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SHORT-TERM IMPACT OF FERTILIZATION ON GROUND VEGETATION IN DECIDUOUS FOREST STANDS AND TREE PLANTATION

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Abstract
This study examines the impact of fertilization with wood ash and ammonium nitrate on ground vegetation in Silver birch stands representing 4 forest types (*Hylocomiosa*, *Myrtilloso-sphagnosa*, *Myrtillosa mel*. and *Myrtillosa turf. mel*.), as well as in a deciduous tree (*Alnus glutinosa*, *Betula pendula, Cerasus avium*) plantation. Ground vegetation was assessed 2 years after application of fertilizers. The mean ground cover of individual species in moss, herb and shrub layer was determined. Species composition, species richness and species diversity were compared between fertilized and unfertilized plots. Shannon diversity index (H) was chosen as an indicator of species diversity. Results show that in Silver birch stands species composition in both control and fertilized plots is typical of the respective forest types. In the Ķeipene plantation, occurrence or increased abundance of several nitrophilous species was observed in the fertilized parcels. Statistically significant differences between H values of control and fertilized plots have been found only in the *Myrtillosa mel.* forest stand in the moss layer, as well as in the herb layer of one of the *Hylocomiosa* stands and Sweet cherry parcel in Ķeipene plantation. Long-term observations are required in order to determine if the observed differences in ground vegetation between control and fertilized areas persist longer.
Key words: wood ash, ammonium nitrate, ground vegetation, deciduous trees, plantation.

Introduction

Over recent years, forest fertilization has been highlighted as a practice to improve tree growth, thus increasing biomass production. A shorter rotation period is another benefit of fertilizer application (Smethurst, 2010). Nitrogen (N), phosphorus (P) and potassium (K) are the nutrients that most commonly limit tree growth. Nitrogen containing fertilizers, such as ammonium nitrate (NH_4NO_3), are applied in forests on mineral soils, whereas fertilizers containing phosphorus (P) and potassium (K), such as wood ash, are mostly used in in peatland forests (Saarsalmi & Mälkönen, 2001). The dose of nitrogen 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} (Pukkala, 2017). Ash is a solid, somewhat powdery residue of biomass combustion. It contains such essential mineral elements for tree growth as P, K, calcium (Ca), magnesium (Mg), and several trace elements. However, wood ash does not contain nitrogen as it is lost through burning. Wood ash has liming properties due to its high content of oxide CaO and hydroxide $Ca(OH)_2$ (Karltun *et al*., 2008). For peatland forests the recommended dose of K is 40-80 kg ha$^{–1}$ and that of P is 40-50 kg ha$^{–1}$, which correspond to a wood ash amount of 2000-5000 kg dry weight (Sikström, Almqvist, & Jansson, 2010). Wood ash and ammonium nitrate can be applied simultaneously to supplement N, P and K, stocks as well as to prevent soil acidification.

Fertilizers are also frequently applied in tree plantations at some stage of development. The most frequently planted tree species in Latvia is Silver birch. Birch trees do not require heavy fertilizing if already growing in nutrient-rich soil. It is recommended to perform soil analyses before fertilization to determine nutrient deficiencies. The second most frequently planted deciduous tree species is Black alder (*Alnus glutinosa*). Black alder is tolerant of higher groundwater level, provided that tree roots are sufficiently supplied with oxygen. It has a capability to fix nitrogen; therefore, it can improve soil conditions and minimize the need for nitrogen containing fertilizers (European Forest Genetic Resources Programme, 2003). Fertilization also improves winter hardiness and fruit quality of sweet cherries (*Cerasus avium*) (Swarts *et al*., 2017).

Ground vegetation is an integral component of forest ecosystems although it is frequently overlooked. It has a role in water and nutrient cycling, soil stabilisation and biodiversity maintenance. Application of NH_4NO_3 and wood ash to forest soils has an impact on soil pH and nutrient availability, which may lead to changes in species composition, species richness, occurrence of cenrtain species and biodiversity of ground vegetation. These changes depend on several factors, such as light availability to herb and moss layers, initial nutrient status, moisture levels and forest site management. Loose ash is not suitable for fertilization, as it may cause a direct plant tissue damage; therefore, a pre-treatment is necessary. A number of studies on the impact of ground vegetation have been carried out in the Nordic countries and Canada, which can be approximated to the climatic conditions in Latvia. Studies show that changes caused by a small single dose would be most likely insignificant, whereas a repeated input may lead to changes in species composition and biodiversity loss (Olsson & Kellner, 2006). Application of fertilizers result in occurrence of species typical of more fertile site types (Kellner, 1993).

The aim of the study was to determine the impact of fertilization with NH_4NO_3 alone or supplemented with wood ash on species composition, richness and diversity of ground vegetation in Silver birch stands and a deciduous tree plantation.

Materials and Methods

Research sites

The study was conducted in five forest stands all over Latvia, where the dominant tree species is Silver birch (*Betula pendula*), representing 4 forest types (*Hylocomios*a, *Myrtilloso-sphagnosa*, *Myrtillosa mel*. and *Myrtillosa turf.mel.*), and in Keipene plantation, where deciduous tree seedlings have been planted in 2012 and 2013 on former agricultural land with mineral soil. The age of forest stands varied from 22 to 71 years. Stand characteristics are shown in Table 1. Ammonium nitrate (NH_4NO_3, dose 0.44 t ha^{-1}) was applied once in each stand from December 2016 till July 2017. In *Myrtillosa mel*. and *Myrtillosa turf.mel.*) stands, additionally wood ash was spread (dose 3 t ha^{-1}). Wood ash was obtained from Fortum and Latgran pellet factories.

The Keipene plantation is located in central Latvia, Ogre municipality, Keipene parish (56°55'59.3'N 25°08'15.4'E). In 2016, prior to fertilization, soil and leaf/needle analyses were carried out and P deficiency was detected. Fertilizers were spread manually in 2017 (dose 0.44 t NH_4NO_3 ha^{-1}) and in parcels, where decreased tree growth was observed, additionally wood ash was spread (dose 3 t ha^{-1}). Wood ash was obtained from SIA Graanul Pellets pellet factory. The element concentration of wood ash was 153.32 g kg^{-1} Ca, 25.96 g kg^{-1} K, 11.58 g kg^{-1} Mg and 9.6 g kg^{-1} P. The following tree species of the plantation were included in the study: Common alder (*Alnus glutinosa* (L.) Gaertn.) Silver birch (*Betula pendula* Roth.) and Sweet cherry (*Cerasus avium* (L.), Moench syn. *Prunus avium* L.).

Ground vegetation survey

Ground vegetation was surveyed 2 years after application of fertilizers. In both Ķeipene plantation and Silver birch-dominated forest stands, ground vegetation was surveyed in plots of 1 m^2 squares, grouped by two and arranged in an equilateral triangle, whose edges are oriented perpendicularly to a 30x30 m plot, where fertilizers were spread (Figure 1). The number of control and fertilized vegetation survey plots in each study site vary from 6 to 12. In each sample plot, the projective cover of each species in moss (mosses, liverworts, lichens), herb (vascular plants, shrubs and tree seedlings up to 0.5 m) and shrub (shrubs and trees 0.5-7.0 m in height) layer in both control and fertilized plots was determined. Along with visual estimation of the percentage cover of each plant species, species occurrence and species richness were determined and compared between control and fertilized plots. Changes in species composition and richness were analyzed for moss and herb layer separately. Shannon diversity index (H) was chosen as a measure to compare species diversity between control and fertilized plots. H was calculated separately for moss, herb and shrub layer using equation 1 (Magurran, 1988):

Table 1

Characteristics of the studied birch stands and amount of fertilizers used per stand

Forest type	Stand age	G, m^2 ha^{-1}	H, m	DBH, cm	Stand volume, m^3 ha^{-1}	NH_4NO_3, t	Wood ash, t
Hylocomiosa	68	31.5	23	20.5	369	0.247	-
Hylocomiosa	71	29	22	21.5	356.6	0.176	-
Myrtilloso-sphagnosa	22	20	18.5	15	192	0.079	-
Myrtillosa mel.	33	15	20	18	149.5	0.159	1.08
Myrtillosa turf.mel.	28	17	17	15	155.5	0.318	2.16

Table 2

Characteristics of the deciduous tree plantation in Keipene and the amount of fertilizers used per parcel

Tree species	Fertilized area, ha	NH_4NO_3, kg	Wood ash, kg	H, m	DBH, cm	Number of trees per ha
Alnus glutinosa	0.12	53	-	5.34	5.60	575
Betula pendula	0.12	53	-	4.12	5.40	576
Cerasus avium	0.09	40	270	3.86	4.11	1024

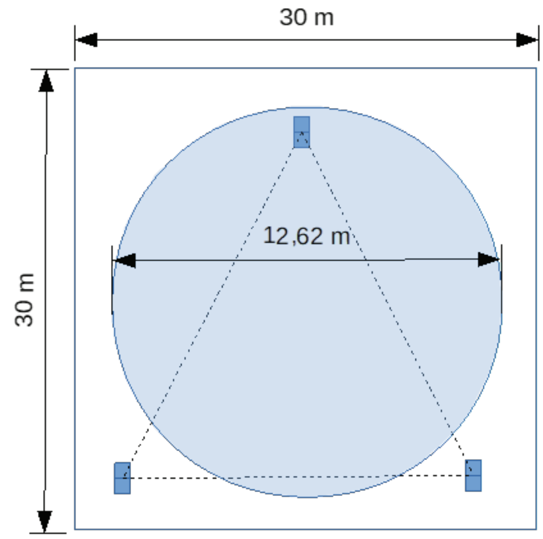

Figure 1. Vegetation survey plot design in relation to the fertilized area.

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

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

The ground cover of each species was used in calculations instead of the number of individuals (Vahdati *et al*., 2016).

Statistical analysis

Shannon diversity index was calculated and vegetation ground cover data were processed with Microsoft Excel. Statistical analyses were conducted, using software RStudio. Student's T-test and Wilcoxon rank sum test were performed to estimate differences between the control and fertilized areas. The test was chosen, depending on normality of data distribution.

Results and Discussion

In all the Silver birch stands species composition still correspond to the respective forest types. In *Hylocomiosa* stands in the moss layer *Hylocomium spledens, Pleurozium schreberi and Rhytidiadelphus triquestrus* predominate. In one of these stands, the total moss cover is larger in plots, where NH_4NO_3 has been added. In the herb layer, the dominant species are *Calamagrostis arundinacea, Carex sp., Vaccinium myrtillus.* The cover of dwarf shrubs does not decrease in a result of fertilization. The projective cover of mosses is slightly lower in the fertilized plots of *Myrtillosa mel.* forest stands. *Calliergonella cuspidata* and *Plagiomnium affine* are the most commonly observed moss species, whereas in the herb layer *Calamagrostis canescens* and *Deschampsia cespitosa* predominate. *Rubus idaeus* has a slightly larger projective cover in fertilized plots and nitrophilous *Lycopus europaeus* occurs only in the fertilized plots. In the *Myrtillosa turf. mel.* forest stands, the dominant moss species in both control and fertilized plots is *Calliergonella cuspidata*, whereas in the herb layer *Agrostis canina* and *Festuca sp.* predominate. In the *Myrtilloso-sphagnosa* stand, *Calliergon cordifolium* is the most commonly observed moss species, whereas in the herb layer the most commonly observed species is *Oxalis acetosella*.

The average H values in control plots in the moss layer range from 0.54±0.12 in the *Myrtilloso–sphagnosa* stand to 0.93±0.18 in one of the *Hylocomiosa* stands. In fertilized plots, the average values range from 0.22±0.10 in the *Myrtillosa turf. mel.* stand, where NH_4NO_3 has been applied together with wood ash, to 0.90±0.18 in *Hylocomiosa* stand, where NH_4NO_3 has been applied. In all the stands the average H value is lower in fertilized plots, except for one of the *Hylocomiosa* stands. Statistically significant differences between H values in control and fertilized plots have been found only in the *Myrtillosa mel.* forest stand, where the average H value in the herb layer is higher but in the moss layer it is lower in fertilized plots, and in one of *Hylocomiosa* stands in the herb layer, where the average value in fertilized plots is lower. A comparison of the H values in control and fertilized plots, depending on site type is shown in Figure 2. The number of species in fertilized plots is higher in the herb layer in *Myrtillosa mel.* and *Myrtillosa turf.mel.* stands, but in the rest of stands it's lower, comparing with the control. The number of species is lower in the moss layer, except for one of the *Hylocomiosa* stands, where it is slightly higher. A comparison of the number of species in control and fertilized plots, depending on site type is shown in Figure 3.

Keipene plantation. Most of them are heliophiles with an Ellenberg value for light (L) in range from 7 to 9. Several nitrophilic species either occur only in the

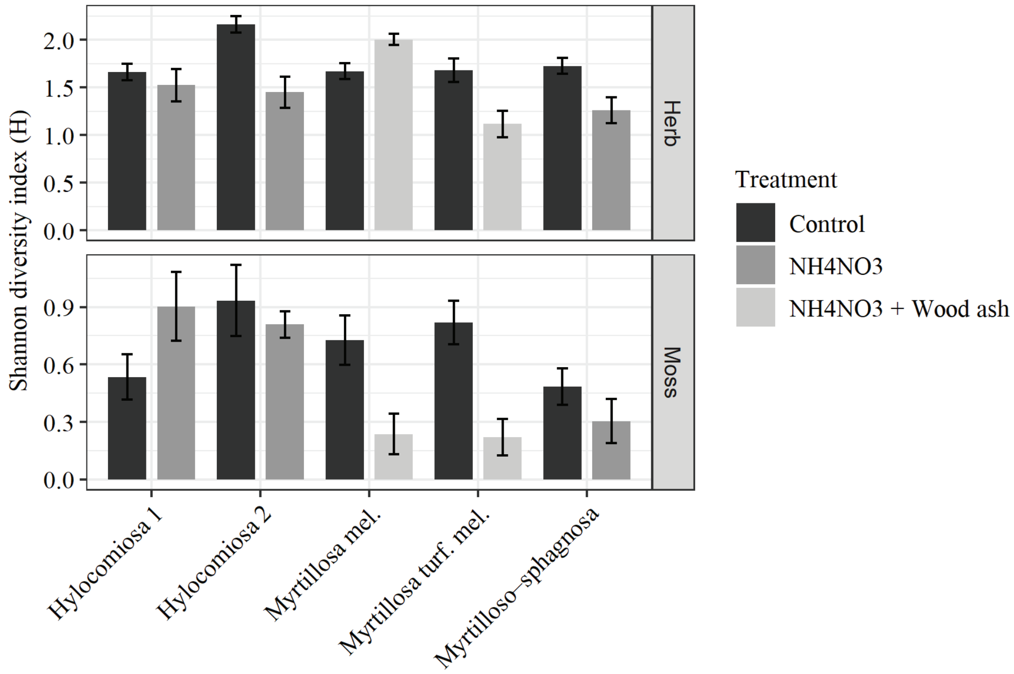

Figure 2. Shannon diversity index in herb and moss layer depending on forest type (mean values ± standard error of the mean (SEM)).

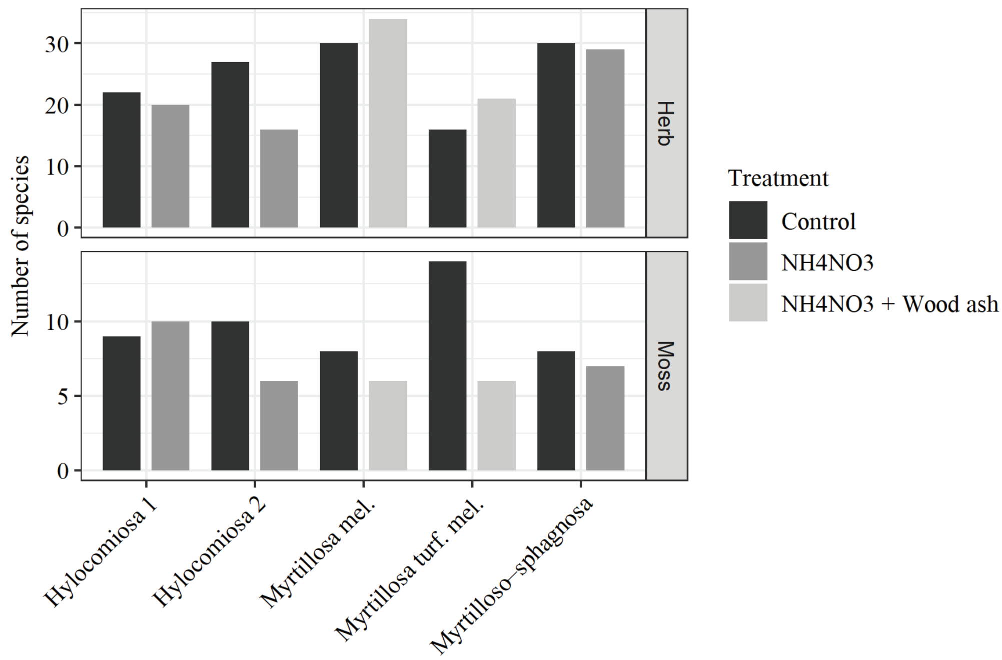

Figure 3. Number of species in herb and moss layer depending on forest type.

Species typical of meadows, pastures and wasty places predominate the ground vegetation of fertilized parcels or have a larger cover. In fertilized parcels, where Silver birch has been planted, larger projective cover and increased occurrence has been observed for *Aegopodium podagraria*. This species is also observed only in the fertilized areas, where Sweet cherry has been planted. Nitrophile *Anthriscus sylvestris* have slightly larger cover in the fertilized birch and alder parcels, whereas *Taraxacum officinale* has increased occurence in these plots. Only in fertilzed plots *Heracleum sibiricum* and *Lathyrus palustris* have been observed. In wild cherry-growing parcels a slighly larger cover has been observed for *Artemisia*

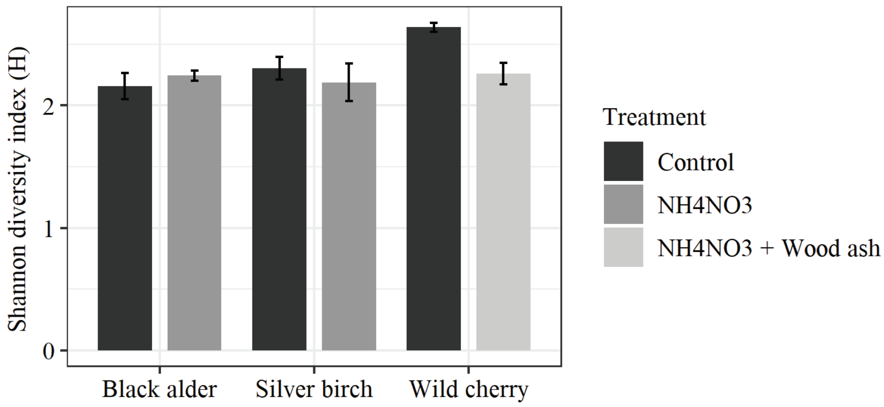

Figure 4. Shannon diversity index in *Ķeipene plantation* depending on tree species (mean values ± SEM).

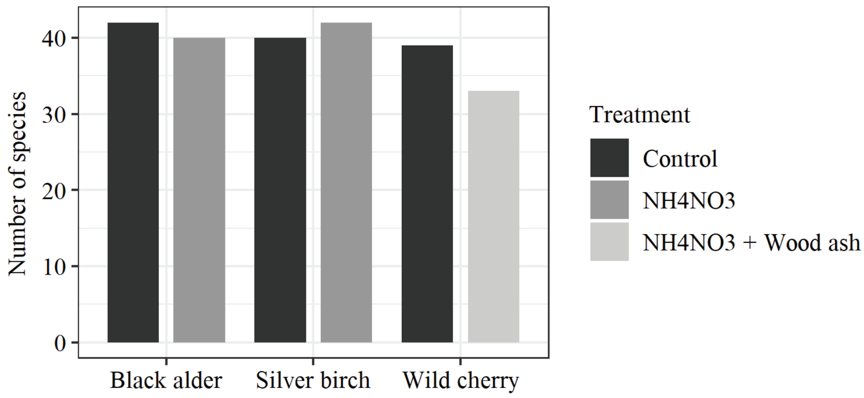

Figure 5. The number of ground vegetation species in Ķeipene plantation depending on tree species.

vulgaris. Only in fertilized parcels of both wild cherry and Black alder *Lolium perenne* has been observed. In Sweet cherry-growing parcels, individually growing plants of *Urtica dioica* have been observed as well as *Tussilago farfara* and *Lolium multiflorum*is occur more frequently than in control parcels. In all the fertilized parcels, *Phleum pratense* has been observed more frequently and had larger cover. Also, *Potentilla anserina* occured more frequently in fertilized parcels.

The average H value in fertilzed Black alder-growing parcel is 2.24±0.04, whereas in control it is 2.16±0.11. In fertilized birch-growing parcels the average H value is 2.19 ±0.15, whereas in control it is 2.30±0.08. In Sweet cherry-growing parcels, the average H value is 2.26±0.09, but in the control area, it is 2.64±0.04 (differeces were statistically significant, p=0.05). Overall, H values in fertilized parcels were lower in Black alder and Sweet cherry-growing parcels, whereas in birch-growing parcel it is slightly larger. A comparison of H values is shown in Figure 4.

The number of species in control parcels ranges from 39 in parcels, where Sweet cherry has been planted, to 42, where Black alder has been planted. In fertilized plots, the number ranges from 33 in Sweet cherry-growing to 42 in birch-growing parcels. No moss species have been observed in the Ķeipene plantation. The number of species in fertilized parcels is slightly lower in those of Sweet cherry and Black alder, comparing with the control, whereas in fertilized birch-growing parcels the number is slightly higher. Comparison of the number of species in control and fertilized parcels depending on tree species is shown in Figure 5.

Studies carried out in Sweden show that after application of N-containing fertilizers, species normally occuring in less fertile forest types – dwarf shrubs (blueberries, lingonberries, heathers), lichens, several mosses – decrease in abundance, whereas grasses (e.g. *Deschampsia flexuosa*) and nitrophilic forbs, e.g. *Rubus idaeus, Epilobium angustifolium* increase (Strengbom & Nordin, 2008). Silfverberg and Hotanen found that after addition of wood ash nitrophilic species (*Cirsium helenoides*, *Daphne mezereum*, *Paris quadrifolia*, *Prunus padus*, *Urtica dioica*) may become dominant over time in sites with peat soils. Similarly as when applying nitrogen fertilizers, also in case of wood ash heathers (*Calluna vulgaris*) are gradually replaced by grasses, such as *Deschampsia flexuosa* (Arvidsson *et al*., 2002). In our study, occurrence of nitrophilic species in fertilized plots have also been observed, particularly in Ķeipene plantation.

The cover of mosses *Dicranum fuscescens, Dicranum polysetum, Hylocomium splendens* and *Pleurozium schreberi* decrease along with increasing N availability, whereas mosses of *Brachythecium* and *Plagiothecium* genera may increase in abundance (Olsson & Kellner, 2006; Press *et al*., 1998; Skrindo & Økland, 2002; van Dobben *et al*., 1999). Following addition of wood ash, moss cover may decrease dramatically and the impact increases along with ash dose (Ozolinčius *et al*., 2007). In our study, we did not obeserve a dramatic change in the moss cover. In one of the *Hylocomiosa* stands, a slightly larger cover was observed in fertilized plots. Two years is a relatively short period of time for assessment of ground vegetation development. Longer-term observations are required in order to draw the final conclusions about the impact of fertilization on ground vegetation.

The results of this study could be transferred to characterize the condition of plantations of shelter belts and to determine the potential of suitable species.

Conclusions

1. In birch-dominated forest stands, there are no significant differences in species composition between control and fertilized plots. In the *Myrtillosa mel.* stand, *Rubus idaeus* has a slightly larger projective cover in fertilized plots, and nitrophile *Lycopus europaeus* occurs only in the fertilized plots. In the Ķeipene plantation occurrence or increased abundance of several nitrophilic species was observed in the fertilized parcels. The impact is more pronounced in parcels, where Sweet cherry has been planted.
2. In general, results do not show a significant impact of fertilization on species diversity in Silver birch stands and Ķeipene plantation. Statistically significant differences between H values in control and fertilized plots have been found only in the *Myrtillosa mel.* forest stand, where the average H value in the herb layer is higher, but in the moss layer it is lower in fertilized plots, in one of *Hylocomiosa* stands in the herb layer, where the average value in fertilized plots is lower and in Sweet cherry-growing parcel of Ķeipene plantation, where the value is lower in fertilized plots.
3. Fertilization has no significant impact on the number of species. The number of species in fertilized plots is higher in the herb layer in *Myrtillosa mel.* and *Myrtillosa turf.mel.* stands, but in the rest of stands it is lower, compared to the control. The number of species is lower in the moss layer, except for one of the *Hylocomiosa* stands, where it is slightly higher. In the Ķeipene planation, the number of species in fertilized Sweet cherry and Black alder parcels is slightly lower comparing with the control, whereas in fertilized birch-growing parcels the number is slightly higher.

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