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瑞典南部相邻桦树和欧洲云杉林分的地表植被和土壤特征

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摘要: 对瑞典南部 23 对相邻的桦树和欧洲云杉林分的地表植被和土壤特征进行了研究。桦树和欧洲云杉林分曲芒发草(*Deschampsia flexuosa* L.)和苔藓植物的频度几乎没有区别, 但桦树林分越桔(*Vaccinium myrtillus* L.)和黑果越桔(*Vaccinium vitis-idaea* L.)的频度远大于欧洲云杉林分的频度。欧洲云杉林分各层土壤(腐殖质层、0～10 cm 矿物质土壤层和 11～30 cm 矿物质土壤层)的酸度稍大于桦树林分各层土壤的酸度。欧洲云杉林分土壤可交换性 K、Ca 和 Mg 离子的含量稍大于桦树林分土壤的含量, 但差别不明显, 只有可交换性 Na 离子的含量在欧洲云杉林分土壤中明显偏高。由于现在硫沉降明显降低, 相对于桦树冠层而言欧洲云杉冠层较高的阳离子干沉降在一定程度上可能中和土壤酸化对瑞典南部欧洲云杉林的影响。

关键词: 桦树; 欧洲云杉; 林分; 地表植被; 土壤特征; 瑞典南部

Differences in ground vegetation and soil characteristics in adjacent birch and spruce stands of southern Sweden

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Abstract: Differences in ground vegetation and soil characteristics were studied in 23 adjacent birch and spruce stands in southernmost Sweden. There were almost no differences between the frequencies of *Deschampsia flexuosa* L. and mosses, but the frequencies of *Vaccinium myrtillus* L. and *Vaccinium vitis-idaea* L. were significantly higher in birch than in spruce quadrats. Each soil layer (humus, 0～10 cm and 11～30 cm) in spruce quadrats indicated slightly higher acidity than in the birch quadrats. Only was the content of exchangeable Na significantly higher in spruce than in birch quadrats, exchangeable K, Ca and Mg did not differ significantly, but were on average also slightly higher in the spruce quadrats. But the relatively higher dry deposition of cations in spruce than in birch canopies might to some extent, counteract acidification effects of spruce forests in southern Sweden when sulphate deposition has decreased strongly.

Key words: birch; spruce; forest stand; ground vegetation; soil characteristics; southern Sweden
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Introduction

Acid deposition is serious in the southern part of Sweden. It is causing lowered biodiversity[1], acid soils[2] and acid waters, and it is foreseen that soil fertility and forest productivity will be negatively affected[3]. This is one of the problems in reaching a sustainable forestry. In comparison to a deciduous forest, a coniferous forest usually receives a greater load of dry deposited protons and most other elements as a result of its greater aerosol trapping capacity[4]. Therefore, increasing deciduous trees in coniferous forest stands has been suggested as one of the strategies to alleviate the negative effects of acid deposition on ground vegetation, soil and water.

In southwestern Sweden there has been observed a general decrease of blueberry (*Vaccinium myrtillus* L.), but an increase of wavy hairgrass (*Deschampsia flexuosa* L.) from the National Forest Surveys. *V. myrtillus* is a species of high importance for the insect biodiversity, due to the edible and nutrient rich in leaves and its honey producing flowers and berries. It is also a species that indicates the negative effect of increased nitrogen deposition, in the beginning probably mostly through an increased competition from *D. flexuosa*. The latter is a grass species that is tolerant to acidity and high amounts of aluminium, and is favoured by nitrogen deposition[5].

To examine the influences of deciduous and coniferous tree species on plant biodiversity and soil conditions in southern Sweden, ground vegetation composition and soil characteristics under birch and spruce stands were studied in paired plots. The aims were to test (1) if *V. myrtillus* is favoured under birch trees in gaps of spruce stands, and if it is more favoured than *D. flexuosa*; (2) if soil conditions are improved by birch, and to some extent by the appearance of *V. myrtillus*.

1 Materials and methods

1.1 Study area

The study area is located in the southern part of the Småland Province, Sweden. Most plots were situated within 2～3 km from 14°15′E, 56°36′N. The elevation is around 150 m. The total annual average temperature of the region is 6.0℃. The coldest month is January (−2.6℃) and the warmest month is July (15.7℃). The highest temperature is 18.2℃ and the lowest is −9.6℃ since 1901. The temperature sum (>5℃) is 1300～1500℃. The total annual precipitation averages 793 mm, the highest is 1061 mm and the lowest is 516 mm since 1901. The main soil type is podzol developed on stony moraine. The spruce stands are planted for about 30～40 years; the birch stands in the gaps of spruce are evolved from natural regeneration. The forest average height was about 25 m. It is dominated by spruce (*Picea abies* (L.) Karst) and some pine (*Pinus silvestris* L.), and the main deciduous species are birch (*Betula verrucosa* Ehrh. or *B. pubescens* Ehrh), aspen (*Populus tremula* L.) and oak (*Quercus robur* L. or *Q. petraea* L.). All stands are lacking shrubs.

1.2 Field methods

In total 23 birch quadrats and 23 spruce quadrats, each with a size of 4 m×4 m, were selected during November to December 1998. The quadrats were selected in pairs, at the most 30 m distances from each other. Around each 4 m×4 m quadrat, we used a 10 m×10 m plot to estimate the number of each tree species and diameter at breast height (*DBH*) of each tree. The breast height area of the surrounding forest of each quadrat was also roughly estimated with relascope.

The point frequency method was used to study the ground vegetation. Within each 4m×4m quadrat, the frequencies of the most important species were estimated along five 4 m transects within the quadrat on 1 m distance from each other. To do this, we selected 20 point plots with 20 cm×20 cm along each transect and recorded the species occurring in each point plot.

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Within each 4m×4m quadrat, soil samples were taken with a soil borer down to 30 cm depth. Four cores were taken within each quadrat, and each core was split up on three different samples: organic horizon, mineral soil 0～10 cm, mineral soil 11～30 cm. Pure sand, clay soils and wet gley soils were avoided.

1.3 Laboratory methods

The soil samples were dried at 40℃ to constant weight, and then they were sieved through 6 mm (organic mor layer) or 2 mm (mineral soil) sieves. The sieved material (the fine soil) was analysed. The remaining water content was determined at 105℃, and the loss on ignition after two hours at 550℃. Extraction procedures were for 10 g (humus) or 20 g (mineral soil) of the soil samples in 100 ml of the extract solution (0.1 M $BaCl_2$ or 0.02 M acid EDTA-solution). pH was determined both in an extract of distilled water (100 ml) and in the $BaCl_2$-solution (100 ml).

Mineral elements were analysed on an ICP-Optima 3000 DV instrument (Perkin Elmer). They all were exchangeable on the soil colloids and extracted in salt solutions. $BaCl_2$ was used for Na, K, Ca, Mg, Al, Fe, Mn, B and acid EDTA (pH 4.8) for Cu, P and Zn. Total-N was analysed according to the Kjehldal method; total-C was analysed through ignition on a Leco-instrument (Carbon Determinator CR 12).

The differences in ground vegetation and soil characteristics were tested using two-tailed t test, assuming unequal variances and equal variances respectively. Mean values, standard deviations and t-test were processed using Microsoft Excel 7.0 and figure was plotted using SigmaPlot for Windows 3.01. Differences showing P values lower than 0.10 were considered as significant.

2 Results

2.1 Characteristics of the forest stands around and in the birch and spruce plots

According to the relascope results, ranges of breast height area of forest stands around the birch and spruce plots (10 m×10 m) were 20～41 m^2/hm^2 and 21～47 m^2/hm^2 respectively (Table 1).

All tree species occurring in birch and spruce plots (10 m×10 m) were similar; they were birch, spruce, pine, oak and poplar (Table 2 and Table 3). However, the dominating species, especially the two main species, were quite different. Every birch plot contained spruce, and the quantity of spruces were usually higher than the quantity of birches even in most of the birch plots. As for spruce plots, only 9 plots included birch trees. The *DBH* of spruce were larger than that of birch in more than 50% of the birch plots, and *DBH* of spruce in the spruce plots were also larger than that of birch.

2.2 Differences in ground vegetation between the birch and spruce quadrats

Differences in the appearance of the main three ground vegetation species, *V. myrtillus*, *V. vitis-idaea* and *D. flexuosa* and mosses between birch and spruce quadrats showed that the frequencies of the *Vaccinium* species and mosses were higher in birch than in spruce quadrats, and the frequency of *D. flexuosa* in birch quadrats was slightly lower than in spruce quadurats. The statistical differences in frequencies of *V. myrtillus* and *V. vitis-idaea* were significant, while those of *D. flexuosa* and mosses were not significant (Fig. 1 and Table 4).

2.3 Differences in soil characteristics between the birch and spruce quadrats

In the humus layer the average figures on the total content of C and the exchangeable amounts of H, Na, K, Ca, P, B, Mn and Zn were slightly higher in spruce than in birch quadrats, but significant differences were found only for Na. The total content of N and the exchangeable amounts of Mg, Al, Fe and Cu of the humus layer showed lower figures in spruce than in birch quadrats, but the differences were not significant (all values in amounts per g dry soil).

In the 0～10 cm mineral soil layer about similar trends appeared: Na and the acid ion Al showed significantly higher values, as well was the water content of the spruce quadrats. Most base cations showed, how-

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ever, also slightly higher average values in the spruce quadrats. In the 11～30 cm mineral soil layer, the contents of Na and Zn were significantly higher in spruce than in birch quadrats (Table 5).

Table 1 The breast height area of forest stands around the plots estimated by relascope (m^2/hm^2)

Plots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Birch	22	22	27	24	25	32	33	32	38	38	40	38	24	27	25	29	40	38	20	20	41	29	24
Spruce	23	23	27	32	32	27	33	35	45	38	47	42	27	32	27	31	38	42	27	21	38	24	30

Table 2 Tree species composition and their *DBH* (cm) in birch plots

Species / Plot	Birch		Spruce		Pine		Oak		Poplar	
	Total No.	Mean of *DBH*	Total No.	Mean of *DBH*	Total No.	Mean of *DBH*	Total No.	Mean of *DBH*	Total No.	Mean of *DBH*
1	3	16.60±7.33	10	13.16±7.35						
2	4	9.20±3.14	4	20.75±4.39						
3	1	14.00±0.00	6	25.72±7.88						
4	6	12.77±5.24	7	11.77±8.43						
5	3	6.60±3.73	11	12.13±5.96					1	3.10±0.00
6	2	13.70±2.12	20	12.43±7.42	1	17.50±0.00			2	6.95±3.18
7	1	27.90±0.00	14	14.49±12.79			1	4.50±0.00		
8	10	7.71±3.54	20	11.82±5.88	2	15.10±2.12				
9	2	5.67±1.53	24	12.60±6.73						
10	4	5.63±4.07	30	10.11±4.57	4	17.80±4.67				
11	8	5.63±1.47	19	12.18±4.22	4	17.93±5.08				
12	2	11.50±1.84	16	13.55±5.29	4	20.18±7.69				
13	11	6.45±2.52	11	18.67±4.73						
14	6	10.28±4.15	11	13.88±9.86						
15	2	9.70±0.42	14	10.71±5.20						
16	5	15.36±7.56	12	12.40±9.81	1	25.70±0.00				
17	2	18.45±1.06	17	15.06±4.01	3	14.30±1.15				
18	2	18.35±2.05	16	13.33±3.57	7	13.81±4.12				
19	4	10.28±5.30	10	10.45±5.89			1	6.20±0.00		
20	1	12.70±0.00	18	10.41±5.61			2	2.35±0.21		
21	2	16.00±2.12	24	10.58±5.09					1	3.80±0.00
22	12	5.69±5.42	16	11.61±4.74	1	18.50±0.00				
23	2	14.25±8.41	14	11.92±4.24	3	6.00±2.23				
Trees in quadrats	15.21±4.94									

Usually the average figures on water content, losses on ignition and cation exchangeable capacity (CEC) of all soil layers were slightly higher in spruce than in birch plots (Table 5 and table 6), but no differences except those mentioned above were significant.

All three soil layers (humus, 0～10 cm and 11～30 cm) in spruce quadrats showed slightly lower pH-values (range in pH-H_2O 3.78 to 4.53 and in pH-$BaCl_2$ 2.87 to 4.17) than in birch quadrats (range in pH-H_2O 3.83 to 4.58 and in pH-$BaCl_2$ 2.90 to 4.20), but without significant differences in *t*-tests. The humus layer of spruce was the most acid, and the 11～30 cm soil layer in birch quadrats was the least acid. The pH-values increased significantly down the soil profile (Table 6).

The base saturation of the mineral soil was very low in all quadrats, 6.6% to 9.3% of the effective CEC, and it decreased down the profiles. There were, however, no differences between spruce and birch (Table 5). As for the percentage of Al in CEC, it increased down the soil profile, also without differences

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between birch and spruce quadrats. The percentage of organic matter (loss on ignition) in spruce quadrats was slightly higher than in birch in the mineral soil, and the 11～30 cm mineral soil layer in birch showed the lowest values. For the percentage of H^+ in CEC it was similar (Table 6).

Table 3 Tree species composition and their *DBH* (cm) in spruce plots

Species / Plot	Spruce		Birch		Pine		Oak		Poplar	
	Total No.	Mean of *DBH*	Total No.	Mean of *DBH*	Total No.	Mean of *DBH*	Total No.	Mean of *DBH*	Total No.	Mean of *DBH*
1	17	15.38±4.62								
2	6	20.15±9.19								
3	12	19.25±3.50								
4	28	12.06±5.68			1	9.80±0.00	1	5.70±0.00		
5	12	15.07±9.89								
6	16	13.19±5.67					1	16.70±0.00		
7	5	21.16±17.31			2	26.15±4.74	1	10.00±0.00		
8	21	12.34±6.08			1	12.10±0.00				
9	27	10.09±5.26			1	15.20±0.00	1	3.10±0.00		
10	17	9.38±6.94	3	3.20±1.75	7	17.56±5.09				
11	20	13.49±4.51	1	5.10±0.00						
12	19	10.98±5.37			3	18.73±5.81				
13	10	17.23±10.42	1	4.60±0.00						
14	13	14.76±7.42	1	2.60±0.00						
15	16	13.98±5.76	1	5.50±0.00						
16	12	14.91±10.68								
17	13	16.68±4.05			3	13.57±1.99				
18	16	15.28±3.97			4	21.60±3.27				
19	13	12.30±6.68	6	10.87±2.26						
20	15	10.09±5.85	6	4.43±3.35						
21	25	10.75±5.26							1	2.80±0.00
22	17	12.68±4.65	10	2.83±0.98						
23	14	12.20±3.85	4	2.00±0.14	4	1.098±4.67				
Trees in quadrats		18.13±7.20								

3 Discussion

Long-term changes of flora, soil acidity and soil cation pools in southern Sweden, and interactions between acid deposition, plant species, soil characteristics and their mechanisms has been studied for many years. [1～10]. It is difficult to find causal relationship between single elements and plant distribution, as many soil variables are closely related[1]. But the density of *D. flexuosa*, one of the most acidtolerant species in southern Sweden, increases with the time and the amount of nitrogen added[10]. Our results indicated a similar development. The frequency of this species was higher both in birch and spruce quadrats, and the difference between spruce and birch was quite small, probably due to the fact that all the soils have become quite acid and nutrient poor. Moreover the stands were always quite young, in the age of 30～40 a.

What concerned the different frequencies of *V. myrtillus* and *V. vitis-idaea* between birch and spruce quadrats, these did not seem to be accounted for by competing *Deschampsia* grass only[10], but other factors such as light and soil characteristics are more likely to have caused the differences.

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There are many factors, such as differences in foliage chemistry, root uptake features and biomass production (nutrient accumulation) that have effects on soil properties[6]. The trend that contents of C of the soil in spruce quadrats were higher than that in birch quadrats is probably due to the fact that decomposition of needles is slower than that of broad-leaves, and needles contain higher amounts of organic acids. To some extent this was illustrated by the percentage of H^+ in CEC (Table 6), which values were the highest in spruce quadrats. This indicated that organic matter played an important role in hydrogen ion saturation of the soil colloids.

Table 4 Significance test of frequencies of the main ground vegetation species between birch and spruce quadrats

	A	B	C	D
t values	5.866**	3.973**	-0.107	2.005
d*f*	32	15	31	37

Notes: A, B, C and D have the same meaning as in Fig. 1 respectively; **, difference is more significant ($P<0.10$).

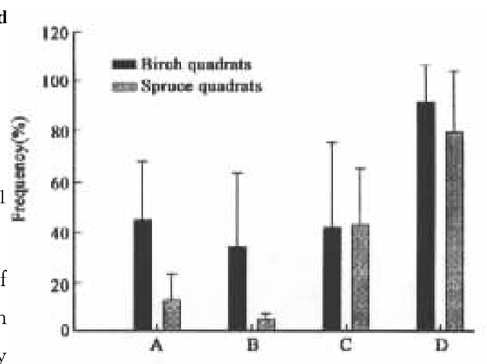

Fig. 1 Frequencies of the main ground vegetation species in birch and spruce quadrats A, frequency of *V. myrtillus*; B. frequency of *V. vitis-idaea*; C, frequency of *D. flexuosa*; D, frequency of mosses.

Also, a coniferous forest receives a greater load of dry-deposited protons (and most other elements) than a deciduous forest, as a result of its evergreen canopy and greater aerosol trapping capacity due to larger leaf area, smaller collector dimensions, etc.[4]. This fact is specifically illustrated by Na, an element that to a great extent comes to the soil through precipitation and adsorption of sea salt aerosols in the canopy[4]. This element was significantly higher in the soil of the spruce quadrats. The net loss of base cations from a spruce soil has earlier been found to be higher than from a deciduous soil[9], but this was not supported by the state of exchangeable elements in our results. It might be due to the fact that all values in the mineral soil were quite low, and statistical differences will then be difficult to obtain. In fact all pH-values of 11～30 cm depth were at the level for Al-buffering, and base saturation values were lower than recommended 20%. It is, however, not possible to exclude the possibility that even basic cations may be dry deposited to a higher extent in the spruce forests, similar to Na. Strongly decreased deposition of sulphates during the last decade might have contributed to such a more positive situation below spruce canopies.

The content of Al and Mn in mineral soil layers of spruce quadrats were also higher than in birch quadrats indicating that spruce promotes soil acidification. The same holds for higher Zn values at 11～30 cm depth. Leaching of Al, Mn and Zn is known to be more serious in spruce quadrats than in birch quadrats[9]. Leaching of Al from forest soils means transferring acidity from the forest ecosystem to the surroundings. The more acidity is leached from the ecosystem, the less does the soil act as an acid neutraliser between atmospheric (or internal) sources and aquatic environments[9]. In this way an increase of deciduous tree species and their total amount in coniferous forests should alleviate this process.

Spruce trees surrounding our small birch quadrats, often in gaps, have certainly effects on the soil also under the birch, and vice versa. In comparison to the ground vegetation, changes of soil characteristics will take much longer time. This is probably the reason why most differences of soil properties between birch and spruce quadrats were not significant.

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Table 5　Losses on ignition, water content, exchangeable elements and significance tests of differences of the soils between birch and spruce quadrats

	Water content (%)	Losses on ignition (%)	C (mg/g)	N (mg/g)	C/N	H (μg/g)	Na (μg/g)	K (μg/g)	Ca (μg/g)	Mg (μg/g)	Al (μg/g)	Fe (μg/g)	Mn (μg/g)	B (μg/g)	Cu (μg/g)	P (μg/g)	Zn (μg/g)
Humus																	
Birch plots																	
Mean values	3.172	38.037	180.865	6.580	29.168	14.278	36.081	187.766	501.123	123.211	466.809	95.605	27.554	0.272	1.751	57.440	14.356
s.d.	1.030	15.304	69.048	3.183	7.525	6.963	14.538	72.788	266.268	49.158	228.955	36.480	21.076	0.245	0.617	19.299	7.025
Spruce plots																	
Mean values	3.404	41.025	190.060	6.249	31.176	14.529	48.677	198.383	631.946	119.293	408.188	94.855	40.560	0.309	1.669	59.959	14.581
s.d.	1.559	21.716	93.063	3.747	5.750	5.916	33.044	85.609	548.186	76.365	225.840	33.189	44.408	0.246	0.792	22.825	9.941
t-test																	
t values	−0.595	−0.539	−0.381	0.147	−1.017	−0.094	−1.67*	−0.453	−1.029	0.207	0.576	0.073	−1.269	−0.505	0.384	−0.384	−0.395
d*f*	44	44	44	44	44	44	44	44	44	44	44	44	44	44	42	42	42
0～10 cm																	
Birch plots																	
Mean values	0.958	6.348	30.647	1.001	31.567	0.940	7.563	19.129	29.150	8.933	269.241	47.807	1.894	0.148	0.417	9.562	1.121
s.d.	0.268	1.599	8.554	0.338	6.690	0.615	2.350	6.947	18.762	4.127	53.670	20.457	2.451	0.144	0.151	5.247	0.614
Spruce plots																	
Mean values	1.569	9.186	32.299	1.062	30.439	2.078	12.658	23.511	60.115	16.209	297.173	49.892	3.890	0.149	0.467	9.539	1.299
s.d.	1.687	11.881	8.647	0.228	5.257	5.056	14.207	20.939	156.116	38.208	52.254	23.069	5.208	0.119	0.185	5.289	0.595
t-test																	
t values	−1.716*	−1.136	−0.644	−0.708	0.627	−1.102	−1.697*	−0.952	−0.944	−0.908	−1.788*	−0.324	−1.663	−0.028	−0.991	0.014	−0.987
d*f*	44	44	43	43	43	44	44	44	44	44	44	44	44	44	43	43	43
11～30 cm																	
Birch plots																	
Mean values	1.091	5.108	21.493	0.836	25.302	0.184	5.731	6.980	12.155	2.904	154.588	17.080	1.785	0.166	0.321	4.169	0.466
s.d.	0.327	1.774	8.917	0.285	3.123	0.142	1.642	2.274	10.640	1.037	77.833	12.880	2.738	0.107	0.130	4.561	0.258
Spruce plots																	
Mean values	1.169	5.544	24.159	0.964	25.740	0.340	7.498	7.771	12.443	3.668	156.882	16.259	1.900	0.156	0.386	4.158	0.627
s.d.	0.339	1.961	10.965	0.430	5.848	0.811	3.965	4.252	15.486	3.741	71.919	11.771	2.209	0.114	0.175	5.418	0.324
t-test																	
t values	−0.792	−0.792	−0.904	−1.187	−0.317	−0.911	−1.974*	−0.786	−0.073	−0.944	−0.104	0.226	−0.157	0.299	−1.420	0.007	−1.858*
d*f*	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44

*: Difference is significant ($P < 0.10$).

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Table 6 Selected chemical properties and significance tests of their differences of the soils between birch and spruce quadrats

	pH-H_2O			pH-$BaCl_2$			Effective CEC(μmolc/g)		
	Ⅰ	Ⅱ	Ⅲ	Ⅰ	Ⅱ	Ⅲ	Ⅰ	Ⅱ	Ⅲ
Birch plots									
Mean values	3.833	4.233	4.577	2.905	3.718	4.206	111.572	36.502	19.616
s.d.	0.184	0.170	0.127	0.230	0.211	0.159	29.127	7.856	9.973
Spruce plots									
Mean values	3.783	4.153	4.536	2.877	3.645	4.172	114.987	43.405	20.162
s.d.	0.134	0.189	0.201	0.166	0.314	0.281	42.088	20.224	10.069
t-test									
t	1.053	1.503	0.841	0.471	0.931	0.504	−0.320	−1.526	−0.185
d*f*	44	44	44	44	44	44	44	44	44

	% of CEC								
	Base cations			Al			H^+		
	Ⅰ	Ⅱ	Ⅲ	Ⅰ	Ⅱ	Ⅲ	Ⅰ	Ⅱ	Ⅲ
Birch plots									
Mean values	37.194	8.048	6.605	44.322	82.353	87.735	12.794	2.583	0.876
s.d.	12.638	2.533	1.525	15.664	4.530	2.117	5.356	1.630	0.410
Spruce plots									
Mean values	39.020	9.263	7.004	41.841	80.823	87.238	12.841	3.408	1.163
s.d.	18.167	8.400	2.190	18.935	11.585	2.824	3.227	4.016	1.511
t-test									
t	−0.386	−0.665	−0.717	0.484	0.59	0.675	−0.036	−0.913	−0.880
d*f*	44	44	44	44	44	44	44	44	44

Note: Ⅰ:humus; Ⅱ:0～10 cm; Ⅲ:11～30 cm.

4 Conclusions

Birch trees in gaps of coniferous forest stands of southern Sweden indicated some positive effects on biodiversity conservation and soil status, already in an early stage of development (30～40 a).

The species, *V. myrtillus* and *V. vitis-idaea*, of special value from a diversity point of view, were more frequent in birch than in spruce quadrats. Slightly less competition from *D. flexuosa* and better light conditions were the most likely reasons for this behaviour. Spruce quadrats showed slightly more of the acidity tolerant species *D. flexuosa* than birch quadrats.

Lower acidification rate of the birch stands were indicated by significantly lower amounts of exchangeable Al and Mn in some of the mineral soil layers, and all soil layers (humus, 0～10 cm and 11～30 cm) in birch were slightly less acidic than spruce quadrats, though not significant.

Higher amounts of esp. exchangeable Na in spruce quadrats indicated the higher adsorption capacity for aerosols of spruce canopies. This could be a positive trapping also of basic cations that usually showed higher figures below spruce canopies.

A general conclusion was that in order to manage the forests in a more sustainable way in the future one way would be to favour the amount of birch species in the dense spruce stands.

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