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INFLUENCE OF THE BOG SOIL CHEMICAL PROPERTIES ON THE FLORAL COMPOSITION OF MICROCENOSES IN BOG FORESTS OF THE STARE BIELE RESERVE IN THE KNYSZYN FOREST

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A b s t r a c t. Studies considering hummocks and hollows structure of bog forests were carried out in the Stare Biele Reserve in the Knyszyn Forest. The aim of the study was better recognition of bog forests spatial structure including recognition of soil chemical composition of hummocks and hollows. The bog forest communities in Stare Biele Reserve have various percentage of hummocks. The hummocks have similar morphological structure and are distinctly separated from hollows in all four bog forest communities. Degree of hummocks development and their morphological structure have big impact on plant distribution on their surface. Soil chemical properties are one of the factors, which influence floral abundance and composition of microcenoses. Soil reaction and calcium content, among other measured properties, exert the biggest influence on the floral abundance and composition of microcenoses.

K e y w o r d s: hollows and hummocks structure, bog forests, bog soils, floral composition, the Knyszyn Forest.

INTRODUCTION

Specific horizontal spatial structure of plant communities is expressed as a tendency for the concentration of certain individual species in various biotopes. Microstructure and microtopography play the most important role in the determination of plant community mosaic.

A swamp community mosaic is determined by such elements as: hummocks, hollows and root grates. Hummocks are covered by trees and species from a coniferous forest. In the hollows, marshy species are found as a result of annual flooding [2].

Numerous studies dealt with the flora of hollows and hummocks. However, there are only few detailed works about habitat conditions on hummocks and in hollows.

Studies on the hummock and hollow structure of bog forests were carried out in the Knyszyn Forest, in the Stare Biele Reserve. The research covered the following plant communities: alder forest *Carici elongate - Alnetum*, moss coniferous forest *Carici chordorrhizae - Pinetum*, spruce marshy forest *Sphagno - Piceetum* and marshy coniferous forest *Vaccinio uliginosi - Pinetum*.

The aims of the study were as follows: better recognition of the bog forest spatial structure in the Stare Biele Reserve, recognition and comparison of hummock morphological structure and hummock and hollow floral composition in the above mentioned forest communities, recognition of soil chemical composition of hummocks and hollows as well as identification of the relationship between soil properties and methods of microcenoses formation and floral composition.

MATERIALS AND METHODS

Spatial structure of the forests was specified by counting the percentage of hummocks, hollows and root grates in the study plots. In each of the studied communities, two well developed hummocks were chosen for the investigation of structure, floral composition and soil properties. Floral composition and soil properties of the hollows were also studied. Three soil samples from different hummock heights and one from the adjoining hollow were taken. The contents of calcium, magnesium, phosphorus, potassium and soil pH were measured.

Content of exchangeable calcium and magnesium ($Ca^{2+}$and Mg^{2+}) was titrated according to 1 M CH_3COONH_4 method. Concentration of assimilable forms of phosphorus and potassium was measured according to the Egner-Riehm's method. Soil reaction was measured in water and in the KCl suspension.

On the basis of relevés, floral composition was studied. The Braun-Blanquet's method was used to study cover and abundance.

RESULTS

Spatial structure

Various numbers of hummocks (expressed in percentage) is observed in the studied plant communities. In the alder forest *Carici elongate-Alnetum*, irregularly shaped hummocks cover from 16 to 40% of plant community area. In the moss coniferous forest *Carici chordorrhizae-Pinetum* irregularly shaped hummocks are also found and they cover around 30% of the area.

The largest area (60%) is covered with hummocks in the marshy coniferous forest *Vaccinio uliginosi-Pinetum.* Hummocks are rare in the spruce marshy forest *Sphagno-Piceetum*, where root grates dominate (40-60% of area).

The transition zones between different communities are characterised by various percentage of hummocks. In the ecotone between *Carici elongate-Alnetum* and *Sphagno-Piceetum* hummocks occur on 12-27 % of the area, however in the transition zone between *Vaccinio uliginosi-Pinetum* and *Carici elongate-Alnetum,* they cover 37% of the area.

Morphological structure of hummocks

In all four bog forest communities, hummocks have a similar morphological structure. They are well developed and distinctly separated from the hollows in all four communities, except the marshy coniferous forest. The highest and the best developed hummocks were found in the alder forest. The lowest hummocks were observed in the moss coniferous forest and marshy coniferous forest. Differences in hummock heights in the same community are small, only in the spruce marshy forest they exceeded 30 cm. These differences are the result of dissimilarity in trees ecology that is responsible for hummock structure and dissimilarity variance of habitat conditions.

Air chambers are specific features of the hummocks. The biggest air chambers were found in the hummocks of the alder forest and the smallest in the hummocks of the moss coniferous forest. Hummocks in the spruce marshy forest differ from others, as they do not have air chambers only empty spaces among roots.

Degree of hummock development and their morphological structure have a big impact on plant distribution on their surface. The top part of hummocks in the moss coniferous forest, in the spruce marshy forest and in the marshy coniferous forest is flat and regularly covered with herbs. Well developed, high hummocks in the alder forest have a smaller cover of the herb layer. Herbs occur mainly on the edge of hummocks, and their central part is covered by litter and mosses in low concentration.

Floral composition of microcenoses

The forest stand of hummocks varies. In the alder forest, *Alnus glutinosa, Betula pubescens*, and *Picea abies* occur on the hummocks. A similar tree composition with an addition of *Pinus silvestris,* is observed in the moss coniferous forest. The composition of tree stands in the spruce marshy forest and in the marshy coniferous forest are more homogenous. In the marshy coniferous forest, the tree stand is additionally built of pine with spruce, whereas in the spruce marshy forest the tree stand is built only by spruce.

The shrub layer in studied plant communities is medium - stocked (30-50%), only in the alder forest it reaches 70%. This layer is built of tree undergrowth and *Frangula alnus.* The herbs layer and its floral composition varies in studied plant species. The largest cover - 70%, was recorded on the hummocks in the moss coniferous forest, whereas the smallest area - 30%, is covered by herbs in the alder forest. The number of recorded herb species on the hummocks ranges from 14 to 16, although in the marshy coniferous forest only 5 herb species were found.

In alder forest plant species from *Phragmitetea Cl.* are dominant, mainly at the edge of the hummocks. This location is related to their ecology. They prefer wet habitats. Similar places are occupied by the above plant species in the moss coniferous forest.

In all the studied communities, plant species from *Vaccinio-Piceetea Cl.* are observed in great number. In the marshy coniferous forest, beside the species from *Vaccinio-Piceetea Cl.* (*Vaccinium myrtillus, Vaccinium uliginosum, Ledum palustre*), a large cover of *Vaccinium oxycoccus* and *Andromeda polifolia* from *Oxycocco-Sphagnetea Cl.* is also observed. *Andromeda polifolia* is not found in any other of the studied plant communities.

The meadow species from *Molinio-Arrhenatheretea Cl.* are abundant in the floral composition of microcenoses. Species like *Lysimachia vulgaris* and *Equisetum palustre* occupy hummocks as well as hollows in the alder forest. *Lysimachia vulgaris* is found also on the hummocks of the spruce marshy forest. In the moss coniferous forest, beside *Lysimachia vulgaris,* other species from *Molinio-Arrhenatheretea Cl.* are also found. *Caltha palustris* was recorded in the hollows and *Lythrum salicaria* - both on the hummocks and in the hollows.

A typical alder forest species, *Thelypteris palustris*, is a standing component of all the studied communities, except the marshy coniferous forest. This species occurs mainly on the hummocks, but it was also recorded in the hollows. It can be an important component of the hollow floral composition.

In the alder and in marshy coniferous forest, the species from *Scheuchzerio-Caricetea fuscae Cl.* are found. Both species from this class, *Menyanthes trifoliata* and *Comarum palustre*, occupy mainly the hollows, although *Comarum palustre* occurs also on the edges of the hummocks.

Moss cover varies. The smallest contribution of this layer is observed on one of the hummocks in the spruce marshy forest, whereas on other hummocks, its contribution is 60%. In the alder forest, the moss cover varies in a wide range from 40% to 90%. In the marshy coniferous forest and in the moss coniferous forest, the moss layer covers 70% of the hummocks. In these communities, mosses developed a multispecies carpet which covers almost all the hummock surface. In other communities, mosses occupy mainly the edges of the hummocks.

Chemical soil properties

The measured chemical soil properties show differentiation in the studied plant communities (Table 1).

pH

In surface layers of the hummocks, pH is similar and ranges from 4.08 to 4.92 in all the studied communities. Bigger differentiation in the hummocks of various communities is observed inside the hummocks, over air chambers. Higher pH values (around 6) at a similar levels are recorded in the hummocks of the marshy coniferous forest and in the alder forest, although in one of the studied hummocks, pH was only 4. Reaction of the soil solution is more acidified, pH amounts to 4. The pH level in the hummock base is similar in all the communities (5.7-6.12), except the marshy coniferous forest, where the reaction is much more acidified. Corresponding regularity is observed in the hollows. In the alder forest, spruce marshy forest and moss coniferous forest, pH is similar. It is much lower (4.23) in the marshy coniferous forest.

Calcium

Calcium content in the upper part of hummocks varied in the studied communities as well as in different hummocks in the same plant association. Much lower calcium content is observed in the marshy coniferous forest. There is a different pattern of calcium content inside the hummocks. The highest concentration of calcium (157 me/100 g of soil) is observed in the alder forest, little lower content in the moss coniferous forest. Concentration of this component decreases several times in the spruce marshy forest, whereas in the marshy coniferous forest, it is as high as 10 me/100 g of soil. The highest content of calcium in the hummock base was found in the spruce marshy forest. Lower concentration is observed in the alder forest and moss marshy forest. In the marshy coniferous forest this concentration is up to 10 me/100 g in other hummock layers. In the hollows, variation of calcium concentration is similar to the pattern observed in the upper layer of hummocks. In the marshy coniferous forest they are characterised by a low calcium content.

T a b l e 1. Chemical properties of the soils

Plant community	Stand	Depth of sampling (cm)	pH KCl	pH H_2O	C^{2+}	Mg^{2+}	P_2O_5	K_2O
					(me 100 g soil)			
Carici elongatae-Alnetum	1	4	4.02	4.45	29.7	3.1	15.03	31.12
		40	5.63	6.05	157.0	33.7	22.67	19.17
		82	5.56	6.08	133.3	16.4	35.74	22.81
		hollow	5.40	5.96	73.4	16.3	31.61	12.94
	2	7	3.55	4.18	10.4	2.2	10.42	26.96
		20	3.64	4.32	10.5	1.5	7.77	10.86
		65	5.48	5.95	139.7	28.3	25.46	18.13
		hollow	5.48	5.95	142.6	2.2	30.27	11.38
	3	7	3.48	4.14	16.9	3.2	13.43	19.17
		48	5.19	5.76	112.6	1.4	25.86	18.65
		65	5.37	5.86	98.1	21.2	30.06	22.29
		hollow	5.13	5.58	90.2	16.9	15.60	18.13
Sphagno-Piceetum	1	7	3.78	4.38	29.0	9.4	8.12	15.54
		46	3.93	4.43	40.0	10.0	4.98	6.71
		57	5.61	6.12	192.1	32.2	19.48	9.30
		hollow	4.46	5.18	114.3	4.6	18.61	7.23
	2	7	3.56	4.16	18.8	3.9	6.79	15.02
		55	3.79	4.31	15.9	3.7	6.75	11.38
		74	5.27	5.96	176.4	38.1	16.92	7.75
		hollow	5.14	5.65	106.0	21.9	13.96	4.63
Carici chordorrhizae-Pinetum	1	14	3.55	4.19	8.1	0.9	10.54	28.00
		46	5.37	5.98	120.4	1.4	21.61	15.02
		57	5.33	5.70	127.4	29.6	16.16	8.78
		hollow	5.43	5.90	116.7	21.2	13.80	9.30
	2	24	4.48	4.92	19.6	5.7	24.58	32.69
		33	5.61	6.01	99.8	25.1	29.21	26.45
		47	5.33	5.75	125.1	26.6	26.80	16.58
		hollow	5.52	5.89	56.3	15.9	14.81	17.10
Vaccinio uliginosi-Pinetum	1	5	3.62	4.45	5.0	1.6	13.27	63.69
		34	3.66	4.23	4.7	3.8	15.11	24.89
		46	3.63	4.19	6.7	1.4	14.56	13.45
		hollow	3.66	4.24	5.9	0.9	20.70	16.69
	2	12	3.46	4.08	3.1	1.8	7.88	24.37
		21	3.45	4.02	8.3	0.8	17.07	51.90
		54	3.62	4.20	9.4	6.4	19.48	18.65
		hollow	3.67	4.23	8.0	5.4	23.33	20.73

Magnesium

Magnesium content in hummocks varied considerably. Some regularity in the magnesium distribution can be found in the base of hummocks. The highest concentration of this component (30 me/100 g of soil) is observed in the spruce marshy forest, a lower concentration is recorded in the moss coniferous forest and alder forest, whereas in the marshy coniferous forest, magnesium content decreases to 1.4 me/100 g of soil. In the hollows, magnesium content varies as well. Its concentration ranges from 2.2 to 16.9 me/100 g of soil in the alder forest, from 4.6 to 21.9 me/100 g of soil in the spruce marshy forest, from 15.9 to 21.2 me/100 g of soil in the moss coniferous forest and from 0.9 to 5.4 me/100 g of soil.

Phosphorus

Differences in the phosphorus content of hummocks in various plant communities are not statistically significant. The highest concentration of phosphorus is observed in the upper layer of one hummock in the moss coniferous forest, whereas the other hummock in this community is characterised by the twice lower concentration of this component. In the alder forest, phosphorus concentration in the hummocks ranges from 10 to 15 mg/100 g of soil. A lower content of this component is observed in the marshy coniferous forest, and the lowest concentration is recorded in the upper layer of hummocks in the spruce marshy forest. Similar pattern of phosphorus concentration is observed in the layer over an air chamber. Concentration of the above element below 20 mg/100 g of soil in the base of hummocks is observed in the spruce marshy forest, marshy coniferous forest and in one hummock in the moss coniferous forest. The highest (30 mg/100 g of soil) amount of this element is found in the alder forest. Phosphorus concentration in hollows varied as well. The highest concentration is observed in the hollows of the alder forest, lower content of about 10% in the marshy coniferous forest. The amounts of phosphorus in the hollows of the spruce marshy forest and moss marshy forest are similar and range from 13.8 to 18.6 mg/100 g of soil.

Potassium

The upper layers of hummocks in studied plant communities do not vary clearly enough, except for one of the hummocks in the marshy coniferous forest, where potassium content was over 60 mg/100 g of soil. In the rest of the studied communities, potassium content ranges from 15 to 32 mg/100 g of soil. In the deeper layers of hummocks, differences in the potassium content are considerable, however these differences are much smaller in the hummock base. The highest amount of potassium is observed in the alder forest and the lowest in the spruce marshy forest. The hollows in the marshy coniferous forest are characterised by the highest concentration of potassium and the lowest potassium content is recorded in the spruce marshy forest.

DISCUSSION

The results related to the spatial structure of bog forests from the Stare Biele Reserve are similar to results obtained by Czerwiński [1] for the whole area of the Knyszyn Forest.

The hummock-hollows structure of the alder moss forest in the reserve is similar to the hummocks-hollows structure of the same plant community in the Narew River Valley, even though these two plant communities developed in two different configurations of a melt-out basin and river valley. Hollow construction and floral composition of both communities is similar. A zonal pattern of hummocks plants is observed. Mosses occur in the zone around the trunk, whereas shrubs, undershrubs and herbs occur in the stabilisation zone. The edge zone is occupied by mosses and plants with roots in the base of the hummocks, that tolerate changes in excessive moisture in the habitat. Percentage of hummocks amounts to 35% and is similar to the hummocks percentage in the Narew valley [3].

The studies confirmed a multilayer structure of plants on the hummocks. This phenomenon was reported by Piotrowska [4]. The first, loose layer is built of alder offshoots, mountain ash and others. This layer is above 1 m tall. The second layer is more dense and is built of herbs. The third layer is built of mosses.

Hummocks in the studied communities have a similar composition, except for those in the spruce marshy forest, only empty spaces among roots were developed in place of air chambers in other communities. This was also reported by Czerwiński [1].

Measurements of soil reaction confirmed hummock oligotrophisation. Precipitation waters are stopped by the trees crowns, flow down on the trunks and wash out biophylic substances from the humus. Wet conditions of hummock microhabitats result in moss development. Moss cause acidification of microcenoses and develop the properties of coniferous forest habitats. Studies on the hummock reaction in the alder forest were conducted by Piotrowska [4], who reported that the pH increases with the depth (form 4.6 in the upper layer of hummock to 7.2 in the base). This regularity, described by Piotrowska, was observed in the hummocks of other plant communities, except a spruce marshy forest. In this latter plant community, pH changes along the hummock profile are small and similar to the reaction of the hollow soil. In other plant communities, differences between pH of the upper layer of hummocks and hollows are considerable. Soil reaction of the chosen hummocks and hollows was also measured by Żurek [6] as part of the studies on the stratigraphy and genesis of peat in the Reserve. The results described in this paper are similar to those obtained by Żurek [6].

Variation of calcium and magnesium content in the studied communities is considerable. Very low concentration of both elements was observed in the marshy coniferous forest. It was reported by Uggla [5] in the description of the chemical composition of Polish soils. Calcium and magnesium are washed out from the upper layer of hummocks and accumulated at the base.

The specified hollow types can be good indicators of habitat abundance, since in each of the studied communities the specified hollow type is predominant [1]. The moss hollows, which occur only in the marshy coniferous forest can be a good example. On the other hand, one type of hummock can occur in various communities.

CONCLUSIONS

Floral composition of microcenoses is differentiated. Soil chemical properties are one of the factors, which influence floral abundance and composition of microcenoses. Soil reaction and calcium content, among other measured properties, have the biggest influence on the floral abundance and composition of microcenoses, especially in the marshy coniferous forest. A poor floral composition of hummocks in the marshy coniferous forest is related to stronger than in other forest habitats, oligotrophication and lower calcium content. A high contribution of mosses, especially *Sphagnum* spp. is also related to the acidic soil reaction. Higher pH values and phosphorus content in the soils of the moss coniferous forest influences variation and floral composition of microcenoses with a large herb layer. The rest of the components, except calcium and phosphorus, do not clearly influence floral composition of microcenoses.

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