREST LITTER OF *ALNUS GLUTINOSA* (L.) Gaertn., *ALNUS INCANA* (L.) Moench, *ALNUS VIRIDIS* (Chaix) Lam. et DC, *ABIES ALBA* Mill., AND *FAGUS SYLVATICA* L. ON CHOSEN SOIL PROPERTIES

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ABSTRACT

The research covered the impact of forest litters on the content of organic carbon, nitrogen and other macroelements as well as the soil reaction. Forest litter samples were obtained from black (*A. glutinosa*), grey (*A. incana*) and green (*A. viridis*) alder forests as well as from beech (*Fagus sylvatica*) and fir (*Abies alba*) forest. Compared to beech and fir trees alders enrich soil with organic carbon and nitrogen much stronger. Out of the three studied alder species the green one enrich the soil most intensively.

Key words: nitrogen, forest soils, litter, alders.

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INTRODUCTION

Forest litter is an organic layer of dead plant and animal parts undergoing different stages of decomposition processes on top of the soil. In forests with years long life cycle, litter is a major source of nutrients systematically enriching the soil [6, 11, 16, 18, 23].

Forest litter decomposition process has often been studied. In the recent years many researchers concentrated on the speed of the process and return to soil of nutrients and thus nitrogen mineralisation in pure or mixed stands [14, 17, 25]. A numerous tree species stimulating the litter creation process may be divided into at least two groups. One of them are the species absorbing atmospherc nitrogen, while the second group of species without this specific ability. The group of species includes mainly alders, playing a significant role in silviculture. The impact of the falling organic elements of various alders is mainly soil enrichment with nitrogen and humus [2, 3, 8, 9]. This is reflected in higher level of fertility in poor sites [20, 26], but at the same time may lead to soil acidification and cation leaching [4, 5, 21].

The aim of this research was to analyze the impact of litters of three domestic alder species growing in southern Poland on chosen soil properties and comparing to the impact of litter of the main species of the lower forest zone of Carpathians in Poland, i.e. beach and fir.

METHODS

The research was held in controlled laboratory conditions. The experiment involved soil samples incubation with a layer of litter in optimal conditions for a 2-month period. The 1300 gram of soil was put in PCV cylinders with 11 cm of diameter. Each soil sample was covered with a layer of 17.7 g of dry litter. The litter was regularly sprinkled with distillated water, which is basically equal to a yearly rainfall of 600 mm. Another control soil samples without litter were also used. Litters for analysis were obtained in Bieszczady, in the late autumn of 1999, from soil surface in forest sites comprising the above-mentioned tree species [24]. The soil and litter propertiesbefore inkubation were determined with the following metods: pH in H_2O, organic carbon (C) with Tiurin method, total nitrogen (N) with Kjeldahl method and total K, Ca, Mg with ASA method after mineralization in a mixture of concentrated $HClO_4$ and HNO_3 (Tab.1).

Table 1. Basic properties of litters and soil before incubation.

Type of litter / soil	pH in H_2O	C (%)	N (%)	C/N	Ca (%)	K (%)	Mg (%)
Fagus sylvatica	5.0	47.40	1.92	24.7	1.15	0.30	0.17
Abies alba	4.6	51.44	1.99	25.8	0.86	0.17	0.07
Alnus incana	5.7	56.11	3.45	16.2	1.34	0.21	0.23
Alnus glutinosa	6.2	51.47	3.59	14.3	1.80	0.27	0.18
Alnus viridis	5.0	49.64	3.23	15.4	1.06	0.25	0.26
Soil	4.4	0.45	0.037	12.2	0.0059	0.0019	0.0009

The soil sample used in an experiment is a *luvic* horizon from *haplic luvisol* [12] developed of loess, from Kraków surroundings, with sand fraction (1.0-0.1 mm) amounted to 11%, silt fraction (0.1-0.02 mm) - 60%, siltand clay fraction (<0.02 mm) - 29% and clay fraction (<0.002 mm) - 9%. Fraction content was determined with areometric method. After the experiment was completed the surface soil layer in cylinders (0-3 cm and 3-6 cm) were analyzed as follows: soil pH in H_2O and 1M KCl, organic carbon (C) with Tiurin method, total nitrogen (N) with Kjeldahl method, dissolvable in 0.03 mol x dm^{-3} CH_3COOH - K, Ca, Mg forms with ASA method, easy hydrolizing nitrogen with Tiurin and Kononowa method [1].

The results were elaborated statistically with (ANOVA) variation method, through homogeny Levene test. Significance of differences between respective averages was tested with Tukey test [7, 19].

RESULTS

A major difference in the total content of nitrogen between alder litter and beech and fir litter affected the experiment results. The amount of nitrogen in alder litter was over 60% higher than in beech or fir litter (Tab.1). Consequentially the ratio C/N in analyzed litters varied from 14.3 to 25.8, which resulted in a different level of

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susceptibility to microbiological decomposition. The decomposed litter products penetrated the soil when watered in a rainfall imitating process and considerably modified soil properties.

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The impact of analyzed litters on the soil reaction.

Reaction changes as effected by litters in the experiment were of minor character. In 0-3 cm level all 3 species of alder litters slightly alkalized the soil (Tab.2). *Alnus viridis* had the largest share in the process with *Alnus glutinosa* and *Alnus incana* following. Slight alkalization affected by alder litter was limited to the level of 0-3 cm. This is the level where *Fagus sylvatica* and *Abies alba* litters reacted in the opposite way than alder litters i.e. slightly acidified the soil. With respect to the control sample, statistically significant differences in pH changes of H_2O was observed only with *Alnus viridis*, and in case of pH in KCl with *Alnus glutinosa* and *Alnus viridis* (Tab.2). Slight soil alkalization with alder litter was probably achieved with the litter reaction itself. There was probably no nitrification in the analyzed period, which causes acidification in natural alder sites conditions [3, 21]. The first signs of nitrification in decomposing fresh leaves and needles were observed after about half a year [10, 27].

Table 2. Reaction (pH), organic carbon (C), total (N) and hydrolizing (Nh) nitrogen in soil after incubation with studied litters (means) and significance of differences with control samples (O)

Type of litter or – O	Depth (cm)	pH		C	N	Nh	
		in H_2O	In KCl	(%)		(% of total N)	(mgx100 g^{-1})
O	0 – 3	4.40	3.68	0.426	0.038	9.58	3.57
Fagus sylvatica	0 – 3	4.40	3.65	0.492	0.042	13.01	*5.49
Abies alba	0 – 3	4.33	3.64	0.506	0.045	13.48	**6.15
Alnus incana	0 – 3	4.51	3.72	0.539	*0.050	17.06	***8.63
Alnus glutinosa	0 – 3	4.56	***3.81	0.555	***0.057	26.57	***15.36
Alnus viridis	0 – 3	***5.04	***3.85	0.683	***0.074	29.12	***21.40
O	3 – 6	4.47	3.71	0.419	0.038	8.31	3.16
Fagus sylvatica	3 – 6	*4.36	*3.68	0.428	0.038	11.38	***4.36
Abies alba	3 – 6	4.39	3.70	0.426	0.039	11.78	***4.62
Alnus incana	3 – 6	**4.35	3.68	0.426	0.039	15.10	***5.89
Alnus glutinosa	3 – 6	***4.23	3.68	0.423	**0.045	20.44	***9.03
Alnus viridis	3 – 6	*4.60	3.70	0.434	***0.044	18.29	***8.10

O - control sample - soil incubated without litter
p - significance level: * <0.05 ** <0.01 * <0.001**
n = 7

The impact of analyzed litters on organic carbon content in soil.

The highest increase in organic carbon content in soil was observed in the level of 0-3 cm under *Alnus viridis* (60% more than in the control sample) (Tab.2). A smaller soil enrichment with organic carbon was observed successively under: *Alnus glutinosa*, *Alnus incana*, *Abies alba* and *Fagus sylvatica*. The increase of organic carbon content in incubated samples with litters in this level was significant but highly verified and thus statistically speaking unimportant.

In the level of 3-6 cm the amount of organic carbon was similar to the carbon content in the control sample and statistically insignificant (Tab.2).

The impact of analyzed litters on total nitrogen content in soil.

In the level of 0-3 cm the total nitrogen content was 0.037% (Tab.2). Only soil with alder litters represented statistically higher total nitrogen content than the control sample and especially under *Alnus viridis* (88.9% more) and *Alnus glutinosa* (42.9% more), where the significance level (p) was lower than 0.001 (Tab.2). Nitrogen in soil incubated with the three species of alders was most variable. Furthermore soil incubated with *Alnus viridis* represented higher, statistically significant content of total nitrogen compared to the all other litters used in inkubation.

The level of 3-6 cm represented a higher statistically significant content of total nitrogen only in the soil covered with *Alnus viridis* and *Alnus glutinosa*, by respectively 9.1% and 12.0% more than in the control sample - O (Tab.2).

The impact of analyzed litters on the amount of hydrolizing nitrogen in soil.

The content of hydrolizing nitrogen in soil level of 0-3 cm of the control sample amounted to 3.57 mg x 100 g^{-1} (Tab.2). The incubated soil with various litters showed a 6.0 times higher content of hydrolizing nitrogen, with *Alnus viridis*, 4.3 times higher with *Alnus glutinosa*, 2.4 times with *Alnus incana* and 1.5 times with *Fagus sylvatica*, and 1.7 times higher with *Abies alba* (Tab.2). Under *Alnus viridis* hydrolizing nitrogen made as much as 29% of total nitrogen (Tab.2), which is reflected in a speedy decomposition process. The average amount of hydrolizing nitrogen in soil incubated with various species of litter was in all cases statistically significant and higher than in the control sample (Tab.2). The level of 3-6 cm hydrolizing nitrogen content in control sample was 3.16 mg x 100 g^{-1} of soil and during incubation increased by 186% (*Alnus glutinosa*), by 156% (*Alnus viridis*), by 87% (*Alnus incana*), by 46% (*Abies alba*) and by 38% (*Fagus sylvatica*) (Tab.2). All were statistically significant cases higher than in the control samples. Hydrolizing nitrogen represented 11% (*Fagus*, *Abies*) to 20% (*Alnus glutinosa*) of total nitrogen.

The impact of analyzed litters on the cation level in soil.

Calcium - Ca
The level of 0-3 cm Ca amounted to: 6.28 mg x 100 g^{-1} of soil respectively ("O" sample) and increased after incubation by 234% (*Alnus glutinosa*), 161% (*Alnus incana*), 85% (*Abies alba*), 68% (*Alnus viridis*), 66% (*Fagus sylvatica*) (Tab.3). It was statistically significantly higher under all five types of litters than in the control sample (Tab.3). The highest level of soil enrichment with calcium was observed in incubation with *Alnus incana* and *Alnus glutinosa* litters.

In the level of 3-6 cm impact of various litters was weak and compared to the control sample there were no significant differences between average calcium amount in soil incubated with litter.

Potassium – K
The level of 0-3 cm K content was 1.81 mg x 100 g^{-1} of soil ("O" sample) and during incubation increased by 129 % (*Fagus sylvatica*), 121 % (*Alnus glutinosa*), 113 % (*Alnus viridis*), 81% (*Alnus incana*), 41% (*Abies alba*) (Tab.3). The level of 3-6 cm represented potassium in amounts ranging from 2.43 (*Abies*) to 3.95 mg/100 g of soil (*Alnus glutinosa*) (Tab.3). These were amounts higher by: 29.1% and 109.5% respectively than in the control sample.

In both analysed cases the average potassium level in soil incubated with litter was statistically significant and higher than in the control sample. The soil enrichment with potassium was most visible after incubation with *Alnus glutinosa*, *Alnus incana* and *Fagus sylvatica*, which had the highest level of potassium before incubation (Tab.1).

Magnesium – Mg
The level of 0-3 cm represented Mg in 0.96 mg x 100 g^{-1} of soil ("O" sample) and due to incubation increased by 198% (*Alnus incana*), 129% (*Alnus viridis*), 123% (*Alnus glutinosa*), 71% (*Fagus sylvatica*), 24% (*Abies alba*) (Tab.3). Except for the soil under *Abies alba* these were higher figures, statistically significant compared to the control sample.

In the level of 3-6 cm statistically significant enrichment of soil with magnesium was visible only under *Alnus incana* (Tab.3).

Table 3. The average content of macroelements in soil after incubation with the five types of litters and with respect to to difference significance based on the control sample (O)

Type of litter or O	Soil depth in cylinders (cm)	Ca	K	Mg
		(mg x 100 g^{-1})		
O	0 – 3	6.28	1.81	0.96
Fagus sylvatica	0 – 3	**10.45	***4.15	***1.65
Abies alba	0 – 3	***11.65	***2.55	1.19
Alnus incana	0 – 3	***16.42	***3.27	***2.87
Alnus glutinosa	0 – 3	***20.99	***4.00	***2.15
Alnus viridis	0 – 3	***10.55	***3.87	***2.21
O	3 – 6	7.09	1.89	1.07
Fagus sylvatica	3 – 6	6.95	***3.47	1.13
Abies alba	3 – 6	7.31	***2.43	1.00
Alnus incana	3 – 6	8.25	***3.24	***1.59
Alnus glutinosa	3 – 6	9.65	***3.95	1.29
Alnus viridis	3 – 6	6.31	***2.66	0.92

O - control sample - soil incubated without litter
p - significance level: * <0.05 **<0.01 *<0.001**
n=7

DISCUSSION

The impact of litters on soil in the above experiment is most significant in the content of total and hydrolising nitrogen, secondly less but still significant in the content of the remaining nutrition elements and it was weakest in soil reaction (Tab.2 and 3). Due to a short period of the experiment most significant are differences observed between the impact of various litters, and less important are amounts of various constituents penetrating the soil. Fresh organic matter needs time for the decomposing process to begin but movement of crumbled litter and its elements may proceed in the form of organic elements. This is reflected in the results as largest variations refer to the amount of organic matter, total and hydrolising nitrogen. The latter is made of simple organic elements easily mineralised. Nitrogen compounds decompose from organic to the first mineral forms may take up to about 1/2 years in maple, beech or oak litter, anf still longer in coniferous species [10, 27]. This is why in the experiment hydrolising nitrogen was analysed. Knowing its content in soil enables better assessment of nitrogen availability for plants as well as susceptibility to decompose of nitrogen organic compounds in given litters.

The results of the experiment prove that out of five analysed litters *Alnus viridis* has the most advantageous impact on the increase of hydrolising nitrogen in soil with *Alnus glutinosa* and *Alnus incana* as the following and eventually *Abies alba* and *Fagus sylvatica*. The same sequence was noted for the impact of litter on the level of total nitrogen in soil. The experiment presents a interspecies variation of alders, as well as dissimilarity from basic forest species which in case of the research area was beech and fir. At the same time the analysis reveals that hydrolising nitrogen provides reliable information as to the stage of litter decomposition process. Additionally it is a source of information as to the amount of inflow of elements in advanced decomposition process.

Alders, tree species with the ability to atmospheric nitrogen fixation are used in difficult post-industrial area afforestation [13, 15], as well as to improve trophic conditions of poor forest sites. The use of alders introduced as admixture is related to numerous growth problems such as space competition with target species. The forests of Southern Poland have two species of alder trees (*A. glutinosa and A. incana)* as well as one shrabby type of alder (*A.viridis).* Their impact on soil enrichment with nitrogen is not identical. This is due to the capacity of the above species to atmospheric nitrogen fixation, as well as to the amount of litter produced. Alder tree species are considered to be providing more nitrogen to soil in comparison with shrabby forms [15], although the opinions differ [22]. Shrabby alder species (*A. viridis*) provide the soil with clearly less litter. However their intensity of atmospheric nitrogen fixation may be higher than in case of the remaining alders, as revealed by the research. This gives reasons for considering *A. viridis* as a standard species in biomelioration of forest site. However due to specific growth properties resulting in shrabby forms and light-requirement, it may not substitute tree species

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as admixture in forests. Optimal sites include open space area such as post-industrial regions with the aim to introduce any green areas as well as high erosion risk areas, where *Alnus viridis* may have supportive and stabilising function.

SUMMARY AND CONCLUSIONS

The experiment held under optimal conditions with the same amount of dry litter revealed that the increase of organic matter and total nitrogen in soil is strongest influenced by *Alnus viridis*, and following by *Alnus glutinosa*, *Alnus incana*, *Abies alba* and *Fagus sylvatica*. Soil enrichment with alkaline cations represents similar but modified sequence.

The following conclusions result from the research:

- enrichment of soil with humus and nitrogen by litter in all analysed *Alnus* species is far stronger compared to *Fagus* and *Abies*.
- out of three analysed alder species *Alnus viridis* is the one providing the soil with most humus and nutrition elements.
- alder litter properties justify the use of the species as biomelioration in the improvement process of poor soils.

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