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Short-Term Ground Vegetation Responses to Fertilization in Latvian Forests: Effects on Species Richness and Diversity

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Abstract: This study investigated the impact of forest fertilization on ground vegetation in deciduous and conifer stands across different forest site types (forests with drained mineral soils, forests with drained organic soils, and dry upland forests), stand age groups (young, middle-aged, and pre-mature), and fertilizer types (ammonium nitrate (NH_4NO_3) and wood ash alone, and both together). Ground vegetation was surveyed one to three years after fertilizer application, with the projected ground cover of individual species in the moss and herb layers determined. Thus, results reflect short-term impact of fertilization. Species richness and diversity (Shannon diversity index, H') were compared between fertilized and control (unfertilized) plots. The results show that species diversity in the moss layer of silver birch stands was significantly affected by fertilization, while species richness was significantly influenced by the interaction between fertilization and forest site type. Differences between control and fertilized plots in birch stands suggest a potentially negative response of the moss layer to fertilization. In contrast, no significant effect of fertilization was observed in Norway spruce stands, where site type and stand age emerged as significant factors. In Scots pine stands, where NH_4NO_3 was applied alone, fertilization had a significant impact on both species richness and diversity in the herb layer. In the moss layer, a marginally significant effect was found for the interaction between fertilization and stand age. NH_4NO_3 alone appeared to enhance herb layer richness, although its effect on species diversity was more variable. Our study highlights the context-dependent nature of fertilization effects on species richness and diversity in Latvian hemiboreal forest ecosystems.

Keywords: forest fertilization; ground vegetation; ammonium nitrate; wood ash; species richness; Shannon diversity index

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1. Introduction

Forests play a significant role in climate change mitigation, as they sequester carbon (C) in biomass and soil while providing renewable resources. The growing demand for woody biomass for energy and construction underscores the necessity to enhance forest productivity. Fertilization is a widely used silvicultural technique to improve tree growth and increase timber production by accelerating stand development and reducing the rotation-period length [1]. This practice is common in the Nordic countries, particularly in Finland and Sweden [2–6]. Fertilization activity peaked in the 1970s, with annually treated areas reaching 150,000 ha in Finland and 200,000 ha in Sweden [6]. The intensity of fertilization has decreased; however, an increase is expected as a result of the growing demand for forestry products. In Latvia, too, forest fertilization took place from the 1960s to the late 1980s, providing a significant amount of additional volume increment. However, this practice had stopped due to the worsening economic situation and inability to switch to the use of tractors instead of utility aircraft to spread fertilizers, unlike in the Nordic countries [7]. Currently, in Latvia, forest fertilization is limited to scientific purposes. A recent study aimed to evaluate its benefits and potential side effects, as well as the feasibility of reintroducing the practice [8].

Boreal coniferous forests most often suffer from nitrogen (N) and, further south, in hemi-boreal forests, additionally from phosphorus (P) deficiency, which manifests itself when stands reach pre-mature age. During this time, a large part of N and other nutrients in the soil is concentrated in the forest floor and under natural conditions, released after the destruction of the forest stand by mineralizing the organic matter in the forest floor [9,10]. Cycling of potassium (K) in forests has been studied to a relatively lesser extent; however, it was proven to be a limiting nutrient in agricultural systems [11,12]. Also, a recent comprehensive meta-analysis demonstrated that the addition of K significantly increased aboveground production by 12.3%, suggesting that K limitation is widespread across other terrestrial ecosystems [13]. The availability of the nutrients mentioned above can be increased by the application of fertilizers. N fertilizers, e.g., NH_4NO_3, are used in forests on mineral soils, where N deficiency is mostly prominent, whereas peatland forests are usually lacking P and K [3]. The dose of N applied with fertilizers in forests on mineral soils is 150 kg ha^{-1}, and the subsequent tree growth response is 20–25 m^3 ha^{-1} [2]. Ash is the solid residue of biomass combustion. It contains substantial amounts of mineral nutrients that are useful for fertilization: P, K, calcium (Ca), magnesium (Mg), and several trace elements. However, wood ash does not contain N, as it is lost through burning. Wood ash also has liming properties due to its high content of calcium oxide (CaO) and hydroxide ($Ca(OH)_2$) [14]. For peatland forests, the recommended dose of K is 40–80 kg ha^{-1}, and that of P is 40–50 kg ha^{-1}, corresponding to a wood ash amount of 2000–5000 kg dry weight ha^{-1} [15]. Wood ash and NH_4NO_3 can be applied simultaneously to supplement N, P, and K stocks, as well as to prevent soil acidification [16].

While fertilizers enhance tree growth, environmental concerns should be addressed regarding soil, water, and biodiversity. The ecological significance of forest ground vegetation in boreal and temperate forests has often been underestimated compared with trees. This stratum plays an important role in water and nutrient cycling, is involved in gas exchange with the atmosphere, reduces soil erosion, and provides the majority of forest's biodiversity [17]. Fertilizer application can lead to direct vegetation damage and/or alter soil acidity and nutrient availability, affecting the species composition, richness, and diversity of ground vegetation [18–20]. Several studies on the impact of ground vegetation have been conducted in the Nordic countries and Canada, which share some climatic similarities with Latvia [19,21–28]. Previous research indicates that the effects of a single small dose are likely to be insignificant, while repeated exposure could result in changes to species composition and a loss of biodiversity [29]. The use of fertilizers may lead to the presence of species commonly found in more fertile site types [22]. Long-term fertilization of old forests (lasting more than 15 years) results in reduced cover of dwarf shrubs, lichens, and mosses, while favoring grasses and nitrophilous herbs. Similar negative effects of long-term fertilization in mature forests are also observed with short-term nutrient optimization in young spruce plantations [26]. The impact of fertilization depends on factors like initial soil nutrient levels, moisture, understory light availability, and site management practices before application [29].

Studies indicate a relationship between site productivity and species diversity. Diversity typically declines as productivity increases or follows a trend of initial rise and subsequent decline [30,31]. Competition explains this pattern—higher soil-nutrient availability boosts productivity, but as plants grow, shading reduces light availability, limiting diversity [32,33]. Several studies have found a decrease in species richness and diversity as a result of N fertilization [22–26]. Excessive N can decrease local species diversity, as fast-growing, N-loving species outcompete others, displacing native species and rare plants. A study conducted in Sweden found that the use of hardened wood ash at doses up to 3 t ha^{-1} did not cause significant changes in the diversity of mosses and herbaceous plants in young spruce stands [27]. In some studies conducted in nutrient-poor vegetation, a varying or even positive impact of N and multinutrient fertilization was observed [28,34].

Currently, limited research exists on the impact of forest fertilization on ground vegetation, particularly in Latvia, highlighting the need for further studies to deepen our understanding. This study aims to investigate how the application of NH_4NO_3 and wood ash to forest soils affects ground-vegetation species richness and diversity. By evaluating the potential benefits and risks of fertilization, the findings aim to provide valuable insights into sustainable forest management.

2. Materials and Methods

2.1. Study Sites

This study was conducted across 20 forest stands in Latvia, where the dominant tree species were Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) H. Karst.), and silver birch (*Betula pendula* Roth). These stands represented three forest site types: dry upland forests, forests with drained mineral soils, and forests with drained organic soils. The ages of the forest stands ranged from 25 to 95 years. The classification into age groups for statistical analysis was based on the following ranges: young stands (1–40 years for pine and spruce, and 1–20 years for birch), middle-aged stands (41–80 years for pine, 41–60 years for spruce, and 21–60 years for birch), and pre-mature stands (81–100 years for pine, 61–80 years for spruce, and 61–70 years for birch). Detailed stand characteristics are shown in Table 1.

Before fertilizer application, commercial thinning operations were conducted in all stands. Fertilization treatments included the application of NH_4NO_3 at a rate of 0.44 t ha^{-1}, which was carried out once between December 2016 and July 2017. In selected plots, additional treatments were applied: in a young Norway spruce stand with drained mineral soil, wood ash was applied at a rate of 3 t ha^{-1} to plots where NH_4NO_3 was previously not applied; and wood ash was also applied at the same rate (3 t ha^{-1}) in a silver birch and a Norway spruce stand with drained mineral soil and one silver birch stand with drained organic soil, in addition to NH_4NO_3. The wood ash was sourced from the Fortum and Latgran pellet factories in Latvia. The concentrations of macro-elements in the ash, extracted using concentrated HNO_3, were as follows: 9.6 g kg^{-1} of P, 26.0 g kg^{-1} of K, 153.3 g kg^{-1} of Ca, and 11.6 g kg^{-1} of Mg.

The study established two types of sample plots for tree measurements: circular (500 m^2) and square (400 m^2). In areas with square plots, fertilizers were distributed manually, while in areas with circular plots, they were distributed mechanically in strips using the existing network of strip roads. The plots were spaced at least 40 m apart and positioned at least 20 m from the stand edge. A buffer strip, at least 3 m wide, was established around each fertilized plot, where fertilizer was also applied. Control plots were established according to the same design. Wood ash and NH_4NO_3 were spread with a Valtra P 191 agricultural tractor, equipped with an Amazone mineral fertilizer spreader. Ash spreading for sites 8 and 20 (Table 1) was carried out with a Belarus 952 tractor and a conical mineral fertilizer spreader with a capacity of 500 L. Application of fertilizers was carried out manually in stands where distribution using machinery was not possible.

2.2. Ground Vegetation Survey

Ground vegetation was surveyed one to three years after application of fertilizers. The sample plots were established in two types of layouts: (1) three pairs of 1 m^2 sample plots arranged in a regular grid within an area of 24 m^2; and (2) double plots of 1 m^2 arranged in an equilateral triangle, whose edges are oriented perpendicularly to the area, where fertilizers were spread, or the respective control area. The numbers of sample plots per each stand varied and are given in Table 1. Detailed species composition of ground vegetation based on dominant tree species and forest site type is shown in Table 2.

In each sample plot, the projective cover of each species in moss (mosses, liverworts, and lichens) and herb (vascular plants, shrubs, and tree seedlings up to 0.5 m) layers in both control and fertilized plots was estimated visually. Differences in species richness (the number of species) and diversity (Shannon diversity index, H') between control and fertilized areas were analyzed for moss and herb layer separately. Additionally, the overall diversity (H') for both layers combined was also assessed.

2.3. Data Analysis

The Shannon diversity index (H') was selected as our measure of species diversity due to its ability to account for both species richness and evenness, providing a comprehensive assessment of biodiversity. H' was calculated and vegetation ground-cover data were processed with Microsoft Excel. H' was calculated both for all the species and separately for the moss and herb layers using Equation (1) [35]:

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

where H'—ground vegetation diversity; n—the total number of individuals; and n_i—number of species per sample plot.

Poisson generalized linear mixed-effects models (GLMMs) were used to analyze the influence of the age group, forest site condition, and fertilization treatment on the number of species (total, herb layer, and moss layer). Linear mixed-effects models (LMMs) with the same factors were used to analyze their influence on the H' index. All the models had forest stand and sample plot included as nested random effects to account for the data structure and repeated measurements within each plot. It was not possible to construct a comprehensive model that incorporates all species, age groups, forest site conditions, and fertilization treatments due to the limitations of the experimental design. Therefore, stands of each dominant tree species were analyzed individually, and multiple models were developed for each species to examine various combinations of factors and their levels. If the effect of any of the factors or their interactions was significant, pairwise comparisons of the estimated mean values for the factor levels were conducted using the Tukey test. The analysis was performed using R version 4.4.0 [36]. GLMMs and LMMs (Table 1) were created using the lme4 v. 1.1-36 package [37] and the lmerTest v. 3.1-3 package [38], while the Tukey test was conducted using the emmeans v. 1.10.1 package [39]. Models used for GLMM and LMM analyses are shown in Table 1.

Table 1. GLMMs and LMMs used for analysis on the impact on ground vegetation species richness and diversity.

No.	Tree Species	Model	Levels of Independent Variables
1	Silver birch	Treatment × site type	Treatments: control; NH_4NO_3. Site types: forests with dried mineral soils; forests with dried organic soils; dry upland forests.
2	Norway spruce	Treatment × site type	Treatments: control; NH_4NO_3. Site types: forests with dried mineral soils; forests with dried organic soils; dry upland forests.
3	Norway spruce	Treatment × age group	Treatments: control; NH_4NO_3. Age groups: young stands; middle-aged stands, pre-mature stands.
4	Norway spruce	Treatment	Treatments: NH_4NO_3, wood ash, NH_4NO_3 + wood ash
5	Scots pine	Treatment × age group	Treatments: control; NH_4NO_3. Age groups: young stands; middle-aged stands, pre-mature stands.

3. Results

3.1. A Comparison of Species Richness (The Number of Species) Between Control and Fertilized Plots

3.1.1. Silver Birch Stands

In middle-aged silver birch stands, the effects of fertilization and forest site type on species richness were assessed (Table 1, model No. 1). In forest stands with drained mineral soils, both control and fertilized plots had higher species richness compared to those in forests with drained organic soils. When comparing the treatments (control vs. fertilized with NH_4NO_3 + wood ash), species richness tended to be higher in fertilized plots in forests with drained mineral soils, while control plots had higher richness in forests with drained organic soils. Total species richness was significantly influenced by forest site type and its interaction with the treatment. The Tukey test results indicated statistically significant differences between the control plots in forests with drained mineral soils and the fertilized plots in forests with drained organic soils, between fertilized plots in forests with drained mineral soils and those in forests with drained organic soils, and between the control and fertilized plots in forests with drained organic soils. When examining the moss layer separately, species richness was higher in control plots compared to fertilized plots in both forest site types. The effect of fertilization on moss species richness was statistically significant, and species richness was significantly higher in forests with drained organic soils compared to forests with drained mineral soils. When examining the herb layer separately, species richness tended to be higher in fertilized plots than in control plots in forests with drained mineral soils, but the reverse was observed in forests with drained organic soils. Species richness was significantly influenced by forest site type and its interaction with the treatment, but not by treatment alone. Statistically significant differences were found between the control plots in forests with drained mineral soils and the fertilized plots in forests with drained organic soils, between fertilized plots in forests with drained mineral soils and those in forests with drained organic soils, and between control and fertilized plots in forests with drained organic soils. A comparison of species richness across vegetation layers and site types is shown in Figure 1A. All p-values and χ^2 values from analyses of deviance are provided in Table 2.

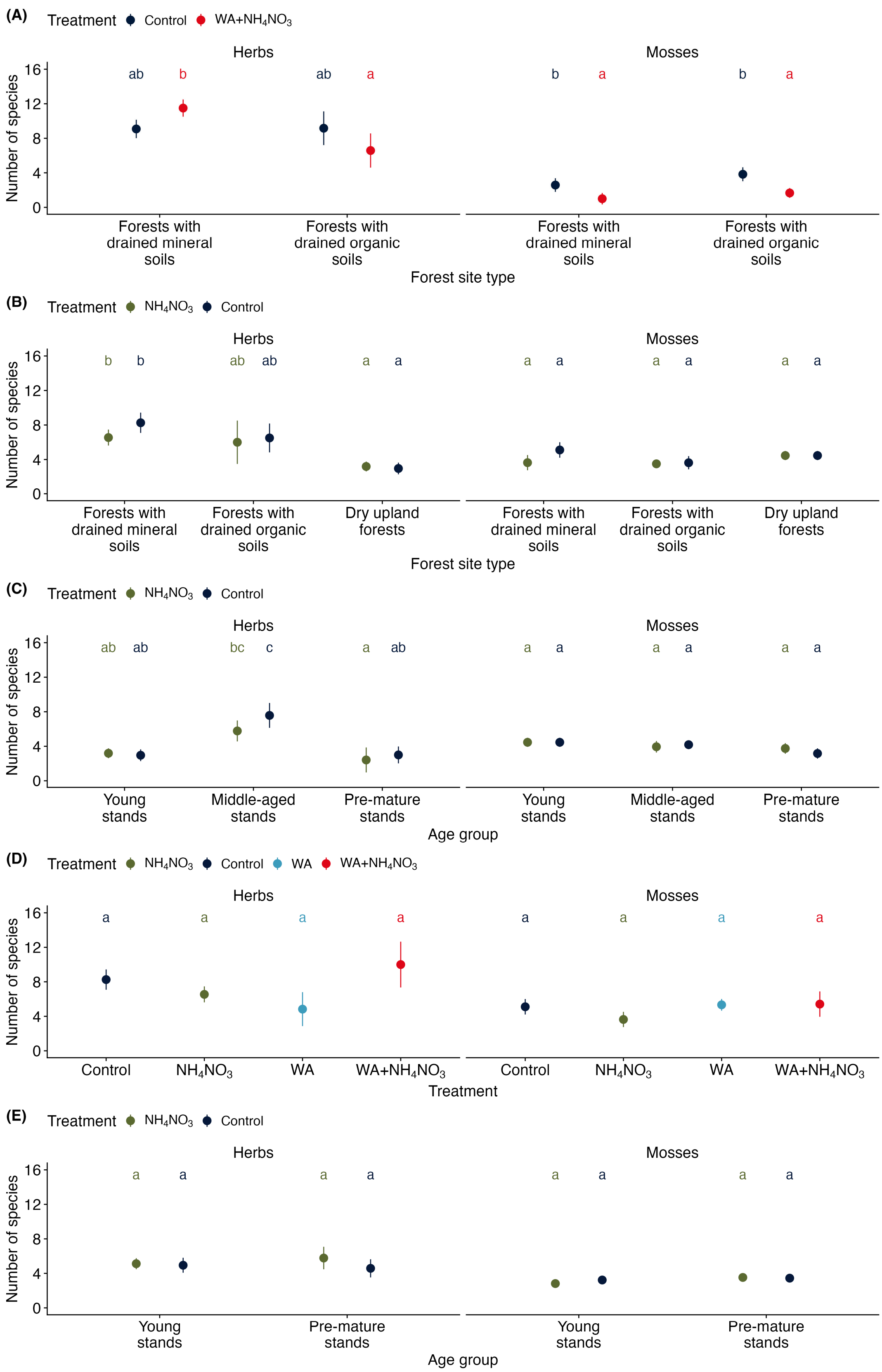

Figure 1. The number of species (mean values and 95% confidence intervals) in the moss and herb layers of silver birch (**A**), Norway spruce (**B**–**D**), and Scots pine (**E**) stands, based on site type, age group, and treatment combinations. WA—wood ash; NH_4NO_3—ammonium nitrate. Letters above the error bars show the results of the Tukey test comparison of the groups—if two groups have the same letter, the difference is not statistically significant (p > 0.05).

Table 2. Results of the GLMMs on the influence of the independent variables on the number of the moss and herb species, as well as the total number of species (combined moss and herb species). The models are explained in Table 1.

Model No.	Independent Variables	Total		Mosses		Herbs	
		χ^2	*p*-Value	χ^2	*p*-Value	χ^2	*p*-Value
1	Treatment	3.8222	0.0506	17.3908	<0.0001	0.0068	0.9342
	Site type	2.1145	0.1459	4.7695	0.0290	7.2157	0.0072
	Treatment × site type	9.0463	0.0026	0.0720	0.7884	8.4208	0.0037
2	Treatment	0.6384	0.4243	0.6890	0.4065	0.2736	0.6009
	Site type	12.8690	0.0016	1.5320	0.4649	24.3245	<0.0001
	Treatment × site type	1.2542	0.5341	1.0947	0.5785	0.8509	0.6535
3	Treatment	0.1801	0.6713	0.0066	0.9351	0.8181	0.3657
	Age group	18.1807	0.0001	3.9093	0.1416	21.3152	<0.0001
	Treatment × age group	1.2676	0.5306	0.7354	0.6923	2.0689	0.3554
4	Treatment	1.6760	0.6423	1.3377	0.7202	1.7013	0.6366
5	Treatment	2.0747	0.1498	0.7385	0.3901	5.9207	0.0150
	Age group	0.6431	0.4226	3.1537	0.0758	0.0898	0.7644
	Treatment × age group	1.4425	0.2297	0.9451	0.3310	0.8167	0.3661

3.1.2. Norway Spruce Stands

In Norway spruce stands, the impact on species richness and diversity was assessed based on stand age, forest site type, and fertilizer type (Table 1, models No. 2–4). In young spruce stands, average species richness in fertilized plots was lower compared to control plots in forests with drained mineral soils and drained organic soils, but in dry upland forests, the opposite was observed. The GLMM test results showed that overall species richness was significantly influenced by forest site type. Tukey test results indicated significant differences between plots in forests with drained mineral soils and dry upland forests. When evaluating moss layer separately, fertilized plots had lower species richness than control plots in forests with drained mineral soils and drained organic soils. However, in dry upland forests, species richness was the same in both control and fertilized plots. Moss species richness was not significantly influenced by any of the factors. When examining species richness in the herb layer separately, we saw that it was higher in forests with drained mineral soils and drained organic soils compared to dry upland forests in both control and fertilized plots. In forests with drained mineral and organic soils, average species richness was lower in fertilized plots compared to control plots, while in dry upland forests, it was higher in fertilized plots. Herbaceous species richness was significantly influenced by forest site type. Statistically significant differences in species richness were found between plots in forests with drained mineral soils and dry upland forests, as well as between plots in forests with drained organic soils and dry upland forests. A comparison of species richness across vegetation layers and site types is shown in Figure 1B. All *p*-values and χ^2 values from analyses of deviance for model No. 2 are provided in Table 2.

When comparing species richness in dry upland forests across all stand age groups, the effect of age group on species richness is statistically significant. The highest species richness was observed in middle-aged stands, in both control and fertilized plots, compared to young and pre-mature stands. Significant differences were found between middle-aged stands and pre-mature stands, as well as between middle-aged and young stands. When analyzing moss species richness separately, the highest average was observed in young stands, while the lowest was found in mature stands. In young stands, moss species richness was the same in control and fertilized plots. In middle-aged stands, moss species richness was higher in fertilized plots compared to control plots, whereas in mature stands, it was lower in fertilized plots compared to control plots. Moss species richness was not significantly influenced by treatment, age group, or their interaction. For herbaceous species richness, the highest number of species was found in middle-aged stands, while the lowest was observed in fertilized plots in pre-mature stands. The number of herbaceous species was significantly influenced by the age group, with significant differences between middle-aged stands and both young and pre-mature stands. In middle-aged and pre-mature stands, species richness in fertilized plots was higher compared to control plots, but in young stands, it was slightly lower. However, the effect of the treatment on species richness was not statistically significant. A comparison of species richness across both vegetation layers and stand age groups is shown in Figure 1C. All *p*-values and χ^2 values from analyses of deviance for model No. 3 are provided in Table 2.

In young spruce stands in forests with drained mineral soils, the effects of different fertilizer types (NH_4NO_3, wood ash, and wood ash + NH_4NO_3) were compared. Across both the moss and herb layers, species richness was the highest in plots treated with wood ash and NH_4NO_3 combined, and the lowest in plots treated with NH_4NO_3 alone. However, fertilizer type did not have a statistically significant effect on total species richness. In the moss layer, the highest species richness was again observed in plots treated with wood ash and NH_4NO_3 combined, and it was the lowest in plots treated with NH_4NO_3 alone. Fertilizer type did not significantly affect moss-layer species richness. In the herb layer, species richness was also the highest in plots treated with wood ash and NH_4NO_3, while the lowest occurred in plots treated with wood ash alone. Similarly, fertilizer type did not have a statistically significant effect on species richness. A comparison of species richness across both vegetation layers and treatments is shown in Figure 1D. All *p*-values and χ^2 values from analyses of deviance for model No. 4 are provided in Table 2.

3.1.3. Scots Pine Stands

In Scots pine stands in dry upland forests, species richness was assessed across different age groups of pine stands, where NH_4NO_3 was used as fertilizer (Table 1, model No. 5).

Comparing average species richness across all understory vegetation layers, the highest species richness was observed in fertilized plots in mature stands. Control plots in mature stands showed species richness similar to both control and fertilized plots in young stands. In both young and mature stands, fertilized plots had higher species richness than control plots. The effect of fertilization on total species richness was statistically significant. When examining moss species richness separately, mature stands (both control and fertilized) had higher species richness than young stands. In pre-mature stands, fertilized plots had the highest species richness, while in young stands, control plots had the highest. However, none of the factors significantly affected moss species richness. For the herb layer, the highest species richness was observed in fertilized plots in mature stands, while the lowest was observed in control plots in the same age group. In both age groups, fertilized plots had higher species richness compared to control plots. Fertilization significantly influenced herbaceous species richness, while age group and the interaction between the two factors did not show significant effects. A comparison of species richness across both vegetation layers and stand age groups is shown in Figure 1E. All *p*-values and χ^2 values from analyses of deviance are provided in Table 2.

3.2. A Comparison of Species Diversity Between Control and Fertilized Plots

3.2.1. Silver Birch Stands

In middle-aged silver birch stands, the effects of fertilization and forest site type on species diversity were assessed (Table 1, model No. 1). When examining species diversity across all ground vegetation layers, both control and fertilized plots in forests with drained mineral soils showed higher H' values compared to plots in forests with drained organic soils. In forests with drained mineral soils, an average was found in the fertilized plots exhibited higher H' values than control plots, whereas in forests with drained organic soils, the opposite was observed. Forest site type and its interaction with fertilization treatment significantly influenced total species diversity. Significant differences in H' were found between control plots in drained mineral soils and fertilized plots in drained organic soils, fertilized plots in drained mineral soils and drained organic soils and between control and fertilized plots in drained organic soils. In the moss layer, the average H' was higher in control plots compared to fertilized plots in both forest site types. The H' in the moss layer was significantly influenced by treatment, while forest site type and the interaction of factors had no significant effects. In the herb layer, fertilized plots in forests with drained mineral soils had higher H' values than control plots, while the opposite was observed in forests with drained organic soils. Herb-layer species diversity was significantly influenced by the interaction between forest site type and treatment. Significant differences in H' were observed between control and fertilized plots in forests with drained organic soils. A comparison of species diversity across both vegetation layers and site types is shown in Figure 2A. All p-values and χ^2 values from analyses of deviance are provided in Table 3.

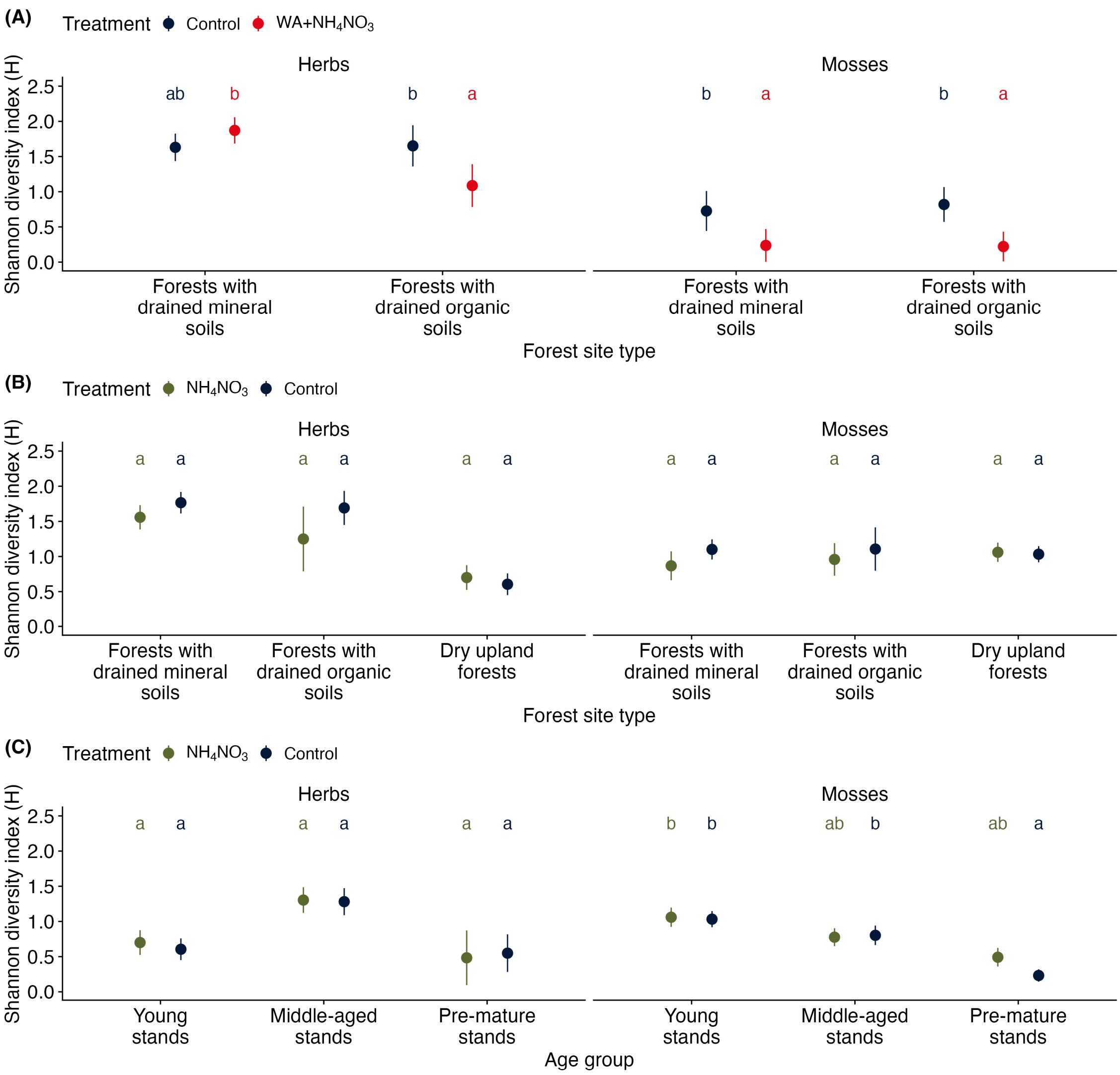

Figure 2. *Cont.*

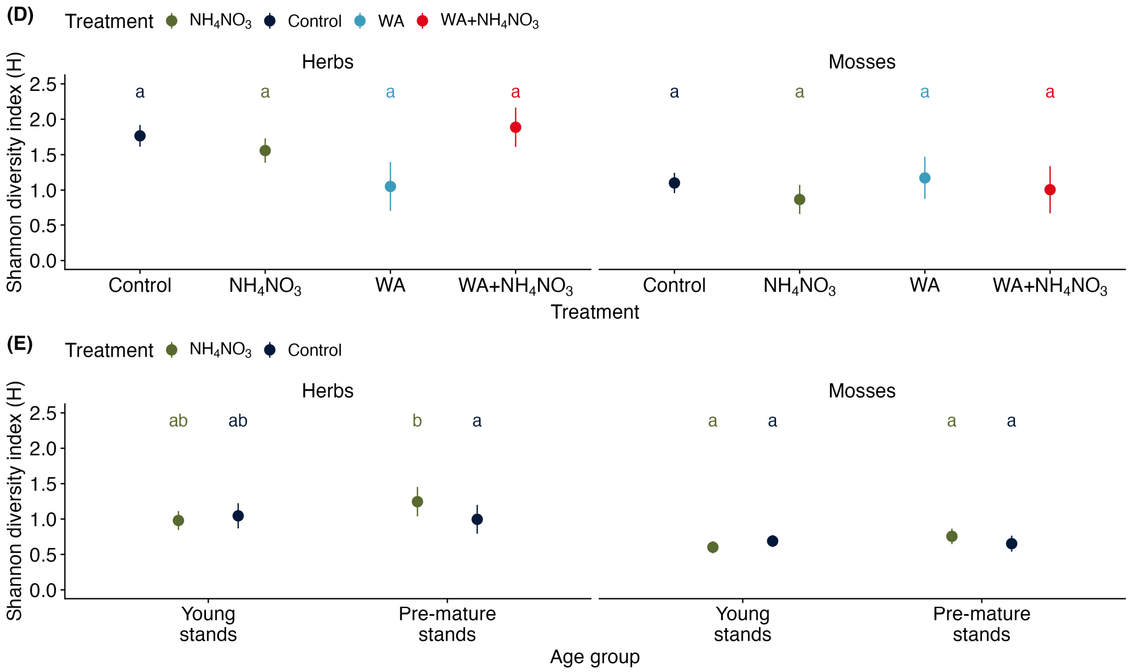

Figure 2. The Shannon diversity index (H′, mean values, and 95% confidence intervals) in the moss and herb layers of silver birch (**A**), Norway spruce (**B**–**D**), and Scots pine (**E**) stands, based on site type, age group, and treatment combinations. WA—wood ash; NH_4NO_3—ammonium nitrate. Letters above the error bars show the results of the Tukey test comparison of the groups—if two groups have the same letter, the difference is not statistically significant ($p > 0.05$).

Table 3. Results of the LMMs on the influence of the independent variables on the Shannon diversity index, H', of the moss and herb species, as well as the total H' (combined moss and herb species). The models are explained in Table 1.

Model No.	Independent Variables	Total		Mosses		Herbs	
		F-Value	***p*-Value**	**F-Value**	***p*-Value**	**F-Value**	***p*-Value**
1	Treatment	3.0264	0.0889	23.8548	<0.0001	2.0243	0.1619
	Site type	0.4070	0.5268	0.1142	1.0000	2.0015	0.1642
	Treatment × site type	16.2833	0.0002	0.2379	0.6281	12.5149	0.0010
2	Treatment	2.5203	0.1151	1.2628	0.2635	2.5789	0.1110
	Site type	8.2926	0.0846	0.0051	0.9949	9.2418	0.0747
	Treatment × site type	1.6717	0.1925	0.7267	0.4857	2.9236	0.0578
3	Treatment	0.0530	0.8183	1.9086	0.1702	0.6725	0.4139
	Age group	5.6386	0.0718	13.3615	0.0119	3.6074	0.1336
	Treatment × age group	1.5743	0.2116	2.0511	0.1341	1.3868	0.2541
4	Treatment	1.6866	0.1913	0.7140	0.5481	1.4609	0.2331
5	Treatment	12.8069	0.0004	0.0115	0.9148	6.3745	0.0125
	Age group	0.0809	0.7843	0.9999	0.3471	0.4795	0.5109
	Treatment × age group	1.9019	0.1696	4.0295	0.0462	3.8537	0.0512

3.2.2. Norway Spruce Stands

In young spruce stands, the Shannon diversity index (H') was evaluated based on forest site type (drained mineral soils, drained organic soils, and dry upland forests) and treatment (control or fertilized with NH_4NO_3) (Table 1, model No. 2).

In forest stands with drained mineral and organic soils, the average H' value was higher in control plots compared to fertilized plots, whereas in dry upland forests, fertilized plots had higher H' values. However, none of the factors had a statistically significant effect on H'. When evaluating the moss layer separately, in forest stands with drained mineral soils and organic soils, H' values in fertilized plots were lower than in control plots, while in dry upland forests, H' values in fertilized plots were slightly higher. However, none of the factors had a significant effect on H'. In the herbaceous layer, the average H' values in drained mineral soils and drained organic soils were higher than in dry upland forests regardless of treatment. In forests with drained mineral soils and drained organic soils, H' values were lower in fertilized plots compared to control plots, while in dry upland forests, fertilized plots had higher values. However, none of the factors significantly affected H' in the herbaceous layer. A comparison of species diversity across both vegetation layers and site types is shown in Figure 2B. All p-values and χ^2 values from analyses of deviance for model No. 2 are provided in Table 3.

In spruce stands in dry upland forests, H' was compared across age groups (Table 1, model No. 3). The highest H' values were found in middle-aged stands, both in control and fertilized plots, compared to young and pre-mature stands. However, none of the factors had a statistically significant effect on H'. When examining the moss layer separately, the highest H' values were observed in young stands, and the lowest in pre-mature stands. In young and pre-mature stands, the H' values in fertilized plots were higher compared to control plots, while in middle-aged stands, the reverse was observed. The H' value in the moss layer was significantly influenced by age group, with a statistically significant difference between pre-mature and young stands. In the herb layer, the highest average H' values were found in middle-aged stands, while the lowest were observed in pre-mature stands. In both young and middle-aged stands, the H' values in fertilized plots were higher than in control plots, while in pre-mature stands, the H' values were lower in fertilized plots compared to the control plots. However, in the herb layer, none of the factors significantly affected the H' index (treatment: $p = 0.4139$; age group: $p = 0.1336$; treatment $\times$ age group: $p = 0.2541$). A comparison of species diversity across both vegetation layers and stand age groups is shown in Figure 2C. All p-values and χ^2 values from analyses of deviance for model No. 3 are provided in Table 3.

In young spruce stands, the effects of different types of fertilizers (NH_4NO_3, wood ash, and wood ash + NH_4NO_3) on species diversity were compared (Table 1, model No. 4). When examining species diversity across all vegetation layers, the highest average H' was observed in control plots, while the lowest was found in plots where only wood ash was applied. However, fertilization treatment did not have a significant effect on H'. When analyzing the moss layer separately, the highest average H' was found in plots where wood ash was applied, while the lowest was observed in plots where only NH_4NO_3 was used. Similarly, the fertilization treatment did not have a statistically significant effect on species diversity. In the herb layer, the highest average H' was observed in plots where wood ash was applied together with NH_4NO_3, while the lowest was found in plots where only wood ash was used. Again, the fertilization treatment did not have a statistically significant effect on H'. A comparison of species diversity across both vegetation layers and treatments is shown in Figure 2D. All p-values and χ^2 values from analyses of deviance for model No. 4 are provided in Table 3.

3.2.3. Scots Pine Stands

In Scots pine stands in dry upland forests, species diversity was assessed in different age groups of pine stands, where NH_4NO_3 was used as fertilizer (Table 1, model No. 5).

When comparing species across all understory vegetation layers, the highest average H' was found in fertilized plots in pre-mature stands, while the lowest H' was observed in control plots in stands of the same age group. In both young and pre-mature stands, fertilized plots exhibited higher average H' values compared to the control plots. The effect of treatment on H' was statistically significant. In the moss layer, in pre-mature stands, higher average H' values were found in fertilized plots, while in young stands, control plots showed higher values. The interaction between the fertilization treatment and age group had a statistically significant effect on H'; however, individual effects were not significant. A marginally significant difference in H' values was found between fertilized plots in young and pre-mature stands. In the herb layer, in pre-mature stands, the H' value in NH_4NO_3-fertilized plots was higher than in control plots, while in young stands, the reverse was observed. The effect of the fertilization treatment on H' was statistically significant. A comparison of species diversity across both vegetation layers and stand age groups is shown in Figure 2E. All p-values and χ^2 values from analyses of deviance are provided in Table 3.

4. Discussion

4.1. The Impact of Tree Species

Due to the experimental design, it was not possible to test the statistical significance among the dominant tree species or directly assess their impact on species richness and diversity interacting with fertilization. This limitation constrains our ability to fully understand species-specific responses to fertilization. However, the observed impact of fertilization on species richness and diversity appears more pronounced in silver birch and Scots pine stands, where the effect of the treatment alone or in interaction with other variables was statistically significant. Evidence from other studies highlight tree species-specific stand differences, which influence ground vegetation. These species-driven differences arise from variations in light availability; soil nutrient cycling; and microclimatic conditions, such as moisture and temperature [40–45]. For example, birch stands have open, light canopies; pine stands have moderately dense canopies; and spruce stands have the densest canopies [46,47]. Also, characteristics of litterfall, including soil litter-layer (O horizon) pH, vary among tree species and influence ground vegetation [48]. The initial species composition can determine how nutrient inputs from fertilization impact species richness and diversity [18].

4.2. Layer-Specific Impact

There was no overall trend in layer-specific differences in species richness and diversity between control and fertilized plots. In silver birch stands, where NH_4NO_3 was applied, fertilization had some statistically significant, site type-dependent effects on moss-layer species richness and a significant, site type-independent effect on species diversity. These findings suggest a potential negative impact of fertilization on the moss layer in birch stands, as both richness and diversity were lower in fertilized plots compared to controls. This aligns with previous studies indicating that bryophytes and lichens are particularly sensitive to increased nutrient availability [20,49,50].

In Norway spruce stands, responses were more variable, with no clear or significant trends observed. In Scots pine stands, fertilization significantly influenced herb-layer species richness, with higher richness observed in fertilized plots, suggesting a positive impact. However, species diversity in the herb layer was less consistent. Studies show that fertilization often affects plant functional types differently. Forbs and nutrient-poor shrubs are most negatively affected by nutrient inputs, while graminoids typically benefit the most [18,20,51]. Depending on initial species composition, herb-layer species richness and diversity can be affected positively or negatively by fertilization. In a short-term (two-year) study carried out in Norway, no significant impact on species richness in the herb layer was found after the application of wood ash and NH_4NO_3. However, the application of wood ash together with NH_4NO_3 or wood ash alone significantly reduced species richness in the moss layer [52].

4.3. The Impact of Forest Site Type

Forest site type had a significant impact on species richness and diversity in silver birch stands and on species richness in Norway spruce stands. In birch stands with drained mineral soils, both control and fertilized plots exhibited higher average species richness and diversity compared to plots in forests with drained organic soils. Also, spruce stands with drained mineral soils exhibited higher species richness, followed by those with drained organic soils and dry upland forest stands. Only in birch stands did forest site type have a significant effect when interacting with fertilization.

According to the Latvian forest classification, forests with drained mineral soils and those with drained organic soils cannot be directly compared in terms of fertility. However, they have distinct characteristics that can influence species composition and initial species richness and diversity. These differences may lead to varying responses to fertilization. Forests with drained mineral soils are formed as a result of the drainage of wet mineral soils or waterlogged meadows; the process of bog formation ceases, while podzolization and gleization processes continue. Forests with drained organic soils are formed as a result of the drainage of wet peat soils or the drainage of transition and lowland bogs. In forests with drained mineral soils, the detritus layer is lower than 20 cm, while in forests with drained organic soils, it exceeds 20 cm. Dry upland forests in this study are slightly lower in fertility, as the more fertile dry upland types were not included in this study. Dry upland forests are formed on sandy soils. There is no peat layer present, and podzolization processes occur [53,54].

The soil C:N ratio is an indicator of the mineralization rate. Organic soils generally exhibit higher C:N ratios than mineral soils [55]. A lower C:N ratio leads to faster nitrogen release into the soil, making it more readily available for plant use [56]. This may help to explain the observed differences between forests with drained mineral soils and those with drained organic soils. Also, tree species is a major factor influencing C:N ratio and topsoil, especially soil O horizon chemistry in general, which could further affect responses to fertilization. Therefore, interaction between fertilization had a significant effect only in birch stands. The lower species richness and diversity in dry upland forests could be explained by lower site fertility.

4.4. Impact of Stand Age

Forest stand age significantly impacted species richness in herb layer in dry upland Norway spruce stands, while no significant effect was observed in dry upland Scots pine stands. Middle-aged spruce stands had the highest species richness in the herb layer, with significantly lower richness observed in young and pre-mature stands. Species diversity in the herb layer did not differ significantly across age groups, indicating that species evenness remained stable. Stand age had a clear impact on the moss layer diversity, while no impact on richness was observed. Young stands exhibited the highest moss diversity, in both control and fertilized plots, compared to middle-aged and pre-mature stands. The diversity observed in young stands may be related to differences in initial canopy cover and light availability, factors which are often more favorable for mosses in younger stands [57].

Other studies on the impact of stand age on species richness and diversity have shown varying results. In Central Europe, a study conducted in a Scots pine plantation found the highest species diversity (excluding mosses) to be in young stands, a finding that was not observed in our study [58]. A review on the relationship between forest structural attributes and species richness in temperate forests highlighted a positive correlation between stand age and species richness in bryophytes and vascular plants in temperate forests. However, this relationship can be more variable in managed forests, where management practices influence canopy gaps and closure and old-growth structural elements [59]. In Norway, a study conducted in natural spruce forests found that age explained only a small portion of species composition variation compared to soil properties, forest management history, and forest structure [60].

A study in Sweden examined forest structures that promote biodiversity and the influence of various factors on these structures. In this study, stand age was also a significant factor, but its effect depended on stand productivity and forest management practices [61]. Similarly, studies conducted in Latvia on Norway spruce stands (both in natural forests and plantations) found that the influence of age on species diversity was secondary to forest structure characteristics (canopy composition, species proportions, understory density and height, etc.) [62,63]. Tullus et al. have shown that vascular plant species richness often decreases with increasing stand age; however, this study offered only information about deciduous forests [64]. Another study conducted in Sweden found that mature stands with layered canopies exhibited the highest species diversity, regardless of soil properties, while young stands had the lowest diversity [65].

4.5. Impact on Fertilizer Type

In young Norway spruce stands with drained mineral soils, where the impact of different fertilizers was assessed, across both vegetation layers, the highest species richness occurred in plots treated with wood ash and NH_4NO_3. The lowest species richness was found in plots treated only with NH_4NO_3. The combination of wood ash and NH_4NO_3 may balance pH effects and nutrient supply; however, due to lack of statistical significance, we should be cautious about making an assumption that there was a potentially positive impact of combined fertilizer use. In silver birch stands, where wood ash was also applied together with NH_4NO_3, a significant, potentially negative effect on the moss layer was observed. In Scots pine stands, the herb-layer richness was potentially positively impacted by the application of NH_4NO_3, thus contradicting the results in Norway spruce stands. Regarding species diversity, no consistent trend was observed among the two layers separately and the total species diversity in spruce stands, while in birch stands, a significant, potentially negative effect in the moss layer was observed from the application of wood ash together with NH_4NO_3. The effect of fertilizers appears to be species-, layer-, and site type-specific. Wood ash application has been often associated with a negative impact on vegetation, although dose and pre-treatment matter [19,66]. Loose ash has a high potential to negatively impact ground vegetation, primarily affecting the cover and certain types of mosses [20,50]. In a study conducted in Sweden, the use of hardened wood ash at doses up to 3 t ha^{-1} did not result in significant changes in moss and herb diversity in spruce plantations, and this finding is consistent with our study [27]. Also, another study carried out in Latvia in a tree plantation with both conifers and deciduous trees on a cutaway peatland showed that wood ash application, along with distance from drainage ditch, had a positive impact on vascular plant species richness [67]. The effects of NH_4NO_3 are primarily associated with shifts towards more nitrophilous flora, increased site productivity, and eutrophication, all of which influence species richness and diversity [30–33,68]. However, this influence may become more apparent after a longer period than that of our study.

5. Conclusions

The findings of our study highlight the context-dependent nature of fertilization effects on species richness and diversity in Latvian hemiboreal forest ecosystems. While these effects were not universally significant, variations were observed across forest site types, vegetation layers, and stand ages. In silver birch stands, the combined application of wood ash and NH_4NO_3 was associated with a potentially negative impact on moss species richness and diversity, suggesting sensitivity to changes in soil chemistry. In Scots pine stands, NH_4NO_3 alone appeared to positively influence herb-layer richness, though its effect on species diversity was less consistent. In contrast, Norway spruce stands showed no significant fertilization effects, with stand age and site type emerging as the primary factors influencing species richness and diversity.

While this study provides valuable insights into the effects of fertilization on ground vegetation, it captures only short-term impacts and a one-time comparison between control and fertilized plots. These limitations underscore the need for caution in generalizing the results. Future research should address these gaps by incorporating broader site selection, longer-term and repeated observations, and more comprehensive biodiversity metrics to enhance our understanding of fertilization impacts on forest understories.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table 1. Characteristics of the studied forest stands. NS—Norway spruce; SP—Scots pine; SB—silver birch; WA—wood ash.

ID	Forest Site Type	No. of Vegetation Plots	Tree Species	Stand Age	G, m^2 ha^{-1}	H, m	DBH, cm	Stand Volume, m^3 ha^{-1}	Fertilizer	Spread Technology
1	Dry upland forests	6 NH_4NO_3, 6 control	NS	84	23.1	17.1	19.4	241.95	NH_4NO_3	Mechanical
2	Dry upland forests	14 NH_4NO_3, 14 control	NS	26	17.45	14.16	13.49	140.82	NH_4NO_3	Mechanical
3	Dry upland forests	18 $NH_4NO_{3,}$ 16 control	NS	50	23.1	18.78	21.05	236.5	NH_4NO_3	Mechanical
4	Dry upland forests	6 NH_4NO_3, 6 control	NS	76	36.73	23.25	24.2	470.48	NH_4NO_3	Mechanical
5	Dry upland forests	12 NH_4NO_3, 12 $control_3$	NS	38	23.05	17.8	16.9	222.23	NH_4NO_3	Mechanical
6	Forests with drained mineral soils	16 NH_4NO_3, 10 control	NS	38	23.58	18.25	19.16	219.72	NH_4NO_3	Manual
7	Forests with drained organic soils	12 NH_4NO_3, 8 control	NS	34	19.19	16.34	17.2	166.7	NH_4NO_3	Manual
8	Forests with drained mineral soils	6 NH_4NO_3, 6 control, 12 WA	NS	36	21.27	18.37	25.03	187.07	NH_4NO_3/WA	Mechanical
9	Dry upland forests	12 NH_4NO_3, 12 control	SP	92	28.95	19.48	18.65	325.8	NH_4NO_3	Mechanical
10	Dry upland forests	12 NH_4NO_3, 12 control	SP	39	24.7	15.2	17.17	210.25	NH_4NO_3	Mechanical
11	Dry upland forests	12 NH_4NO_3, 12 control	SP	76	25.67	22.63	25.55	301.88	NH_4NO_3	Mechanical
12	Dry upland forests	8 NH_4NO_3, 4 control	SP	38	18.17	17.67	18.2	157.1	NH_4NO_3	Manual
13	Dry upland forests	22 NH_4NO_3 12 control	SP	32	19.1	16.56	17.35	157.47	NH_4NO_3	Manual
14	Dry upland forests	6 NH_4NO_3, 6 control	SP	84	37.57	25.1	29.23	473.73	NH_4NO_3	Mechanical
15	Dry upland forests	12 NH_4NO_3, 12 control	SP	31	19.65	15.92	17.92	158.87	NH_4NO_3	Mechanical
16	Dry upland forests	6 $NH_4NO_{3,}$ 6 control	SP	83	37.07	24.3	24.17	493.87	NH_4NO_3	Mechanical
17	Dry upland forests	12 NH_4NO_3, 12 control	SP	25	19.15	10.77	13.22	111.65	NH_4NO_3	Manual
18	Dry upland forests	6 NH_4NO_3, 6 control	SP	55	26.39	17.77	20.53	275.06	NH_4NO_3	Mechanical
19	Forests with drained mineral soils	12 NH_4NO_3, 12 control	SB	35	15.38	19.34	18.19	149.29	NH_4NO_3 + WA	Manual
20	Forests with drained organic soils	12 NH_4NO_3, 12 control	SB	38	17.03	17.05	15.38	155.18	NH_4NO_3 + WA	Mechanical

B.

Table 2. Presence/absence of individual ground vegetation species depending on the dominant tree species and forest site type: 0 = absent; 1 = present.

Species	Silver Birch		Norway Spruce			Scots Pine
	Forests with Drained Mineral Soils	Forests with Drained Organic Soils	Forests with Drained Mineral Soils	Forests with Drained Organic Soils	Dry Upland Forests	Dry Upland Forests
Aulacomnium palustre	0	0	0	0	1	1
Brachythecium rutabulum	1	1	1	0	1	1
Calliergonella cuspidata	1	1	1	0	0	1
Cirriphyllum piliferum	0	0	1	0	0	1
Climacium dendroides	0	1	1	0	0	0
Dicranum sp.	0	0	0	0	1	0
Dicranum majus	0	0	1	0	1	1
Dicranum montanum	0	0	0	0	0	1
Dicranum polysetum	1	1	1	1	1	1
Dicranum scoparium	0	1	1	1	1	1
Eurhynchium angustirete	0	0	1	0	0	1
Funaria hygrometrica	0	0	0	0	1	0
Hylocomium splendens	1	1	1	1	1	1
Marchantia polymorpha	0	0	1	0	0	0
Plagiochila asplenioides	0	1	0	0	1	1
Plagiomnium affine	1	1	1	0	1	1
Plagiomnium cuspidatum	0	1	1	0	0	0
Plagiomnium ellipticum	0	1	1	1	0	1
Plagiomnium undulatum	0	0	1	0	1	0
Pleurozium schreberi	1	1	1	1	1	1
Polytrichum commune	0	1	1	1	1	1
Polytrichum juniperinum	0	0	1	0	1	1
Pseudoschleropodium purum	0	0	1	0	1	0
Ptilium crista-castrensis	0	0	1	1	1	1
Rhytidiadelphus squarrosus	1	0	1	1	1	1
Rhytidiadelphus triquetrus	0	1	0	1	1	1
Rhodobryum roseum	1	1	1	1	1	1
Sphagnum angustifolium	0	1	0	0	0	1
Sphagnum girgensohnii	0	0	0	0	1	1
Sphagnum squarrosum	0	1	0	0	0	0
Sphagnum spp.	0	0	0	0	1	0
Cetraria Islandica	0	0	0	0	0	1
Cladonia rangiferina	0	0	0	0	0	1
Cladonia stellaris	0	0	0	0	0	1
Achillea millefolium	0	0	0	0	0	1
Aegopodium podagraria	0	1	0	1	0	0
Agrostis sp.	1	0	1	0	0	1
Agrostis canina	0	1	0	0	0	0
Agrostis gigantea	0	0	1	0	0	0
Agrostis tenuis	0	0	1	0	0	1
Amelanchier spicata	0	0	0	0	0	1
Anemone nemorosa	0	0	1	1	1	0
Anemone ranunculoides	0	0	1	1	0	0
Asarum europaeum	0	0	0	1	0	0
Athyrium filix-femina	0	1	1	0	0	1
Angelica sylvestris	1	1	0	0	0	1
Anthoxanthum odoratum	1	0	0	0	0	0
Anthriscus sylvestris	1	0	0	0	0	0
Betula pendula < 1 m	0	1	1	1	1	1
Calamagrostis arundinacea	0	0	0	0	1	0
Calamagrostis canescens	1	0	0	0	0	0
Calamagrostis epigeios	0	0	0	0	0	1
Calamagrostis sp.	0	0	0	1	0	0
Calluna vulgaris	0	0	0	0	0	1
Carex hirta	0	0	0	0	0	1
Carex leporina	0	0	0	0	0	1
Carex nigra	0	1	0	0	0	1
Carex pilulifera	0	0	0	0	0	1
Carex rostrata	0	1	0	0	0	0
Carex sylvatica	0	0	0	0	0	1

Table 2. *Cont.*

Species	Silver Birch		Norway Spruce			Scots Pine
	Forests with Drained Mineral Soils	Forests with Drained Organic Soils	Forests with Drained Mineral Soils	Forests with Drained Organic Soils	Dry Upland Forests	Dry Upland Forests
Carex vesicaria	0	1	0	0	0	0
Carex sp.	1	1	0	0	1	1
Chamaenerion angustifolium	0	0	1	1	0	1
Chelidonium majus	0	0	1	0	0	0
Cirsium heterophyllum	0	1	0	0	0	0
Cirsium oleraceum	0	1	0	0	1	0
Comarum palustre	1	1	0	0	0	0
Convallaria majalis	0	1	0	1	1	1
Corylus avellana	0	0	0	0	1	1
Dactylis glomerata	0	0	0	0	0	1
Deschampsia cespitosa	1	0	0	0	1	1
Dryopteris carthusiana	1	1	1	1	1	1
Dryopteris cristata	1	0	0	0	0	0
Dryopteris expansa	0	1	0	0	0	0
Dryopteris filix-mas	0	0	0	0	0	1
Empetrum nigrum	0	0	0	0	0	1
Epilobium sp.	0	0	1	0	0	0
Equisetum palustre	0	1	0	0	0	0
Festuca sp.	0	1	1	0	0	1
Festuca rubra	0	0	0	0	0	1
Festuca ovina	0	0	0	0	0	1
Filipendula ulmaria	0	1	0	0	0	0
Fragaria vesca	1	1	1	1	1	1
Frangula alnus	1	1	1	1	0	1
Galeobdolon luteum	1	0	0	0	0	0
Galeopsis sp.	0	0	1	0	0	1
Galeopsis tetrahit	0	0	0	0	0	1
Galium sp.	1	1	1	1	0	1
Galium album	0	0	1	0	0	0
Galium boreale	0	0	1	0	0	0
Galium palustre	0	1	0	0	0	0
Galium odoratum	0	0	1	0	0	0
Galium uliginosum	0	0	1	0	0	0
Geranium robertianum	1	0	0	0	0	0
Geum rivale	1	0	0	0	0	0
Goodyera repens	0	0	0	0	1	1
Hepatica nobilis	0	0	1	1	0	0
Hieracium pilosella	0	0	0	0	1	1
Hieracium praealtum	0	0	0	0	0	1
Hieracium sp.	0	0	1	1	0	0
Hypericum perforatum	0	0	1	1	0	0
Hypericum quadrangulum	0	0	1	0	0	0
Impatiens parviflora	0	0	0	0	1	1
Juncus conglomeratus	0	0	0	0	0	1
Juncus effusus	0	1	0	0	0	0
Juniperus communis	0	0	0	0	0	1
Lamium album	0	0	1	0	0	0
Luzula pilosa	1	1	1	1	1	1
Lycopodium annotinum	0	0	0	0	0	1
Lycopus europaeus	1	1	0	0	0	0
Lysimachia sp.	0	0	1	1	0	0
Lysimachia vulgaris	1	1	1	0	1	1
Maianthemum bifolium	1	1	0	0	1	1
Melampyrum nemorosum	0	0	0	0	1	0
Melampyrum pratense	1	0	0	0	1	1
Melampyrum sylvaticum	0	0	0	1	1	1
Mentha sp.	1	0	0	0	0	0
Moehringia trinervia	0	0	0	0	1	0
Molinia caerulea	0	1	0	0	0	1
Mycelis muralis	1	1	1	1	1	1
Oxalis acetosella	0	1	1	1	1	1
Phragmites australis	1	0	0	0	0	0
Pinus sylvestris	1	0	0	0	1	1
Poa sp.	0	0	1	0	0	1
Poa palustris	0	1	0	0	0	0

Table 2. *Cont.*

Species	Silver Birch		Norway Spruce			Scots Pine
	Forests with Drained Mineral Soils	Forests with Drained Organic Soils	Forests with Drained Mineral Soils	Forests with Drained Organic Soils	Dry Upland Forests	Dry Upland Forests
Poa nemoralis	1	0	1	0	1	0
Poa trivialis	0	0	1	0	0	0
Pohlia nutans	0	0	1	0	0	0
Potentilla sp.	0	0	0	0	0	1
Potentilla erecta	1	0	0	0	0	1
Prunella vulgaris	0	0	1	0	0	0
Pteridium aquilinum	0	0	0	0	1	1
Prunus padus	0	0	1	0	0	0
Quercus robur < 1 m	0	0	0	0	0	1
Ranunculus sp.	1	0	0	1	0	0
Ranunculus acris	0	0	1	0	0	0
Ranunculus cassubicus	0	0	1	0	0	0
Ranunculus repens	0	1	1	0	0	0
Rubus sp.	1	0	0	0	0	0
Rubus idaeus	1	1	1	1	1	1
Rubus saxatilis	1	1	1	1	1	1
Rumex acetosa	0	0	0	0	0	1
Rumex acetosella	0	0	1	0	1	1
Rumex sp.	0	0	1	1	0	0
Salix sp.	1	0	0	0	0	0
Senecio vulgaris	0	0	0	0	0	1
Scutellaria galericulata	1	0	0	0	0	1
Solidago sp.	1	0	0	0	0	1
Solanum dulcamara	1	1	0	0	0	0
Sorbus aucuparia	1	0	0	1	1	1
Stellaria graminea	0	0	1	1	0	0
Stellaria holostea	0	1	1	0	1	0
Stellaria media	1	1	1	0	0	1
Stellaria nemorum	0	0	0	1	0	0
Stellaria sp.	0	0	1	1	0	0
Taraxacum officinale	0	0	1	1	0	1
Trientalis europaea	1	1	0	1	1	1
Urtica dioica	1	0	1	1	0	1
Vaccinium myrtillus	1	1	0	1	1	1
Vaccinium vitis-idaea	1	0	0	1	1	1
Vaccinium uliginosum	0	0	0	0	1	0
Veronica chamaedrys	1	0	1	1	1	1
Veronica officinalis	0	0	0	1	1	1
Vicia sp.	1	0	1	0	0	0
Viola sp.	1	1	1	1	1	1

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