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*Regular research paper*

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# ECOLOGICAL GROUPS OF VASCULAR PLANT SPECIES IN THE HERB LAYER OF THE PINE FORESTS OF NORTHERN AND CENTRAL EUROPE

ABSTRACT: The species of vascular plants of the herb layer, were studied on ten forest sites representing pine forests of the alliance *Dicrano-Pinion*. These sites are located along the N-S transect in Northern and Central Europe, between 50°28' and 70°09' N – in Norway (NO1), Finland (FN1, FN2, FN3), Estonia (ES1), Latvia (LT1), Lithuania (LI1), and Poland (PL1, PL2, PL3). The relation was determined between the geographical location of these forests and the proportion in total species number and cover of the plants in the herb layer with known ecological, habitat and climatic requirements for light (L) and temperature (T) and soil requirements for moisture (F), acidity (R), and content of nitrogen (N). The indication method was applied using the species scale of Ellenberg *et al.* (1991), indicating the climatic and habitat requirements of the plant species on the basis of the values of the L, T, F, R and N in the macroclimatic gradient. The species which behave in a similar manner with respect to the habitat factors mentioned were clustered into the indicator species groups. The distinct directional changes of the share of these groups along the North-South transect were observed: 1) gradual appearance of the species characteristic for the moderately warm areas; 2) decrease of the share of the hygrophilous and acidophilous species.

KEY WORDS: plant ecological groups, Ellenberg indication method, temperature, moisture, acidity, nitrogen content, habitat conditions.

## 1. INTRODUCTION

The indicator value of a species or a plant community depends largely upon the degree of coupling with climatic and habitat conditions. Not only the number of species ought to be considered, but also their cover; the larger cover of the species, the higher its value as the indicator of the conditions.

The species, which behave in a similar manner with respect to habitat conditions, can be clustered into the ecological groups of indicator plants (Ellenberg, 1974; Wójcik, 1983; Roo-Zielińska and Solon, 1998; Roo-Zielińska, 2002; van der Maarel, 1993).

The species scale of Ellenberg (in Lindacher 1995) was used for purposes of this paper. This scale serves to determine the conditions of the abiotic environment on the basis of existence of indicator plant species of known ecological and habitat requirements.

The geobotanical characteristics of the each of the pine forest sites on the N-S transect (Solon, 2003a, in this volume) constitute in the present study the basis for the consideration of the spatial variability of the share of vascular species belonging to the herb layer, featuring different ecological and habitat requirements. The ten selected sites representing pine forests of the alliance *Dicrano-Pinion* are located along the N-S transect in Northern and Central Europe, between 50°28' and 70°09' N – in Norway (NO1), Finland (FN1, FN2, FN3), Estonia (ES1), Latvia (LT1), Lithuania (LI1) and Poland (PL1, PL2, PL3)

The analysis was conducted with respect to the following environmental factors: two climatic ones – light and temperature, and three related to soil habitat – moisture, acidity, and the nitrogen content. The species of similar climatic and soil requirements were put together to form the ecological groups of indicator plants.

The preceding papers of the present volume were devoted to characterisation of the climatic conditions, in which the analysed pine forests grow (Breymeyer, 2003, in this volume). The morpholithological genesis and the differentiation of soil properties were described (Degórski, 2003, in this volume) as well as the species diversity of the herb layer depending upon the geographical location of the forest associations (Solon, 2003b, in this volume). The information contained in the papers mentioned implies that the factor determining the functioning of the pine forest ecosystems located along the N-S transect is constituted by the changing climate with the habitat conditions having a modifying significance.

The information provided in these papers is helpful in the interpretation of the tendencies and the direction of spatial variability of the ecological groups of species in the macro-climatic gradient.

The purpose of the analysis carried out was:

1) to compare the share of the so-called "ecological groups", that is – the species of the herb layer (their number and the cover) featuring similar climatic and habitat requirements;

2) to illustrate the spatial differentiation of the share of these groups depending upon the geographical location of the pine forests analysed and to present the tendencies of change confirmed by the statistical analysis. And on this basis

3) to answer to the question whether the plant species of the herb layer "responded" to the climatic conditions changing in the meridional direction and to the soil habitat conditions, which change is less pronounced.

## 2. METHODS

The basis for the plant indication analysis of the ten study sites was constituted by the floristic characteristics of the sites, registered in the form of the phytosociological relevé. The subject of the study is constituted solely by the species of vascular plants of the herb layer (layer C).

The indication analysis was carried out with the use of the Ellenberg indicator number for each species (in Lindacher 1995) and its ecological and habitat requirements were assessed on the 9-point scale (corresponding to the increase of intensity of a given factor) with respect to:

• light (L): from L1 – distinctly full shadow species, to L9 – full light species;

• temperature (T): from T1 – the species of the coldest areas (boreal-arctic), to T7 – the species of the moderately warm climatic conditions;

• moisture (F): from F1 – the species of the extremely dry soils, to F9 – the species of the wet soils;

• acidity – "reaction figure" (R): from R1 – the species of the very acid soils, to R9 – the species of the neutral and basic soils;

• the nitrogen content (N): from N1 – the species of the soils very poor in mineral nitrogen, to N9 – the species only in soils very rich in mineral nitrogen.

The species of similar climatic and habitat requirements were assumed to form groups according to the following scheme:

• the light indicator values (L) – the full shadow species (L1–2); the half shadow species (L3–5); the half light species (L6–7); and the full light species (L8–9);

• the temperature indicator values (T) – the species of the cold areas (T1–2); of the moderately cool areas (T3–5); of the moderately warm areas (T6–7);

• the moisture indicator values (F): the species of the dry soils (F1–3); of the fresh soils (F4–5); of the moist soils (F6–7); of the wet soils (F7–9);

• the acidity indicator values (R): the species of the acid soils (R1–3); of the weakly acid soils (R4–6); of the neutral and basic ones (R7–9);

• the nitrogen content indicator values (N): the species of the soils poor in nitrogen (N1–3); of the soils moderately rich in nitrogen (N4–6); of the soils rich and very rich in nitrogen (N7–9).

Each of the groups mentioned contains the species, which display the appearance in a wide habitat spectrum, and cannot therefore be the indicators of the conditions, in which they exist. These species were assigned by Ellenberg (1991) the indicator values: L0 – for light, T0 – for temperature , F0 – for soil moisture, R0 – for soil acidity, and N0 – for the content of nitrogen in the soil.

For each of the ten study sites percentage share of the individual indicator species groups were calculated, separately for the species number and for the cover. The statistical relation between the geographical location (latitude) of the sites, and the share of ecological groups was described with the regression lines using the CurveExpert software.

## 3. RESULTS

### 3.1. LIGHT INDICATORS

The largest group, both in terms of the species number and the cover on all the sites of the N-S transect, is constituted by the half shadow plants (L3–5) and half light plants (L5–7) (Fig. 1).

On the northernmost sites, the Norwegian (NO1) and the two Finnish ones (FN1 and FN2), there are no full shadow plants (L1–2), and their share on the remaining sites, both in the total number of species (6.7–10.0%), and – particularly so – in the cover (2.5–9.6%) are quite low (Fig. 1). A somewhat bigger share of these plants, especially in total cover, is noted on the Lithuanian site (LI1) and one of the Polish site (PL1). On the majority of sites the group is represented by *Luzula pilosa*, and on the Polish sites (PL1 and PL2) also by *Polygonatum multiflorum* and *Monotropa hypoptis*.

The full light indicators (L8–9) constitute a relatively well represented group (around 22%) on the two southernmost Polish sites – PL2 and PL3 (Fig. 1A). The plants involved are *Epiloboium angustifolium*, *Calluna vulgaris*, *Genista tinctoria*, *Rumex acetosella*, and *Lycopodium clavatum*. Additionally, on the PL3 site, an exceptionally full light plant (L 9) grass species *Poa compressa* was observed. On the Finnish sites (FN2, FN3) the full light (L 8) common heath *Calluna vulgaris* dominates within this group in terms of cover, while in Norway (N1) the observed strongly full light plant (L9) though of quite limited cover, is *Loiseleuria procumbens* (Fig. 1B).

It is worthy to note that in the majority of the study sites the species featuring a wide spectrum of requirements, that is – neutral with respect to the light intensity (L 0) – were not observed. Only on site PL2 one such grass species was observed of a limited cover i.e. *Festuca rubra*.

It must be noted that a differentiation of the share of species with the extreme requirements as to light intensity is observed along the N-S transect under study. On the three northern sites there are no full shadow species (L1–2), which appear in the further part of the transect (Fig. 1). The interdependence between the geographical location of the study sites, and the share of this group of species (L 1–2) is best described by the quadratic equation $y = a + bx + cx^2$ (where a = –59.83, b = 2.67, c = –0.03), the correlation coefficient reaching the value of $r = 0.91$ (Fig. 2A).

The interdependence between the geographical location and the share of the full light group of species (L8–9) is also best rendered by the quadratic function $y = a + bx + cx^2$, (where a = 304.51, b = –9.28, c = 0.07) though the correlation value is $r$ = 0.77 (Fig. 2B).

### 3.2. TEMPERATURE INDICATORS

On all the sites of the N-S transect the largest group is constituted by the neutral species (T0) with respect to the temperature especially in terms of values of share in cover (71.4 – 97.7%). The next group is constituted by the indicators of the moderately cool areas (T3–5), their share being largely differentiated: 14.3–26.1% in the total number of species, and 0.6–28.2% in the total cover (Fig. 3).

Only on the northernmost Norwegian site (NO1) two boreal-arctic species (T2) are observed, with a small cover i.e. *Arctostaphylos alpinus* and *Loiseleuria procumbens* (Fig. 3A,B). On the Norwegian site (N1), on three Finnish ones (FN1, FN2 and FN3), and on the Estonian one (ES1) there are no species from the group T 6–7, associated with the moderately warm areas (Fig. 3A,B). These species appear with the Latvian site (LT1), their share in terms of species number and cover increasing in the southern direction, along with

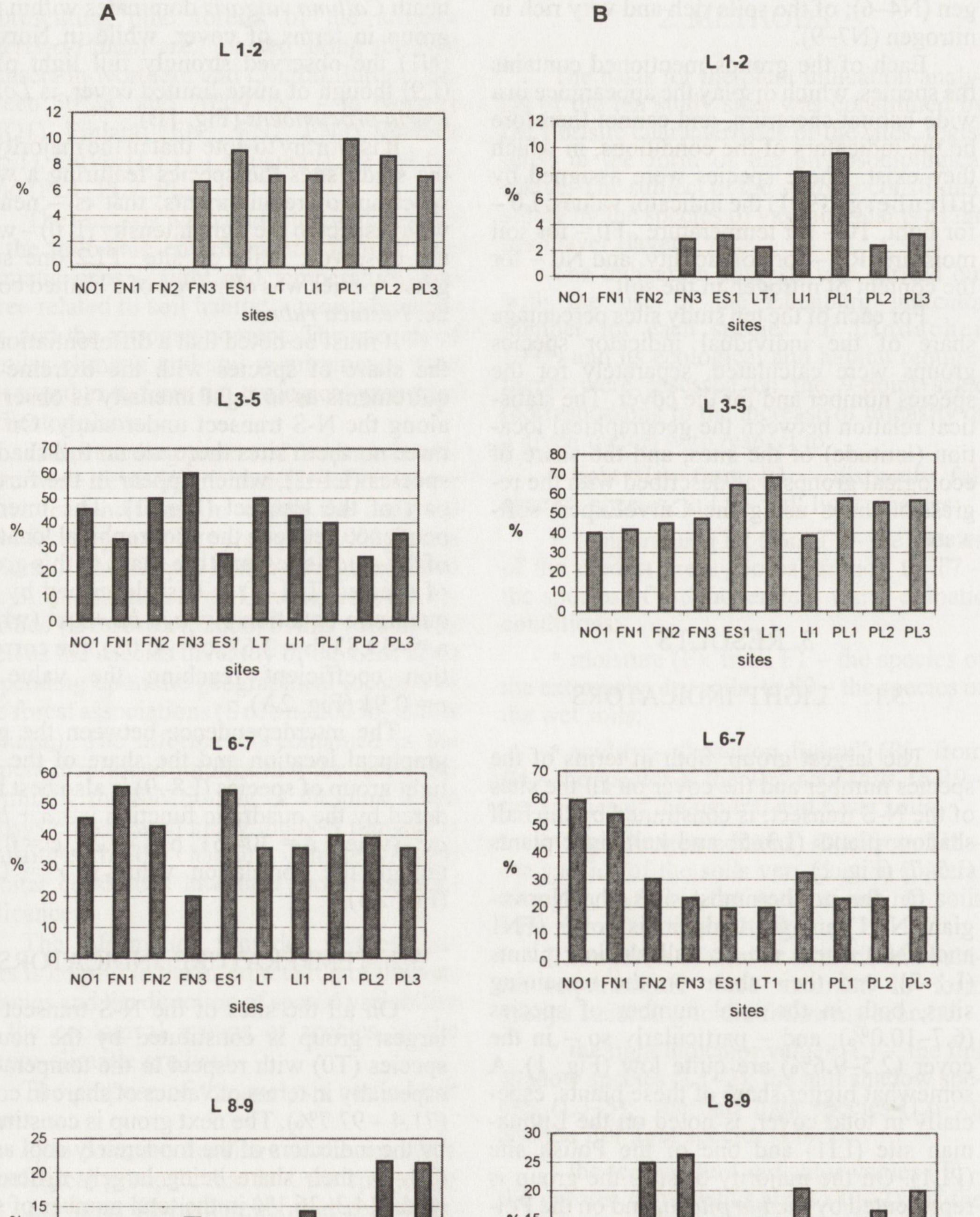


Fig. 1. The share of the ecological species groups of vascular plants of the herb layer as indicators of light intensity (L) on the N-S transect site codes between: 50°28' and 70°09' N – in Norway (NO1), Finland (FN1, FN2, FN3), Estonia (ES1), Latvia (LT1), Lithuania (LI1) and Poland (PL1, PL2, PL3) (see also Breymeyer 2003); A – the share of number of species in total species number; B – the share of the cover of the species in total species cover. The ecological species groups: L 1–2 – full shadow species; L 3–5 – half shadow species; L 6–7 – half light species; L 8–9 –full light species.

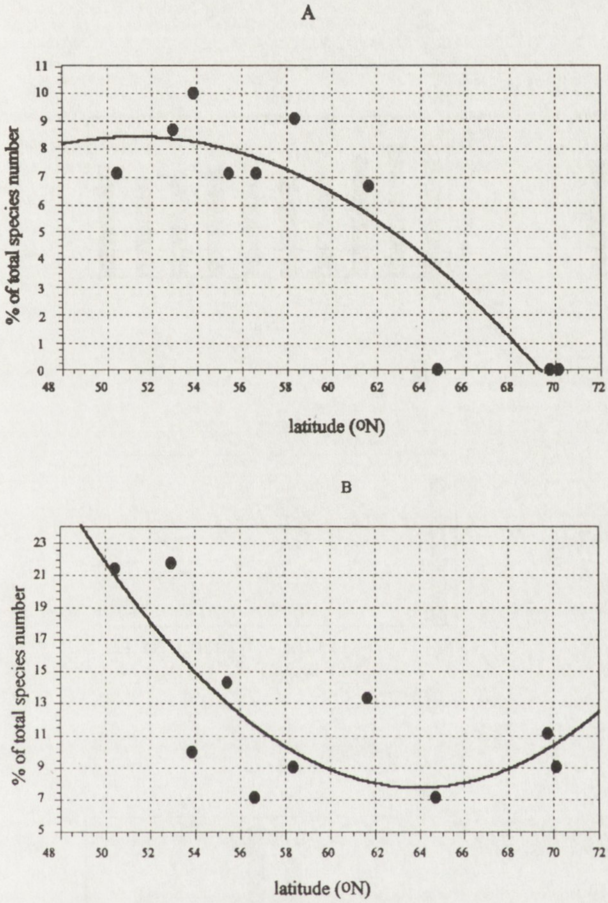


Fig. 2. A – Relation between geographical location of the study sites and the share of number of the full shadow plant species (L1–2) represented by the quadratic function ($y = a + bx + cx^2$ where a = –59.83, b = 2.67, c = –0.03) with the correlation coefficient $r$=0.91; B – Relation between geographical location and the share of number of the full light species (L8–9), represented by the quadratic function $y = a + bx + cx^2$ (where a = 304.51, b = –9.28, c = 0.07) with the correlation coefficient $r$ = 0.77.

diminishing latitude (Fig. 3). On the Latvian site (LT1) *Peucedanum oreoselinum* (T 6) appears, though with small cover, and on the Lithuanian site (LI1), this species appears with a bigger cover (Fig. 3B); C*himaphila umbellata* (T 6) is observed as well. On the next Polish site, PL1, the respective species are *Peucedanum oreoselinum*, *Pulsatilla patens* and *Thymus serpyllum*. On the next Polish site in the southern direction (PL2) besides *Peucedanum oreoselinum* other “moderately warm” species appear like *Genista tinctoria*, *Scorzonera humilis*, and “the warmest” one (T 7) – *Chamaecitisus ratisbonensis* (Fig. 3).

The relation between geographical location and the appearance of the group of “moderately warm” species (T6–7) is best reflected through the quadratic function $y = a + bx + cx^2$, (where a = 304.88, b = –9.02, c = 0.07) with the value of the correlation coefficient $r$ equal 0.90 for the number of species (Fig. 4A), and somewhat higher $r$=0.94 (where a =232.74, b = –7.17, c = 0.05) for their share in the cover (Fig. 4B).

### 3.3. SOIL MOISTURE INDICATORS

The largest group on all the study sites of the N-S transect with respect to both the number of species and their cover is constituted by the species, as indicators of fresh soils

(F 4–5), roughly between 27% and 58% of the total number of species (Fig.5A), and approximately between 27% and 60% of the total cover (Fig. 5B). A large group is constituted by the species with the wide spectrum of requirements (neutral) with respect to this feature (F 0) roughly between 20% and 53% in the total species number (Fig. 5A, and from around 22% to 55% in the total cover (Fig.5B). The group of species as indicators of moist soils (F 6–7) was observed with relatively high cover on the four northern sites: NO1, FN1, FN2, and FN3 (between 40% in Norway and roughly 18% on the Finnish site FN3). These values of share are decreasing in the southern direction (Fig. 5B). On the northern sites, especially in Norway (NO1) the hygrophilous species *Empetrum nigrum* is distinctly the dominating one. On the site FN2, side by side with *Empetrum nigrum*, an indicator of the wet soils, *Ledum palustre* (F 9) appears, which is also present in Estonia (ES1), although on both sites with a rather small cover (Fig. 5).

It should be emphasised that on the five northern sites the group of the dry habitat species (F 1–3) were not observed, though they appear on the remaining sites, but with a small cover (Fig. 5).

The relation between the geographical location and the share of number of the plant species as indicators of dry soils (F 1–3) is represented by the quadratic function $y = a + bx + cx^2$, (where a = 130.16, b = –3.69, c = 0.03) with the correlation coefficient $r$ = 0.86 (Fig. 6A).

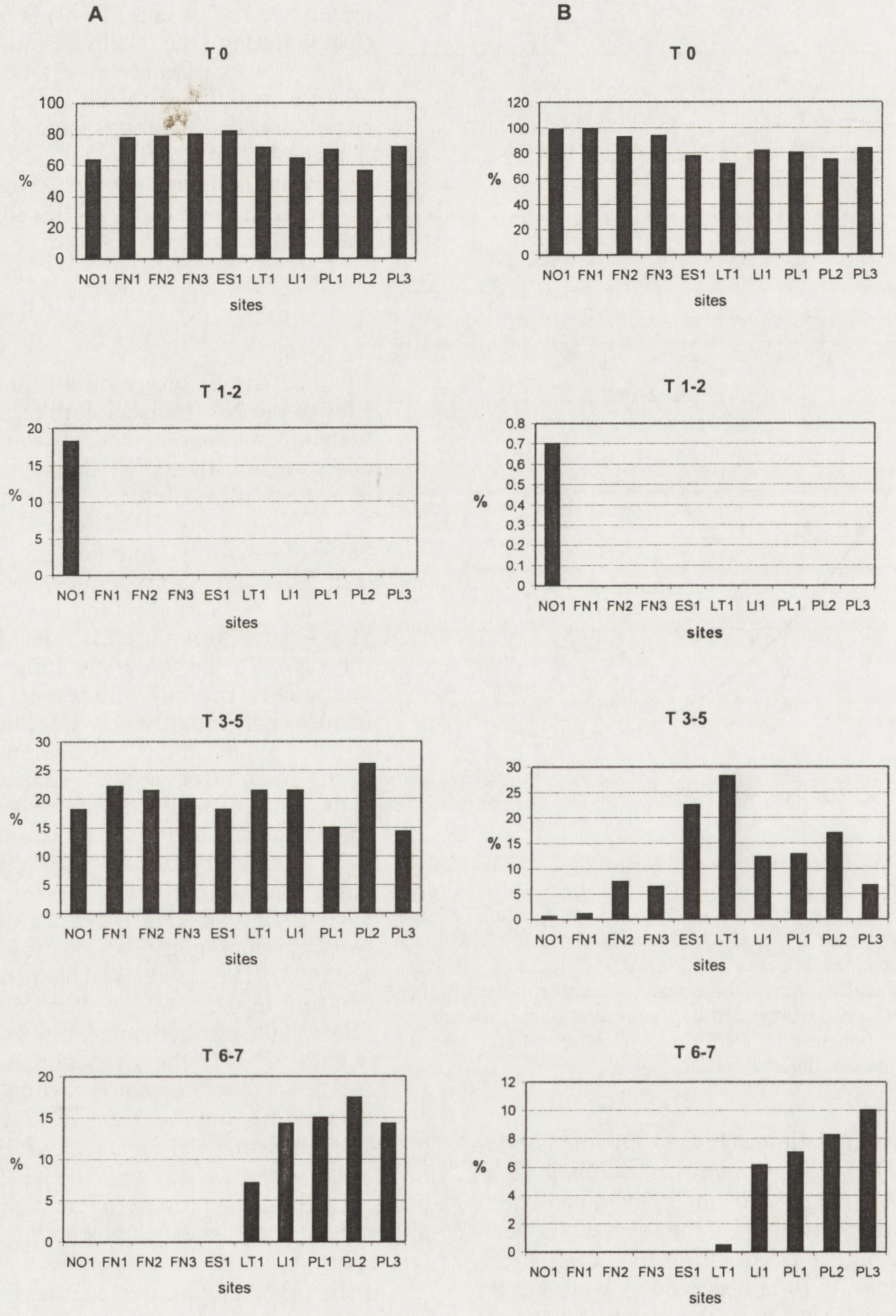


Fig. 3. The share of the ecological species groups of vascular plants of the herb layer, featuring different requirements with respect to temperature (T) on the N-S transect (site codes – see Fig. 1 and Breymeyer 2003); A – the share of number of species in total species number; B – the share of the cover of species in total species cover. The ecological species groups: T0 – with wide spectrum to the temperature conditions; and as indicators: T 1–2 – of the cold areas; T 3–5 – of modearately cool areas; T 6–7 – of moderately warm areas.

The relation between geographical location, and the share of cover of the plant species as indicators of the moist soils (F 6–7) is best described by the quadratic function $y = a + bx + cx^2$, (where a = 223.68, b = –8.97, c = 0.09) with the very high value of the correlation coefficient: $r$ = 0.98 (Fig. 6B).

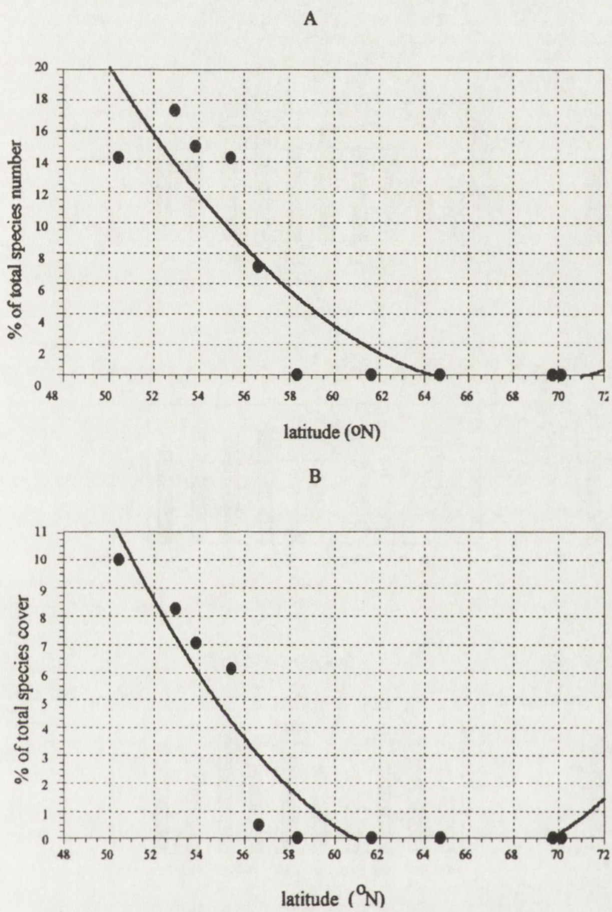


Fig. 4. A – Relation between geographical location of the study, sites and the share of the plant species groups indicative of the moderately warm areas (T6–7) represented by the quadratic function ($y = a + bx + cx^2$) where a = 304.88, b = –9.02, c = 0.07) with the correlation coefficient $r = 0.90$ for the number of species; B – with the correlation coefficient $r = 0.94$ (where a = 232.74, b = –7.17, c = 0.05) for the cover of species.

## 3.4. SOIL ACIDITY INDICATORS

In view of both the number of species and their cover the largest group on all the sites of the N-S transect is constituted by the species, as indicators of the acid and very acid soils (R 1–3), approximately between 40% and 78% of the total number of species (Fig. 7A), and between 58% and 92% in the total cover (Fig. 7B). There is also a quite large group of the species featuring wide spectrum of requirements (neutral) with respect to this characteristic (R0), accounting for approximately 13 to 36% of the total number of species (Fig. 7A) and between roughly 4.1 and 40% of the total cover (Fig. 7B). It is worthy to note that on the three northern sites, the Norwegian (NO1) and the two Finnish ones (FN1 and FN2), no species were observed proper for the weakly acid soils (R 4–6), only neutral and acidophilous ones appear on these sites (Fig. 7). The indicator of the weakly acidic soils, the species *Equisetum pratense*, appears with a small cover on the Finnish site (FN3).

The largest share of the species indicative for the weakly acidic habitats (R 4–6) is observed on the Lithuanian and two Polish sites (LI1, PL1, PL2) (Fig. 7). These species are following: *Peucedanum oreoselinum*, *Carex montana*, *Chimaphila umbellata*, on the Lithuanian site (LT1), *Peucedanum oreoselinum* and *Polygonatum multiflorum* and *Pulsatilla potens* on the Polish site (PL1), *Festuca rubra*, *Genista tinctoria* and *Polygonatum odoratum* (R7) on the site PL2. On the site PL3, side by side with *Chimaphila umbellata* and *Carex montana*, *Poa compressa* is observed, although with a small cover, but as indicator of alkaline soils (R 9).

It is worthy to note that the number of the acidophilous species (R 1–3) drops in the southern direction, while the presence of the indicators of the weakly acidic soils increases (Fig. 7).

The relation between the geographical location and the share of the number of species as indicators of the acid soils (R 1–3) is best described by the linear regression function $y = a + bx$, (where a = –21.94, b = 1.33) with the value of the correlation coefficient $r = 0.75$ (Fig. 8A).
The relation between the geographical location and the share of the number of species, as indicators of the weakly acidic soils (R4–6) is also best represented by the linear regression function $y = a + bx$, (where a = 122.43, b = –1.76) with, however, somewhat higher value of the correlation coefficient, namely $r$=0.85 (Fig. 8B).

## 3.5. INDICATORS OF NITROGEN CONTENT IN THE SOIL

On all the sites of the N-S transect the largest group of species, in particular with respect to the values of share in total cover, is constituted by indicators of the soils poor in nitrogen (N 1–3), namely approximately be-

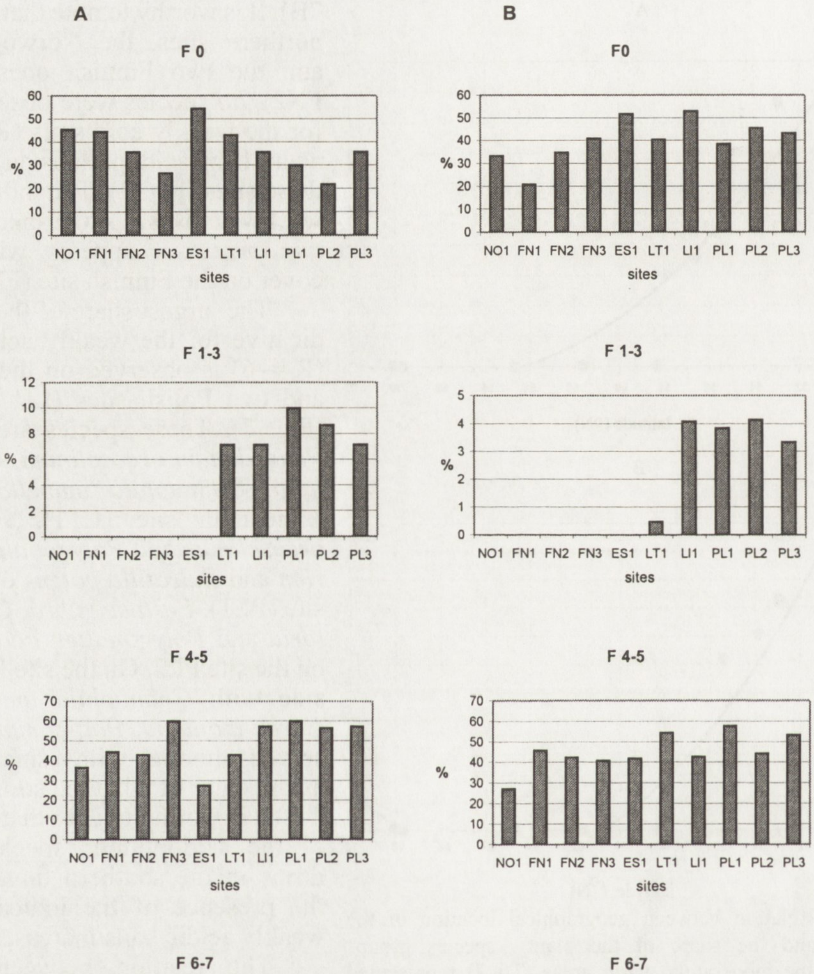


Fig. 5. The share of the ecological species groups of vascular plants belonging to the herb layer, featuring different requirements with respect to the moisture of the soils (F) on the N-S transect (site codes – see Fig. 1 and Breymeyer 2003); A – the share of number of species in total species number; B – the share of the cover of species in total species cover. The ecological species groups: F0 – with the wide spectrum to the moisture conditions and as indicators: F 1–3 – of the dry soils; F 4–5 – of the fresh soils ; F 6–7 – of the moist soils; F 9 – of the wet soils.

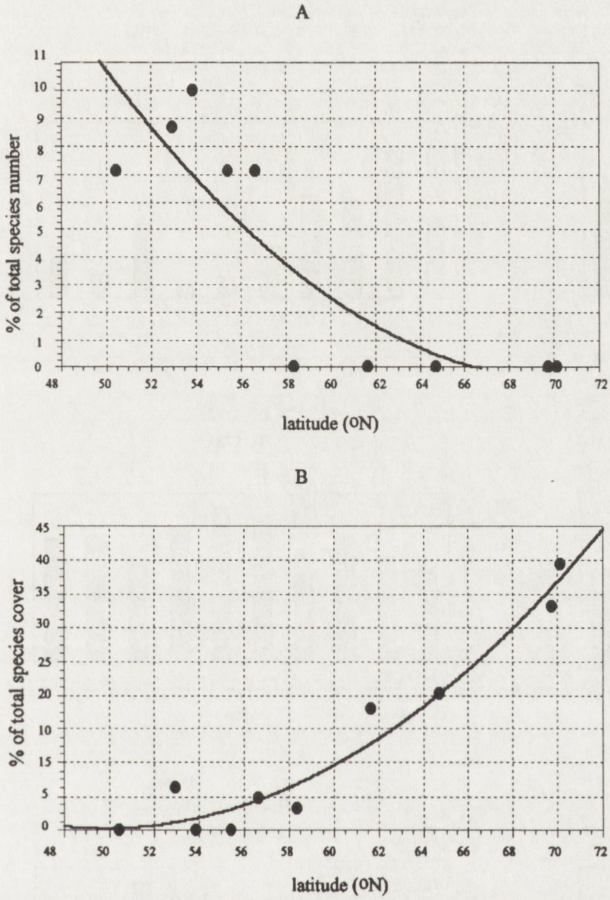


Fig. 6. A – Relation between geographical location of the study sites and the share the number of plant species, as indicators of dry soils (F1–3) represented by the quadratic function $y = a + bx + cx^2$ (where a = 130.16, b = –3.69, c = 0.03) with the correlation coefficient $r$ = 0.86; B – Relation between geographical location and the share of the cover of species as indicators of the moist soils (F6–7), represented by the quadratic function $y = a + bx + cx^2$ (where a = 223.68, b = –8.97, c = 0.09) with the correlation coefficient $r$ = 0.98.

tween 60% and 89% in the species number (Fig. 9A) and between 68% and 99.4% in total cover (Fig. 9B). These plants include, first of all, the ones appearing on all the sites being the indicators of the soils extremely poor in mineral nitrogen like: *Vaccinium vitis-idaea* and *Calluna vulgaris*, and, definitely less frequently – *Festuca ovina*, *Genista tinctoria* and *Thymus serpyllum*.

It is worthy to note that the species featuring the wide spectrum of requirements as to the content of nitrogen in the soil (N 0) constitute a small percentage (Fig. 9B). These are the seedlings of the trees like *Pinus silvestris*, *Picea abies*, *Sorbus aucuparia*, as well as such species of herb layer as *Lembotropis nigricans*, *Viola riviniana*, *Monotropa hypopitis* and *Festuca rubra*.

A small group is constituted by the species requiring the soils moderately rich in nitrogen (N4–6), appearing, in particular, on the Polish site, PL1 (Fig. 9). On two sites – the Finnish (FN3) and the Polish (PL2) one nitrophilous species was observed, i.e. *Epilobium angustifolium*.

No statistically significant dependence was found between the geographical location of the pine forest sites and the share of species featuring different requirements with respect to the content of nitrogen in the soil.

## 4. DISCUSSION

The analysis demonstrated that the largest groups on the transect are constituted by the half – shadow and half – light species, neutral ones with respect to the temperature, and the ones, which are the indicators of fresh, very acidic, and poor in mineral nitrogen soils.

It should be emphasised that the plant species building the herb layer of the sites "responded" to the increase of temperature in the southern direction, since the farther South, the more of the species indicative for the moderately warm areas, both in terms of the number of species and of their cover. On the other hand, their complete absence was noted on the five northern sites. The statistically significant dependence of the presence of this group of species upon latitude was observed.

A similar analysis using the same methodology was carried out along the continentality gradient also in the pine forests. This analysis showed the distinct directional changes from the West to the East with respect to the majority of the species groups of the defined indicator of continentality. Along with the increasing presence of the features of climatic continentalism, the oceanic and suboceanic species receded (their number and cover decreased). This variability in space is well correlated with longitude (Roo-Zielińska, 2002).

The variability of the vegetation cover according to the gradient of continentality on the

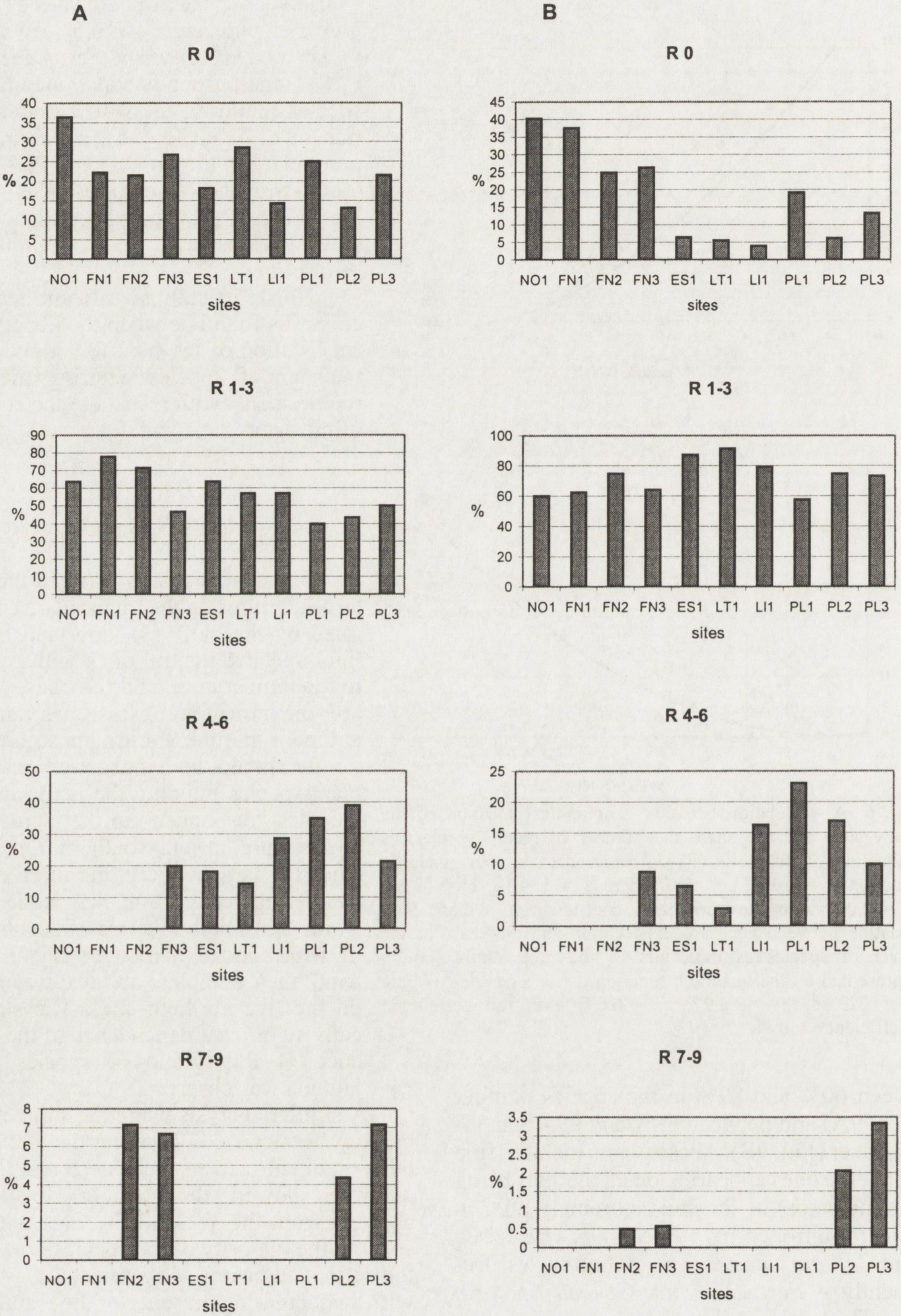


Fig. 7. The share of the ecological species groups of vascular plants belonging to the herb layer, featuring different requirements with respect to the acidity of the soils (R) on the N-S transect (site codes – see Fig. 1 and Breymeyer 2003); A – the share of number of species in total species number; B – the share of the cover of species in total cover. The ecological species groups: R0 – with the wide spectrum to the acidity of soils and as indicators: R 1–3 – of the acid soils; R 4–6– of the weakly acid soils; R 7–9 – of the neutral and basic soils.

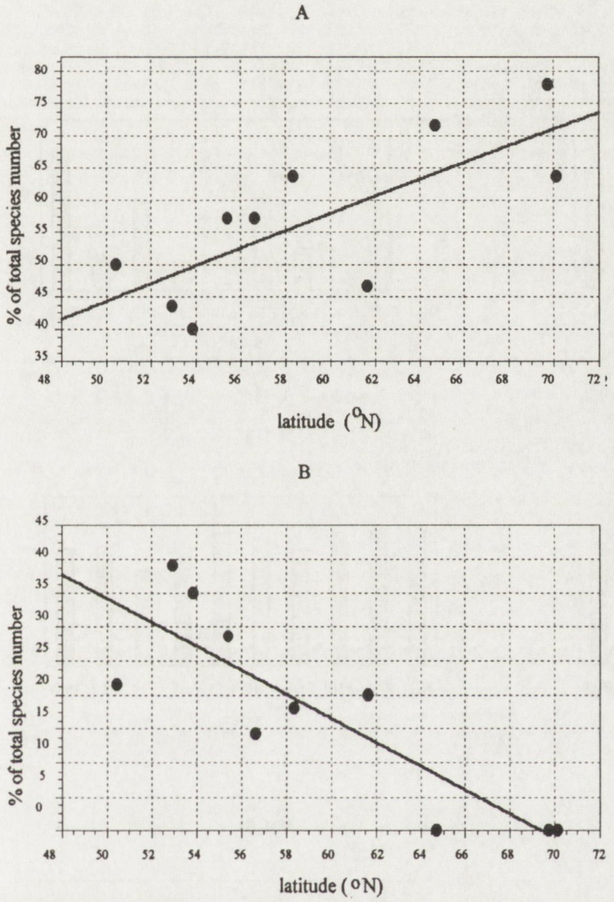


Fig. 8. A – Relation between geographical location of the study sites and the share the number of plant species as indicators of the acid soils (R1–3) represented by the linear regression function $y = a + bx$, (where a = –21.94, b = 1.33) with the correlation coefficient $r$ = 0.75; B – Relation between geographical location and the share of the number of species as indicators of the weakly acid soils (R4–6), represented by the linear regression function $y = a + bx$, (where a = 122.43, b = –1.76) with the correlation coefficient $r$ = 0.85.

area of Poland is presented on the isorhythmic map of Degórski (1984). This map was elaborated through interpolation of the values taken by the Ellenberg's indicator of continentality on the basis of the floristic composition of the oak-hornbeam forests. The change of the composition of the herb layer in these forests along the W-E transect was taking place in parallel with the increase of the degree of continentality of climate. Degórski (1984) demonstrated high correlation between the results achieved by two methods: the climatological one and the one of the Ellenberg indicator method ($r$ = 0.90).

It appears, therefore, that the scale of the temperature, and of the degree of continentality of Ellenberg *et al.* (1991), ascribed to the plant species, can be treated as good measures of macroclimatic differentiation of the vegetation and the composition of the plant communities.

The soils analysed along the N-S transect are under the influence of a humid climate, which is reflected through the domination of precipitation over evapotranspiration on the entire area of study and therefore, the significant moisture of the soils, especially in the North of the study area was noted (Degórski, 2003, in this volume). This characteristic of habitats finds a confirmation in the appearance on the analysed sites of the groups of species featuring known requirements as to soil moisture. The group of the species of the moist habitats was observed, with quite significant cover, on four northern sites: NO1, FN1, FN2 and FN3, with their percentage values of share distinctly decreasing in the southern direction. It is worthy to note that the relation between geographical location and the cover of this species group is statistically significant, with a very high value of the correlation coefficient, namely $r$ =0.98.

The strong moist of the northern sites is confirmed by the lack of the species indicative of the dry soils on the five northern sites; such species appear in the southern areas, even though with the small cover. The statistically significant correlation between the latitude and the indicators of the dry soils is observed only for the number of species. On the other hand, the share of the sporadic species (with small cover) may turn out important for the analysis of changes over time, as they may become the symptoms of the approaching, frequently anthropogenic, changes in the phytocoenosis (Roo-Zielińska, 1993).

The results of the studies of Degórski (2003, in this volume) imply that although the values of the $pH_{H2O}$, ranging between 3.6 and 4.0 in the humus layer, do not display statistically significant differences between the analysed soil profiles, yet the share of the hydrogen ions in the absorption complexes decreases towards the South, while the share of the bivalent cations increases. It is worthy to

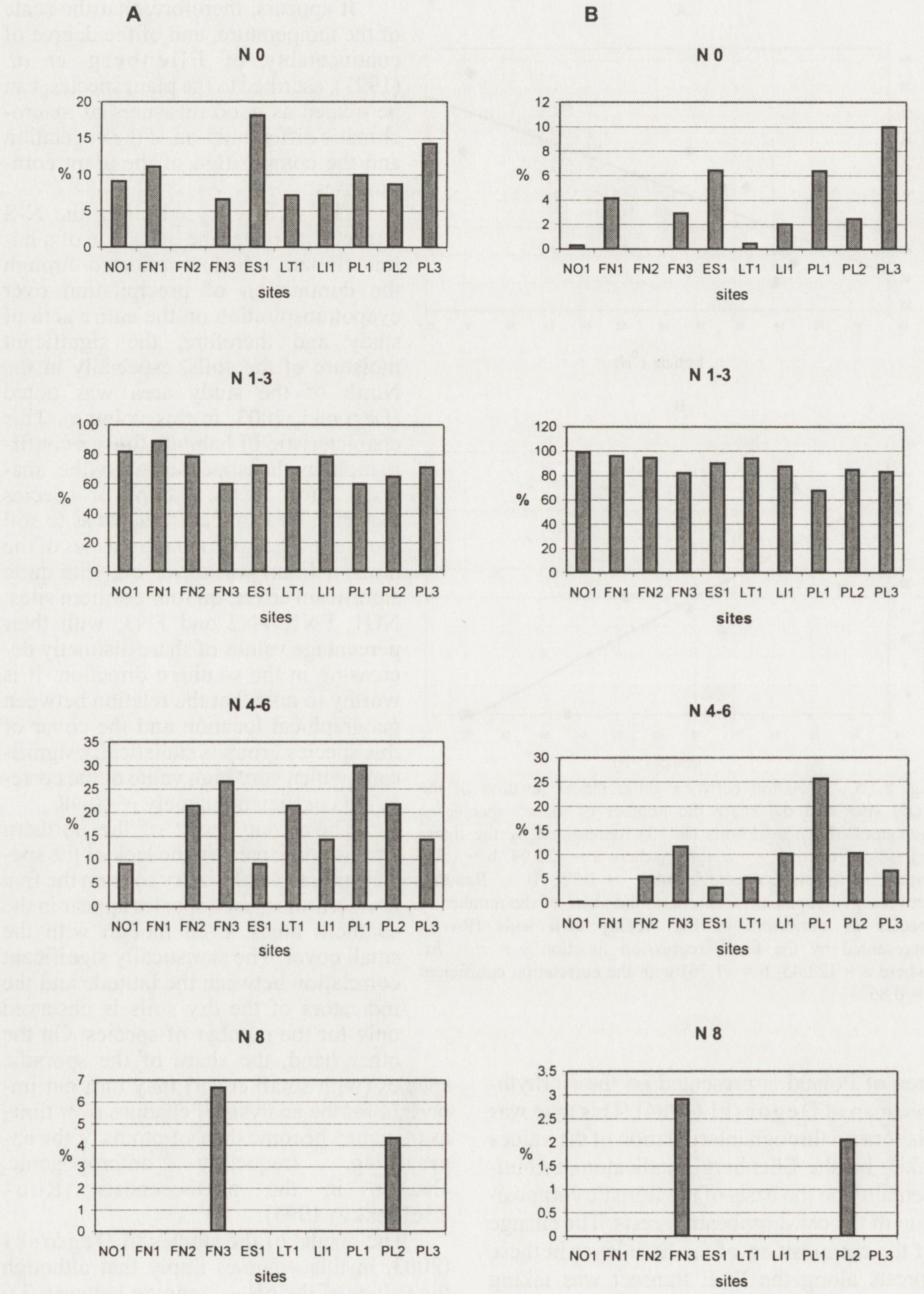


Fig. 9. The share of the ecological species groups of vascular plants belonging to the herb layer, featuring different requirements with respect to nitrogen content of the soils (N) on the N-S transect (site codes – see Fig. 1 and Breymeyer 2003); A – the share of number of species in total number; B – the share of the cover of the species in total species cover. The ecological species groups: N0 – with the wide spectrum to the nitrogen content in the soils and as indicators: N 1–3 – of the soils poor in nitrogen; N 4–6 – of the soils moderately rich in nitrogen; N 8 – of the soils rich in nitrogen.

note that the number of the acidophilous species declines towards the South, while the number of those indicative for the weakly acidic soils – increases. It is confirmed by the statistically significant correlation between the geographical location of the pine forests, and the share of these species groups.

Finally, it ought to be emphasised that with respect to all the analysed climatic and soil factors a clearly distinct character is observed of the two northernmost sites, the Norwegian (NO1) and the Finnish (FN1). This fact is confirmed by the analysis carried out by Solon (2003b, in this volume), who demonstrated the statistically significant separation between these two sites and the remaining ones with respect to the similarity of the species composition of the vascular plants forming the herb layer.

## 5. CONCLUSIONS

Distinct directional changes were observed along the N-S transect in the share of the majority of the ecological species groups, namely:

• in accordance with the air temperature increase towards the South the species of the moderately warm areas appear. This fact is equally visible in the number of species and in the cover; the variability in question being well correlated with latitude;

• in the southward direction the share of the species of the moist soils decreases, while the species indicative of the dry habitats appear. The dependence of the presence of these species groups upon latitude is well represented by the high values of the correlation coefficient. This tendency of changes is in agreement with the measurements of moisture of the soils analysed;

• the share of the species proper for the acid and very acid soils decrease in the southern direction, while the species indicative of the weakly acid soils appear. They are not observed on the northern sites. The dependence of the presence of these species groups upon latitude is well expressed through the high values of the correlation coefficients;

• it seems that in the determination of the macroclimatic differentiation of the sites of the same type of forest community, i.e. in this case the pine forests, the number of species is a better measure than their cover. In the majority of the statistical analyses the higher values of the correlation coefficient with the latitude were obtained for the number of species than for their cover;

• there are no full – shadow plant species on the three northern sites; these species appear on the fragment of the transect farther to the South, and the relation exists between the geographical location of the study sites and the share of this species group; it is confirmed by the high value of the correlation coefficient, $r = 0.91$.

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## 6. REFERENCES

Breymeyer A. 2003 – Pine ecosystem response to warning along North-South climatic transet in Europe: presentation of research project. – Pol. J. Ecol. 51, 4:403–411.

Degórski M. 1984 – Porównanie stopnia kontynentalizmu w Polsce określanego metodami klimatologiczną i bioindykacyjną [Comparison of the degree of continentalism in Poland determined with the climatological and bioindication methods] – Przegląd Geograficzny, 56, 3–4, pp. 55–73 ( in Polish).

Degórski M. 2003 – Morpholithological genesis and soil properties of the pine forest ecosystems in relation to the pine forest ecosystems in relation to the North-South transect in Europe. – Pol. J. Ecol. 51: 441–459.

Ellenberg H. 1974 – Zeigerwerte der Gefasspflanzen Mitteleuropas, – Scr. Geobot. 9: 982. Gottingen.

Ellenberg H., Weber H. E., Düll R., Wirth V., Werner W., Paulissen D. 1991 – Zeigerwerte von Pflanzen in Mitteleuropa – Scripta Geobotanica, 18, Göttingen.

Lindacher R. (Ed.) 1995 – Phanart Datenbank der Gefässpflanzen Mitteleuropas. Erklarung der Kennzahlen, Aufbau und Inhalt [Phanart Database of Central European Vascular Plants. Explanation of Codes, Structure and Contents] – Veröffentlichungen Geobotanischen Instituts der ETH Stiftung Rübel, 125, Zürich.

Roo-Zielińska E. 1993 – The current state and changes in the meadow flora in the Nida valley, southern Poland. – Fragm. Flor.Geobot. 38(2), pp. 581–592.

Roo-Zielińska E. 2002 – Stopień kontynentalizmu borów sosnowych wyrażony zmiennością kompozycji gatunkowej runa wzdłuż transektu równoleżnikowego Chrisdorf (Niemcy wschodnie) – Uzlogi (Białoruś wschodnia) [The degree of continentalism of the pine forests expressed through the variability of the herb layer species composition along the parallel transect Chrisdorf (eastern Germany) – Uzlogi (eastern Belarus')] – Przegląd Geograficzny 74, 4, pp. 569–591 (in Polish).

Roo-Zielińska E., Solon J. 1998 – Charakterystyka geobotaniczna i analiza zasięgów borów i borów mieszanych na transektach badawczych: klimatycznym (wzdłuż 52$^{o}$N, od 12$^{o}$ do 32$^{o}$E) i śląskim [The geobotanical characteristics and the analysis of reach of the pine and mixed forests on the study transects: the climatic (along 52$^{o}$N, between 12$^{o}$ and 32$^{o}$ E) and the "silesian" one];. (In: Bory sosnowe w gradiencie kontynentalizmu i zanieczyszczeń w Europie Środkowej – badania geoekologiczne [Pine forests in Central European gradient of continentality and pollution – geoekological studies] Eds: Breymeyer A., Roo-Zielińska E.) – Dokumentacja Geograficzna, 13, pp. 79–99 (in Polish).

Solon J. 2003a – Scots pine forests of the Vaccinio-Piceetea class in Europe: forest sites studied . – Pol. J. Ecol. 51, 4. 421–439.

Solon J. 2003b – Changes in herb layer heterogeneity of Scots pine forests along the North-South transect – Pol. J. Ecol. 51, 4: 481–492.

van der Maarel E. 1993 – Relations between sociological-ecological species groups and Ellenberg indicator values – Phytoceonologia, 23, pp. 343–362.

Wójcik Z. 1983 – Charakterystyka i ocena siedlisk polnych metodami bioindykacyjnymi [Characterisation and assessment of the field habitats with bioindication methods] – Wyd. SGGW-AR, pp. 7–79 (in Polish).

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