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SHORT-TERM IMPACT OF NITROGEN FERTILIZER AND WOOD ASH ON FOREST GROUND VEGETATION

Guna Petaja, Ilze Kārkliņa, Zaiga Zvaigzne

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The aim of the study was to determine a short-term impact of nitrogen fertilizer and wood ash on floristic composition and species diversity of forest ground vegetation. The study was conducted in 11 forest stands representing *Myrtillosa*, *Hylocomiosa* and *Oxalidosa turf. mel.* forest types. The mean projective cover of each species in moss, herb and shrub layer in sample plots was determined, species composition was analysed and species richness and species diversity was assessed. Ellenberg indicator values and Shannon diversity index were calculated and compared between control and treatment plots. Results indicate that in both control and treatment plots species composition corresponds to the respective forest types. An increased occurrence of nitrophilous species was observed after addition of ammonium nitrate, whereas wood ash fertilization might have resulted in higher diversity of moss species. A repeated vegetation survey will show, if those changes will persist longer.

Key words: ground vegetation, nitrogen fertilizer, wood ash, floristic composition, species diversity, species richness.

Guna Petaja, Ilze Kārkliņa, Zaiga Zvaigzne.Latvian State Forest Research Institute "Silava", Rīgas street 111, Salaspils, LV-2169, E-mail: guna.petaja@silava.lv.
Guna Petaja. Daugavpils University, Vienibas street 13, Daugavpils, LV-5401.

INTRODUCTION

Biological diversity is the variety of living organisms at all the levels – from genes to ecosystems (Dise et al. 2011). Changes in vegetation link to numerous environmental problems, and biodiversity is considered a top priority in the EU (EEA 2019). Diverse, species-rich ecosystems are highly valuable, therefore nowadays biodiversity conservation is an essential part of sustainable forest management. There are several ways humans have influenced forest ecosystems, such as logging, nitrogen and phosphorous input, land-use change, climate change etc.

Increased nitrogen deposition is one of the major causes of biodiversity loss in Europe (Sala et al. 2000). Boreal forests are particularly sensitive to increased nitrogen content because they are adapted to low nutrient levels and are not efficiently buffered against acidification. Several studies have indicated a decrease in cover of ericaceous species and a decline of the characteristic bryophytes as a result of nitrogen addition (Brunet, Diekmann, Falkengren-Grerup 1998). Also in temperate forests invasion of nitrophilic species and disappearance of lichen species have been observed (Mäkipää & Heikkinen 2003, Nordin et al. 2005). In many ecosystems nitrogen is the limiting nutrient and increasing its availability results in increased productivity and invasion of new nitrophilous species. As productivity of fast-growing species that are able to exploit excess nitrogen increases, rare, low-abundance species are at risk and competitive exclusion may occur. Nitrogen addition also may acidify the ecosystem, causing long term changes, resulting in disappearance of species typical to intermediate and high pH (Dise et al. 2011). It has been observed that along with increasing N concentration in plant tissues, their palatability and susceptibility to parasites increase. Plant groups that are the most impacted by nitrogen addition are bryophytes, lichens, forbs and nutrient-poor shrubs. On the other hand, graminoids may benefit from increased nitrogen levels. Several studies show that the effect of nitrogen addition (34–108 kg N ha^{-1} yr^{-1} over a period of 18 years) to boreal forests may persist as long as 9 years (Strengbom et al. 2001).

Wood ash is a by-product of biomass combustion. It contains all the major nutrients required for plant growth, except for nitrogen: calcium (Ca), potassium (K), magnesium (Mg), silicon (Si), aluminium (Al), iron (Fe) and phosphorus (P), and can be used as liming material as well (Karltun et al. 2008). In Finland, wood ash has been used as a fertilizer in forests since 1935, where it has been applied to soil for conifer stands on drained peatlands. Large amounts of wood ash have been produced in Sweden as well and research on its use to restore acidified forest soils in the southern part of it has been carried out (Lundström et al. 2003). In a study carried out in Latvia wood ash application resulted in a significant increase of the volume increment of Norway spruce on drained peat and mineral soil (Okmanis et al. 2016). Regardless of the practical and ecological benefits from wood ash recycling to forests, there is a number of potential problems arising with its use. One of them is the impact on ground vegetation as a result of changes in pH and soil nutrient content.

Studies on the impact of fertilization with nitrogen-containing fertilizer and wood ash on forest ground vegetation in Latvia are lacking. The aim of the study was to determine a short-term impact of nitrogen fertilizer and wood ash on forest ground vegetation species diversity, species richness and floristic composition in *Myrtillosa*, *Hylocomiosa*, and *Oxalidosa turf.mel.* stands.

MATERIAL AND METHODS

The study was conducted in 11 forest stands, where the dominant tree species is Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) or Silver birch (*Betula pendula*), representing 3 forest types. The age of forest stands varied from 43 to 82 years. Stand characteristics are shown in Table 1. In all the stands commercial thinning has been done in the recent years.

In forest stands, where wood ash was applied (2 t ha^{-1}), the soil amendment was spread in November 2014. In the rest of the stands ammonium nitrate (NH_4NO_3, 0.44 t ha^{-1}) was applied from December 2016 till July 2017. Wood ash was taken from wood pellet plant 'NewFuels' and biomass-fired heat and power plant 'Fortum'. Wood ash composition is shown in Table 2.

There were two designs of vegetation field survey sample plots:
a) double plots of 1m^2 squares arranged in an equilateral triangle, whose edges are oriented perpendicularly to the 30x30 m plot, where fertilizers were spread; b) a rectangular area of 200 m^2, where vegetation was surveyed in two 100 m^2 squares and 5 smaller squares of 1m^2 located in the centre and at each corner of the larger sampling area. Sample plot design is shown in Fig.1.

In each sample plot vegetation was surveyed according to the Braun-Blanquet method. The projective cover of each species in moss (liverworts, mosses, lichens), herb (vascular plants, dwarf shrubs, shrubs and trees up to the height of 0.5 m) and shrub (shrubs and trees at the height 0.5 - 7.0 m) layer in both control and treatment sample plots was determined.

Along with estimation of the percentage cover of each species, species occurrence and species richness was compared between control and

Table 1. Characteristics of the studied forest stands

Stand key	Forest type	Tree species	Average stand age	Fertilizer applied
301-209-13	*Oxalidosa turf. mel.*	Norway spruce	48	WA
301-231-12	*Oxalidosa turf. mel.*	Norway spruce	43	WA
301-228-5	*Hylocomiosa*	Norway spruce	48	WA
301-221-17	*Hylocomiosa*	Norway spruce	48	WA
011-106-8	*Myrtillosa*	Scots pine	82	NH_4NO_3
011-174-6	*Hylocomiosa*	Norway spruce	75	NH_4NO_3
011-125-5	*Hylocomiosa*	Scots pine	61	NH_4NO_3
012-208-16	*Hylocomiosa*	Norway spruce	67	NH_4NO_3
021-10-1	*Hylocomiosa*	Silver birch	74	NH_4NO_3
021-4-25	*Hylocomiosa*	Scots pine	74	NH_4NO_3
021-60-7	*Hylocomiosa*	Silver birch	64	NH_4NO_3

*WA – wood ash, NH_4NO_3 – ammonium nitrate

Table 2. Chemical composition of wood ash and applied doses of elements

Elements	Concentration, g kg^{-1}	Dose, kg ha^{-1}
P	5.1	10.2-20.4
K	16.3	32.6-65.2
Ca	101.7	203.4-406.8
Mg	16.7	33.4-66.8
Mn	1.3	2.6-5.2
Fe	4.1	8.2-16.4

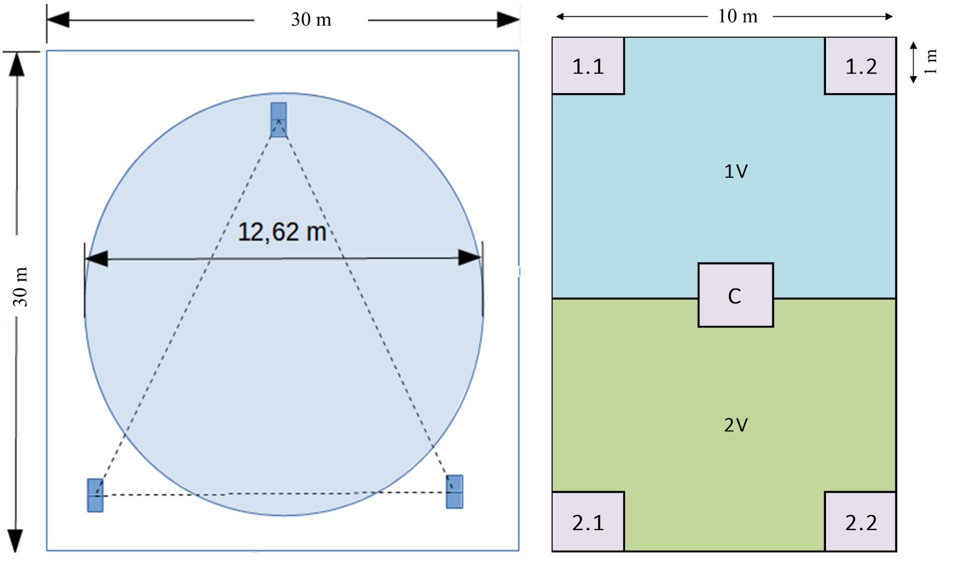

Fig. 1. Sample plot design in vegetation field surveyed.

treatment plots of each stand. Changes in composition and species richness were analyzed separately for moss and herb layer.

Species diversity was estimated as Shannon-Wiener diversity index (H'). Shannon-Wiener diversity index was calculated separately for moss, herb and shrub layer using formula 1 (Magurran, 1988):

$$H' = -\sum \left(\frac{n_i}{N}\right) \log_2 \left(\frac{n_i}{N}\right), \quad (1)$$

where
H' - ground vegetation diversity; N – the total number of individuals; n_i- number of species per sample plot.

In our case instead of the number of individual plants the percentage cover was used in calculations, as it has been done in several other studies, e.g. Vahdati et al. 2016. The larger is the value of H', the higher is species diversity.

Ellenberg's indicator values were calculated for each sample sub-plot and the weighted average for each stand was determined using formula 2.

$$Weighted\ average = \frac{\sum_{i=1}^{n}(rij * x}{\sum_{i=1}^{n} rij} \quad (2)$$

where
r_{ij} - the response of species i in sample plot j;
x_i – the indicator value of species i.

All the calculations were done in MS Excel.

Ellenberg indicator values for light (L), reaction (R) and nitrogen (N) were compared between control and treatment plots as it is expected that those parameters may change as a result of fertilization.

Statistical analysis was done with RStudio (R version 3.2.5 and Rstudio version 1.1.463.). Shapiro-Wilk test was used to determine, ifdata correspond to normal distribution. T-test for independent samples was used to determine if there are statistically significant differences in Ellenberg indicator values and H' values between control and treatment plots at the significance level α=0.05.

RESULTS AND DISCUSSION

Impact assessment of wood ash

In *Oxalidosa turf.mel.* forest stands in both control plots and plots treated with wood ash the most frequently observed mosses were *Plagiomnium ellipticum, Plagiomnium affine* and *Rhodobryum roseum,* which are typical to moist and wet habitats and base-rich or slightly acidic soils. *Rhodobryum roseum* was observed as solitary individuals and did not form a large percentage cover. In plots, where wood ash was spread, *Eurhyncium hians* (commonly observed on base-rich soils) and *Hylocomium splendens* (typical to a wide range of habitats), were observed more frequently, comparing with control plots and they also had larger percentage cover. In one of the *Oxalidosa truf. mel.* stands in plots, where wood ash was spread, mesoeutrophic, moist-habitat moss *Plagiochila asplenioides* was observed more frequently, while in the other stand it was absent. Only in treatment plots ubiquitous *Rhytidiadelphus squarrosus* and *Eurhynchium angustirete*, that grows on base-rich, neutral or slightly acidic soils, were observed. Only in control plots solitary individuals of *Ptilium crista-castrensis* (typical to rather acidic soils), *Rhytidiadelphus triquetrus* (typically grows on both calcerous and acidic soils) and *Eurhynchium striatum*(grows on base rich to slightly acidic soils) were observed. Several species were observed that are not typical to *Oxalidosa turf.mel.* - nitrogen-rich habitat species *Cirriphyllum piliferum* and eutrophic *Brachythecium rutabulum*. The latter was more frequently observed in treatment plots. In the herb layer the most frequently observed species in both control and treatment plots were *Oxalis acetosella,* nitrophilous *Rubus idaeus* and moist-habitat species *Circaea alpina*. Nitrophilous *Mercurialis perennis, that is also* typical to calcerous soils was observed only in one stand and it was more frequently observed in treatment plots. This species as well as nitrophilous *Urtica dioica* and *Rubus idaeus* and mesotrophic *Maianthemum bifolium* form a larger percentage cover in treatment plots. All the mentioned species, except for *Rubus idaeus* and *Maianthemum bifolium* forms a larger percentage cover in plots, where wood ash was applied. Only in plots treated with wood ash solitary individuals of mesoeutrophic *Melica nutans*, *Milium effusum* and *Aegopidium podagraria*, moist habitat species *Angelica sylvestris* and olygomesothrohic *Stellaria graminea,* calciphilous *Lathyrus vernus,* nitrophilous *Taraxacum officinale* and *Convallaria majalis* were observed. Only in control plots mesoeutrophic *Hepatica nobilis*, eutrophic *Galeobdolon luteum*, *Viola epipsila*, *Viola riviniana, Geranium* were observed. In the shrub layer *Rubus idaeus*, *Frangula alnus*, *Corylus avellana*, and solitary individuals of *Sorbus aucuparia*, *Lonicera xylosteum, Urtica dioica* and *Cirsium oleraceum* were observed.

In *Hylocomiosa* stands, in moss layer both control and treatment plots the most frequently observed moss species were ubiquitous *Pleurozium schreberi* and *Plagiomnium ellipticum*. In control plots *Eurhyncium angustirete* and *Polytrichum commune* (typical to damp, acidic habitats) were observed more frequently than in control plots, whereas in treatment plots *Hylocomium splendens*, *Rhodobryum roseum* as well as *Plagiomnium undulatum* (typical to moist habitats and calcerous to neutral soils), were observed more frequently. Only in treatment plots *Dicranum scoparium* (occurs in various habitats) and *Rhytidiadelphus triquetrus* were observed. In herb layer the dominant species were typical to *Hylocomiosa* forest type - *Oxalis acetosella*, *Luzula pilosa*, *Galeobdolom luteum, Vaccinium myrtillus. Luzula pilosa*, as well as *Trientalis europaea* and *Veronica chamaedrys* was more frequently observed in treatment plots, whereas *Hepatica nobilis* and calciphilous, nitrophilous *Mycelis muralis* were more frequently observed in control plots. Only in control plots *Galium boreale* (typical to dry, sparse woodlands), *Lathyrus vernus* (typical to base rich soils), *Athyrium filix-femina* (typical to moist, acidic habitats), *Equisetum sylvaticum* (typical to wet, open woodlands), *Maianthemum bifolium* (typical to shady habitats and soils with high hummus content), *Mercurialis perennis* (typical to dry habitats, wide pH range), mesoeutrophic species *Galeopsis tetrahit* and*Calamagrostis arundinacea* were observed, whereas only in treatment plots ruderal and nitrophilous *Chamaenerion angustifolium*, mesoeutrohpic *Pteridium aquilinum*, *Melampyrum sylvaticum*, *Convallaria majalis* that are rather typical to acidic soils, *Stellaria nemorum* (nitrophilous, typical to wet habitats) were observed. In the shrub layer *Frangula alnus*, *Quercus robur, Sorbus aucuparia* were observed.

Overall species composition in both control and treatment plots correspond to that typical to the respective forest types. In both control and treatment plots, many wet habitat species are observed. It was expected that more species typical to basic soils will appear in treatment plots, however several species normally growing on acidic soils were also observed in treatment plots.

In both of *Hylocomiosa* forest stands and one of the *Oxalidosa turf. mel.* stands, Shannon diversity index value in moss layer was significantly larger in treatment plots ($p= 0.018$, $p=0.0041$ and $p=0.023$, respectively). As for the herb layer, statistically significant differences between H’ values in control and treatment plots were not observed. In terms of species richness, no consistent tendency was observed for the impact of fertilization. The total number of ground vegetation species per stand, where wood ash was applied, ranged from 38 to 43 in control plots (7-14 in moss layer, 24-27 in herb layer, 1-4 in shrub layer) and from 24 to 45 species in treatment plots (9-14 in moss layer, 16-29 in herb layer, 2-4 in shrub layer). Greater species richness in moss layer was observed in stands corresponding to the *Oxalidosa turf.mel.* forest type, whereas the opposite was observed for herb layer, where greater species richness was observed in *Hylocomiosa* stands. In *Oxalidosa turf. mel.* stands the number of species in herb layer tended to be slightly higher. The number of species in the shrub layer is low, therefore it does

Table 3. Values of Shannon diversity index (H') and species richness in control and treatment plots in stands, where wood ash impact was assessed

Stand key	H'						Species richness					
	Control			Treatment			Control			Treatment		
	M	H	S	M	H	S	M	H	S	M	H	S
301-231-12	0.70	1.63	0	1.056	1.68	0.85	14	26	1	14	28	3
301-209-13	1.25	1.53	0.14	1.17	1.71	0.17	12	27	4	9	29	4
301-221-17	1.066	1.08	0	0.57	0.97	0	9	26	3	6	16	2
301-228-5	0.87	1.62	0	1.40	1.83	0.044	7	24	2	9	27	2

*H'- Shannon diversity index, M-moss layer, H-herb layer, S-shrub layer

Table 4. Ellenberg indicator values for light, reaction and nitrogen in control and treatment plots of each forest stand, where wood ash impact was assessed

Stand key	Fertilization regime	L	R	N
301-221-17	WA	5.70	3.14	3.08
	C	5.43	4.09	4.14
301-228-5	WA	4.98	4.92	5.41
	C	4.57	5.07	5.09
301-231-12	WA	4.07	5.19	6.00
	C	3.79	4.69	5.80
301-209-13	WA	5.31	3.08	3.09
	C	4.58	4.60	5.87

*WA – wood ash, C – control, L-light, R-reaction, N-nitrogen

not contribute much to the assessment of species diversity and species richness. Values of Shannon diversity index and the number of species in control and treatment plots are shown in Table 3.

The average Ellenberg indicator values for light (L), reaction (R) and nitrogen (N) of each stand in control and treatment plots are shown in Table 4. In one *Oxalidosa truf.mel.* (301-231-12) and one *Hylocomiosa* (301-228-5) stand Ellenberg indicator value for light (L) was significantly larger in treatment plots ($p = 0.00092$ and $p = 0.019$, respectively). This could be rather explained by logging in the area, because the expected result of fertilization is the opposite - decreased light availability to the ground vegetation. The Ellenberg indicator value for reaction R in *Oxalidosa turf.mel.* stand 301-221-17 was significantly larger in treatment plots ($p= 0.038$), which could be explained by wood ash addition and thus higher soil pH. In one of the *Hylocomiosa* (301-221-17) stands the indicator value for N was significantly lower in treatment plots, comparing with control plots ($p=0.00044$).

Wood as application could be the cause of higher moss diversity in *Oxalidosa turf. mel.* forest type, however differences were observed only in one stand. Moss diversity in treatment plots of *Hylocomiosa* stands could be lower as a result of interspecific competition between mosses and vascular plants. Generally it can be assumed that impact on vegetation is small and in most of cases statistically insignificant. The significantly higher Ellenberg indicator values in treatment plots in one of the *Oxalidosa turf.mel.* stands could indicate that soil reaction has become less acidic.

Impact assessment of nitrogen fertilization

In *Myrtillosa* stand in the moss layer several lichen species were observed - *Cladonia stellaris*, *Cetraria islandica*, *Cladonia rangiferina*. It has been reported that lichens are particularly sensitive to addition of fertilizers (Mäkipää, R. 1994), however in this case addition of ammonium nitrate does not seem to have a negative impact on them. The first two species mentioned were observed only in treatment plots, whereas *Cladonia rangiferina* was more frequently observed in treatment plots. *Ptilium crista-castrensis* and *Dicranum scoparium* were observed only in control plots, whereas moist-habitat species *Aulacomnium palustre* was observed only in treatment plots. *Dicranum polysetum* and *Pleurozium schreberi* were more frequently observed in treatment plots. In herb layer *Vaccinium vitis-idaea* and *Vaccinium myrtillus* dominated and were more frequently observed in treatment plots. Only in treatment plots *Melampyrum pratense*, *Goodyera repens* (both typical to acidic soils) and *Chamaenerion angustifolium* were observed.

In *Hylocomiosa* stands, where Silver birch is the dominant tree species, in moss layer *Pleurozium schreberi* and *Rhytidiadelphus triquetrus* are the most frequently observed species in both control and treatment plots, whereas *Hylocomium splendens* is more frequently observed in treatment plots. Only in control plots moist and wet habitat species *Plagiomnium ellipticum*, *Plagiomnium undullatum, Calliergon cordifolium, Climacium dendroides,* as well as *Eurhyncium hians* (typical to base-rich soils) and *Pseudoschleropodium purum* (occurs in a wide range of habitats) were observed. Only in treatment plots *Dicranum majus* (typical to acidic soils) and *Plagiomnium cuspidatum* (typical to basic soils) were observed. In the heb layer the most frequently observed species in both control and treatment plots were *Oxalis acetosella*. In control plots *Maianthemum bifolium* was frequently observed and in treatment plots - *Rubus caesius*, as well as *Trientalis europaea* that is typical to more fertile growth conditions and *Lysimachia vulgaris,* which is common in damp forests. In control plots *Rubus saxatilis* is observed more frequently. Only in control plots ruderal species *Epilobium montanum* and *Taraxacum officinale* were observed, as well as moist-habitat species *Filipendula ulmaria, Geum rivale*, and *Juncus sp.* Only in treatment plots nitrophilous *Rubus idaeus* was observed.

In *Hylocomiosa* stands, where Scots pine is the dominant tree species, in the moss layer the most frequently observed moss species are *Hylocomium splendens* and *Pleurozium schreberi*. Both species are slightly more frequently observed in control plots. Only in control plots several *Sphagnum* species were observed, that indicate a locally wet habitat . Other species observed only in control plots were *Polytrichum commune*, *Polytrichum juniperinum*, *Dicranum majus*. Only in treatment plots *Rhodobryum roseum*, *Calliergon cordfolium*, *Calliergonella cuspidata*, *Plagiomnium ellipticum* were observed. In the herb layer in control plots the most frequently observed species were *Luzula pilosa* and *Vaccinium vitis-idaea*, whereas in treatment plots *Oxalis acetosella* was observed more frequently. Only in control plots graminoids *Deschampsia caespitosa*, *Carex sylvatica*, *Carex nigra*, *Carex pilulifera* were observed. Only in treatment plots several nitrophilous species: *Rubus idaeus*, *Mycelis muralis*, *Galeopsis tetrahit, Dryopteris filix-mas*, *Impatiens parviflora* were observed. *Impatiens parviflora* is an expanding adventive species in Latvia and is considered an invasive species in Lithuania (Dobravolskaitė 2012). Other species observed only in treatment plots – ruderal *Chamaenerion angustifolium*, *Convallaria majalis*, wet habitat species *Angelica sylvestris* and *Lycopodium annotinum*, which considered an endangered species in Latvia. In the shrub layer *Betula pendula* and *Sorbus aucuparia* were observed.

In *Hylocomiosa* stands, where Norway spruce is the dominant tree species, in moss layer the most frequently observed species were *Pleurozium schreberi*, *Hylocomium splendens* and *Dicranum polysetum*. Only in control plots *Ptilium crista-castrensis* was observed. In treatment plots *Polytrichum commune*, *Plagiomnium affine*, *Sphagnum girgensohnii, Dicranum scoparium* were observed more frequently than in control plots. Only in treatment plots *Rhytidiadelphus squarrosus* was observed. In the herb layer in treatment plots *Deschampsia caespitosa,*

Table 5. Values of Shannon diversity index (H') and species richness in control and treatment plots in stands, where ammonium nitrate was spread

Stand key	H'						Species richness					
	Control			Treatment			Control			Treatment		
	M	H	S	M	H	S	M	H	S	M	H	S
11-106-8	0.63	0.39	-	0.95	0.66	-	7	3	-	7	6	-
11-125-5	0.93	2.16	-	0.81	1.45	-	10	27	-	6	16	-
11-174-6	0.23	0.22	-	0.53	0.26	-	4	3	-	4	3	-
12-208-16	0.24	0.88	0	0.45	0.71	0	5	9	1	5	9	1
21-10-1	0.72	1.55	0.11	0.53	1.89	0.11	10	18	2	7	18	2
21-4-25	0.64	1.83	0	0.78	1.94	0	8	19	1	7	26	1
21-60-7	0.54	1.66	0	0.90	1.52	0	9	22	1	10	20	1

*H'- Shannon diversity index, M-moss layer, H-herb layer, S-shrub layer

Table 6. Ellenberg indicator values for light, reaction and nitrogen in control and treatment plots of each forest stand, where the impact of nitrogen fertilizer was assessed

Stand key	Fertilization regime	L	R	N
11-106-8	N	5.83	3.023	1.65
	C	5.90	4.04	2.44
11-125-5	N	5.71	3.31	3.68
	C	5.46	4.49	4.14
11-174-6	N	5.78	4.02	1.88
	C	5.85	4.60	2.81
12-208-16	N	5.50	3.92	3.42
	C	5.53	4.18	3.43
21-10-1	N	5.60	3.55	3.91
	C	5.96	4.00	2.62
21-4-25	N	4.65	4.21	4.46
	C	5.50	3.69	2.94
21-60-7	N	5.60	4.12	3.40
	C	5.59	5.04	4.77

*N- ammonium nitrate, C - control

Vaccinium myrtillus, Vaccinium vitis-idaea, Luzula pilosa, *Oxalis acetosella*, *Trientalis europaea* were observed more frequently than in control plots. Only in control plots *Veronica officinalis*, *Poa nemoralis*, *Goodyera repens, Rumex acetosella* were observed. Only in treatment plots *Stellaria holostea*, nitrophilous *Moehringia trinervia, Dryoptheris carthusiana* (typical to rather acidic soils), *Impatiens parviflora* were observed. In the shrub layer *Frangula alnus* was observed.

Also in areas, where ammonium nitrate was applied, the floristic composition in treatment plots in general did not differ from that typical to the respective forest types. In both forest types regardless of dominant tree species, nitrophilous species occurred in treatment plots.

In areas, where the impact of nitrogen fertilization was assessed, in the *Myrtillosa* stand, the H' value of the moss layer was higher in treatment plots and the difference is statistically significant (p=0.0057). In *Hylocomiosa* stands in most cases a similar tendency is observed, however no statistically significant differences were found between control and treatment plots. Regarding the herb layer, the H' value in one of the *Hylocomiosa* stands, where the dominant tree species is Silver birch, is significantly lower (p=0.0032), but in another stand of the same forest type, where Scots pine is the dominant species, it is significantly higher (p=0.011).

In sites, where only nitrogen fertilizer was applied, in total 21 unique species in moss layer, 41 species in herb layer and 4 species in shrub layer were observed. The number of species per stand in treatment plots ranged from 9 to 34 species (5-10 in moss layer, 4-27 in herb layer, 1-4 in shrub layer) and in control plots – from 8 to 38 species (4-10 in moss, 4-28 in herb, 1-2 in shrub layer). Values of Shannon diversity index (H') and species richness in control and treatment plots are given in table 5.

The average Ellenberg indicator values in control and treatment plots in stands, where nitrogen fertilizer was applied, are shown in Table 6. Ellenberg indicator value for reaction and nitrogen (N) are significantly smaller in *Myrtillosa* stand in treatment plots (p=0.0047), whereas in *Hylocomiosa* stands 21-10-1, 21-4-25 and 21-60-7, the Ellenberg indicator value for N is significantly larger (p=0.007, p= 0.00031, p= 0.00018, accordingly), which could indicate an increased nitrogen concentration in soil after fertilization. In 11-125-5 and 21-60-7 stands Ellenberg indicator value for reaction is significantly smaller in treatment plots (p=0.0004 and p=0.0025, accordingly), which could be expected as a result of acidification. The Ellenberg indicator value for light L is significantly smaller in treatment plots in stands 21-10-1 and 21-4-25 (p=0.0023 and p=0.017, accordingly), which could be explained by the impact of fertilization – thicker tree canopies result in decreased light availability to forest floor.

CONCLUSIONS

1. The observed impact of fertilizers on forest ground vegetation composition in our study is small and the species composition still corresponds to the respective forest types. Several species were observed that indicate for a locally wet habitat. In case of nitrogen fertilization, occurrence of new nitrophilous species in the herb layer was observed. A repeated vegetation survey will show, if these changes in composition will persist longer.

2. No consistent pattern of species richness was observed that could be explained by fertilization. Greater species richness in moss layer was observed in stands corresponding to the *Oxalidosa turf.mel.* forest type, whereas the opposite was observed for herb layer, where greater species richness was observed in *Hylocomiosa* stands.

3. Shannon diversity index values show that diversity of mosses was higher in treatment plots in stands representing each studied forest type after addition of wood ash. In *Myrtillosa* forest stand, where nitrogen fertilizer was applied, the Shannon diversity index in moss layer was significantly higher in treatment plots. A similar tendency was observed in *Hylocomios*a stands, however a significantly higher value of Shannon diversity index for the moss layer in treatment plots was observed only in one stand. Regarding the herb layer, species diversity in birch stands was lower in treatment plots, which could be the result of nitrogen fertilizer addition.

4. Higher Ellenberg indicator value for reaction in *Oxalidosa turf.mel.* stand in plots treated with wood ash could indicate increase in soil pH after fertilization. In *Hylocomiosa* stands after addition of ammonium nitrate, according to significantly higher N values and significantly lower R values in treatment plots, soil nitrogen content maybe have increased and soil pH may have decreased.

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