Thaiszia - J. Bot., Košice, 15, Suppl. 1: 289-300, 2005 http://www.upjs.sk/bz/thaiszia/index.html

THAISZIA
JOURNAL OF
BOTANY

Effects of forest management on alien plant invasions of woodlands

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CHMURA D. & SIERKA E. (2005): Effects of forest management on alien plant invasions of woodlands. – Thaiszia – J. Bot. 15, Suppl. 1: 289-300. – ISSN 1210-0420.

Abstract: In the Silesian Upland (southern Poland) in the years 1997-2001 total 283 phytosociological relevés were taken using commonly applied Braun-Blanquet method. The geobotanical survey was carried out in natural, semi-natural, as well as in disturbed forest communities. The woodlands were chosen systematically and randomly within the study area and the patches in them were chosen in relation to presence and different cover-abundance of a neophyte i.e. alien invasive species introduced after 1500. Of total 18 alien plant species found during phytosociological research in the study area only 3 are very frequent: woody species *Quercus rubra, Padus serotina* and herbaceous annual *Impatiens parviflora*. PCA analysis confirmed the biggest mean cover and the widest synecological amplitude of these species. The alien trees are used as productive admixtures to tree stands in forest management. The most vulnerable forest communities to invasions are those which are also frequently exploited by forestry i.e. *Leucobryo-Pinetum, Querco roboris-Pinetum and Tilio-Carpinetum.* Such species as *Impatiens parviflora, Solidago gigantea, Reynoutria japonica* are mainly connected with mesic forest communities of *Querco-Fagetea class*, which are dominated by the former. *Impatiens parviflora* also occurs in mixed coniferous forest and communities of *Alnetea glutinosae* class. The representatives of neophytes recorded in woodlands occur basically in various types of plant communities, however their cover increases with decreases in number and cover of native species.

Keywords: forestry, plant invasions, forest communities, phytosociological data.

Introduction

In Poland, especially in lowlands, the climax zone community is oak-hornbeam forest *Tilio-Carpinetum* TRACZ. 1962, apart from it in river valleys there are habitats for woodlands of *Salicetea purpurae* class and *Alno-Ulmion* BR.-BL. et R.TX. 1943 alliance of *Querco-Fagetea* class i.e. floodplain and riparian forests. Long-term land use, including forestry, caused that nowadays forest vegetation is altered into woodlands with dominant tree *Pinus sylvestris* L. Most of coniferous and mixed coniferous forests are man-made woodlands, considerable part of them is still exploited by forest management.

Forestry through timber production and forest cultivation is followed by many accompanying phenomena as habitat fragmentation, changes in water relations, soil erosion, euthrophication, species impoverishment. Tree felling lead to thinning of tree stands and enhance spread of native expansive herbs. Natural plant diversity and regeneration ability of community decrease. Choice of woody species for afforestation of clear-cuts often results in development of single-species and even-aged monocultures, characterized by poor species richness of forest floor (DZWONKO & LOSTER 1991, MEDWECKA-KORNAŚ 1994). A lot of examples of disturbances due to forestry were given by OLACZEK (1974, see also ŁASKA 2001). One of effects of silviculture are promotions of biological invasions, directly – alien woody plants cultivations (ADAMOWSKI et al. 1998) and indirectly – facilitation of herbal invaders penetration due to system of forest roads (PASZEK, ZAŁUSKI 2000).

The aim of the following study was to show the impact of forestry on alien plant invasions, emphasizing role of alien invasive species at community level based on phytosociological data and to examine which forest community is the most susceptible to invasions. Another goal was examine whether Braun-Blanquet method could be useful tool of assessment of alien plant invasions.

Methods

In the Silesian Upland (southern Poland) in the years 1997-2001 total 283 phytosociological relevés were taken using commonly applied method by BRAUN-BLANQUET (1964). The geobotanical survey was carried out in natural, semi-natural, as well as in disturbed forests. The patches were chosen in relation to presence and different cover-abundance of a (kenophytes sensu KORNAŚ) neophytes i.e. alien invasive species introduced after 1500 (KORNAŚ 1990, PYŠEK 2004). As the woody alien taxa are concerned, the cultivation sites were excluded; only spontaneous stands were examined. Values of Braun-Blanquet scale were transformed using the following scale: r = 0.1, 1 = 5, 2 = 17.5, 3 = 37.5, 4 = 62.5, 5 = 87.5 (VAN DER MAREEL 1979). The relevés were numerically analysed using ordination methods (non-standarized PCA) by means of the statistical packages MVSP 3.0. (KOVACH 1998). Competitiveness of neophytes were distinguished based on degrees of domination (ALEXANDROWICZ 1958). A degree of domination was expressed by percentage of neophyte in general cover of particular layer in each studied phytocoenosis according to the following formula:

$$a\% = \frac{i}{S} \times 100$$

where:
percentage of neophyte in general cover of a layer;
i – mean cover of neophyte in a particular plot;
S- sum of mean cover of all species in a given plot.
Five degrees of domination were distinguished after TROJAN (1975):
M– monopoly species – range: 79.1-100 (% in cover of a layer),
D– dominant species – range: 59.1-79,
W– codominant species – range: 39.1-59,
S– subdominant species – range: 19.1-39,
I – influent species – up to 19

The nomenclature of species follow MIREK et al. (2002) and syntaxonomical names were adopted after MATUSZKIEWICZ (2001). To asses statistically significant relationships between covers and frequencies of native and alien plant species in forest communities the Pearson correlation coefficients were calculated at level significance for $p < 0.05$.

Forest vegetation of study area

In the centre of the Silesian Upland woodlands occupy only ca. 17% of an area. Forest vegetation of the investigated area is diversified. The total 17 forest associations were recorded. The most frequent patches are of coniferous woodlands *Calamagrostio villosae-Pinetum* STASZK. 1958, *Leucobryo-Pinetum* W.MAT. (1962), *Molinio-Pinetum* W.MAT Et J.MAT 1973, quite frequent but occupying smaller areas are patches of *Fraxino-Alnetum* W.MAT. (1952), *Ribeso nigri-Alnetum* SOL.-GÓRN. (1975) 1987, *Luzulo pilosae-Fagetum* W.MAT. 1964 Et A.MAT 1960 and *Vaccinio uliginosi-Pinetum* KLEIST 1929. Amongst quite frequent, weakly preserved there are *Tilio-Carpinetum* TRACZ. 1962, *Carici-Fagetum* PANC.-KOTEJ. In.W.MAT. 2001 as well as mixed coniferous, acidophilous oak associations: *Querco roboris-Pinetum* W.MAT. (1952) et POL.1955), *Calamagrosti-Quercetum* (HARTM. 1934) SCAM et PASS.1959. The rarest and smallest in size are patches of: *Astrantio-Fraxinetum* OBERD. 1953, *Salici-Populetum* R.TX. 1931 MEIJER DREES 1936, *Carici remotae-Fraxinetum* KOCH 1926 ex FARBER 1936 (CABAŁA 1990).

Results

Of total 18 alien plant species found during phytosociological studies in the investigated area only 3 are very frequent: (trees) *Quercus rubra* L. (110 records), *Padus serotina* (EHRH.) BORKH. (98) and herbaceous annual *Impatiens* *parviflora* DC (124). Red oak and black cherry were reported in 13 plant communities. They both were not noted in the patches of floodplain forests as *Carici-remotae Fraxinetum* and *Ficario-Ulmetum minoris* KNAPP 1942 EM. J.MAT. 1976. Moreover *P. serotina* did not occur in plant communities from alliance *Fagenion*, and *Q. rubra* did not appear in alder forest *Ribeso nigrae-Alnetum*. Of other woody aliens *Robinia psedoacacia* L. is the most common, found in 6 sites, especially in the patches with loose tree stands as *Calamagrostio-Quercetum* and patches with *Pinus sylvestris* L. of anthropogenic origin. Both *Acer negundo* L. and *Aesculus hippocastanum* L. appear very rarely, mainly associated with forests of *Querco-Fagetea* class: *Tilio-Carpinetum*, *Carici remotae-Fraxinetum* as well as anthropogenic *Betula pendula-Carex brizoides*. As the *Impatiens parviflora* is concerned, its synecological amplitude is the biggest; the species was observed in 17 plant communities of 18 distinguished ones among those being invaded. The neophyte was not only recorded in termophilous beechwood association *Carici-Fagetum*. Of remaining species *Solidago gigantea* AITON reveals the widest phytosociological spectrum but its frequency is low. Goldenrod was encountered in 7 forest communities, with maximum number of stands – 4 in *Calamagrostio-Quercetum*. American species *Lupinus polyphyllus* LINDL. was noted in 4 plant communities, of witch more than half of localities are from coniferous woodlands. Single occurrence in phytosociological records was revealed by *Oxalis fontana* BUNGE, appearing in fertile hornbeam forests: *Tilio-Carpinetum*, and beechwood *Luzulo pilosae-Fagetum* and acidophilous mixed coniferous and bog coniferous forests *Calamagrostio-Quercetum, Molinio-Pinetum.* Similarly *Reynoutria japonica* HOUTT. has single stands in various forest communities: *Carici-Fagetum, Calamagrostio-Quercetum* and *Lueucobryo-Pinetum.* Other species occur sporadically not more frequent than in two stands as: *Conyza canadensis* (L.) CRONQUIST, *Erigeron annuus* L.(PERS), *Galinsoga ciliata* (RAF.) S.F.BLAKE, *G. parviflora* CAV., *Juncus tenuis* WILLD., *Solidago canadensis* L (Tab. 1).

Comparison of mean cover-abundance of alien invasive plants, here expressed by domination degree, demonstrates that examined species are mostly influents, only 2 of herbal plants are also subdominants: *Impatiens parviflora* and *Lupinus polyphyllus*. Additionally *I. parviflora* is also codominant. As the woody species are concerned, their role was analysed also in reference to each layer of community. Red oak and black cherry were recorded with higher cover-abundance in shrub and tree layers than in the ground flora as seedlings. In herb layer woody plants are subdominants and codominants (*Padus serotina, Quercus rubra*). These species in tree stand of forests sometimes play considerable role being codominants, dominants and even rarely monopoly species scoring very high cover at poor species richness of natives (Tab. 2). The species as *Conyza canadensis, Erigeron annuus, Impatiens glandulifera, Juncus tenuis, Oxalis fontana, Reynoutria japonica, Solidago canadensis, Galinsoga ciliata, G. parviflora,* do not play significant role in floristic composition of distinguished forest communities. Their cover-abundances are small, very rarely approximating 19 % of total cover of herb layer.

Taking into account Shannon diversity index one can admit that the biggest differences in minimum and maximum values occur in the phytocoenoses with *Impatiens parviflora*, there also one of the lowest medium *H'* reported for all neophytes. The highest values of *H'* were for the rarest species with single occurrence as *Juncus tenuis, Solidago canadensis, Erigeron annuus* with some exceptions – *Galinsoga ciliata, Conyza canadensis* (Tab. 2). Of the woody taxa *Robinia pseudoacacia* has the highest average value of Shannon diversity index, the lowest was noted for the most common *Quercus rubra*.

The ordination of the forest communities on the basis of average cover of neophytes along Axis I and Axis II displays their differentiation (Fig.1). Right part of diagram show mainly coniferous plant communities of *Vaccinio-Picetea* class, in which a major role is played by planted woody trees in forestry as *Quercus rubra* – productive admixture, ensuring increase of wood production as well as *Padus serotina* – admixture species of biocenotic importance conferring biological resistance to woodlands. Moreover, such species as *Solidago gigantea* and *Reynoutria japonica* are associated with more richer in nutrients habitats of *Querco-Fagetea* communities, here situated in the middle part of diagram. On the left side of diagram there are mixed coniferous and deciduous forests, dominated by neophyte *Impatiens parviflora* DC and wet riparian forests of *Alnetea glutinosae* class, where *Padus serotina* is important constituent of tree stands.

Analysis of numbers of the aliens occurrence and their mean cover in relevés, yielded distinct differences in frequency of invasions and mean covers by invaders between distinguished forest associations (Fig. 2). Three the most invaded semi-natural plant communities are: *Leucobryo-Pinetum, Querco roboris-Pinetum and Tilio-Carpinetum*. Of them the highest mean cover-abundance was recorded in pine wood *Leucobryo-Pinetum*, beech woods of *Fagenion* order, *Querco roboris-Pinetum* next in *Tilio-Carpinetum* and alder forest *Fraxino-Alnetum*. Of disturbed woodland communities *Pinus sylvestris-Impatiens parviflora* community has the highest cover of neophytes due to dominant species *Impatiens parviflora*.

Statistical analysis of correlations of floristic composition, cover-abundances, frequencies of alien and native plant species confirm some well-known dependencies (Tab. 3). Based on Braun-Blanquet scale and their transformed values followed VAN DER MAAREL (1979) weak negative but significant correlations between cover-abundance of aliens and species number, cover of natives were revealed. It means that the poorer floristically plant communities are the more susceptible and/or more invaded they are by the aliens. Also it was turned out that sum of Van der Maarel values (cumulative cover) is better predictor than mean cover of all species (Tab. 3). Moreover, correlations between cover of species are stronger supported by statistical tests than correlations using only or with contribution of species number. Weak or medium correlations may be caused by large percentage intervals used in Van der Maarel scale which can not give exact results or they reflect real relationships between native constituents of forests and introduced plants. The latter is congruent with analysis of Alexandrowicz's domination degrees of alien plants which demonstrated that considerable majority of them are only influents in floristic composition.

High correlations between total frequencies of aliens and their number of occurrence in particular forest communities (*Leucobryo-Pinetum, Querco roboris-Pinetum, Luzulo pilosae-Fagetum*) may be signal of a large susceptibility of a given community to alien plant invasions (Tab. 3). They can also result from frequent presence of particular forest association in the study area or specific habitat preferences and phytosociological affiliations of a neophyte to such phytocoenoses e.g. very common neophyte - *Impatiens parviflora* associated with communities of *Querco-Fagetea* class. If a specific plant community is vulnerable to invasion, independently on extrinsic or intrinsic factors, one can predict the more total stands of neophytes in forests in an area, the more stands of neophytes in a given community.

Discussion and conclusions

In forest interiors under conditions of competition not many species tend to establish permanently. In spite of that there are considerable differences in frequency of found neophytes. Other authors conducting geobotanical studies in the same area reported the same neophytes in relevés and in floristic mapping (SENDEK 1974, CELIŃSKI et al. 1978, CELIŃSKI et al., 1991, CABAŁA 1990). Amongst herbs *Impatiens parviflora* dominated, and of woody plants, *Quercus rubra* and *Padus serotina* were the most frequent. As these species are concerned, definitely their former frequent cultivation affected their frequent escape from cultivation and naturalization. This phenomenon is known as "tens rule" WILLIAMSON (1993). CABAŁA (1990) emphasized the fact that many forest associations in the Silesian Upland are of anthropogenic origin e.g. pinewood *Leucobryo-Pinetum* and coniferous, mixed forests *Querco roboris-Pinetum*. Besides, they are exploited by forestry and this lead to disturbance of forest floor, impoverishment of floristic composition and finally facilitate penetration and establishment of aliens. In the study area majority of neophytes occur in forest roads system. This enhances their penetration into forest interiors. In forest associations which can be classified to particular syntaxa, neophytes do not play major role. Despite this, relations between floristic impoverishment of woodlands and presence, abundance of alien plant species were confirmed at the phytosociological level. The similar results was obtained by KENNEDY et al. (2002), but those ecological studies were more detailed and conducted on the permanent plots in grasslands.

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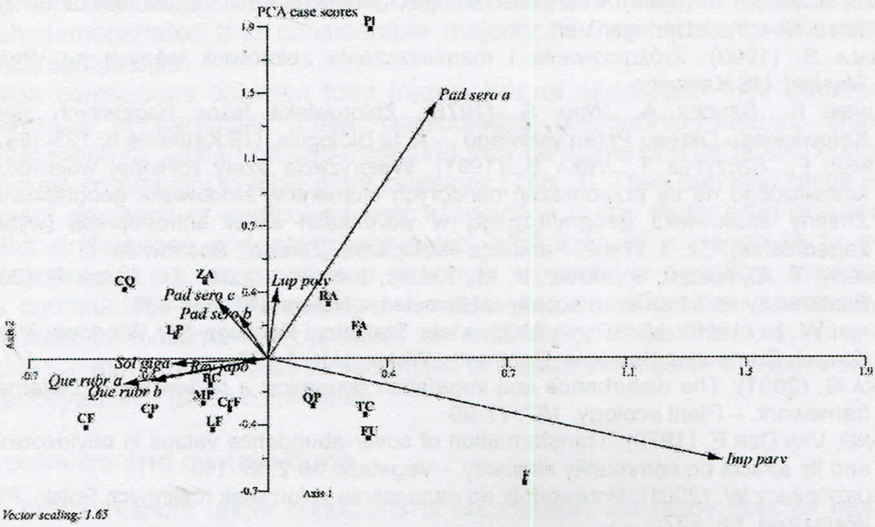

Fig. 1. Ordination diagram of the forest communities of Silesian Upland. The first two PCA axes explained 47.6% variance of species abundance data.

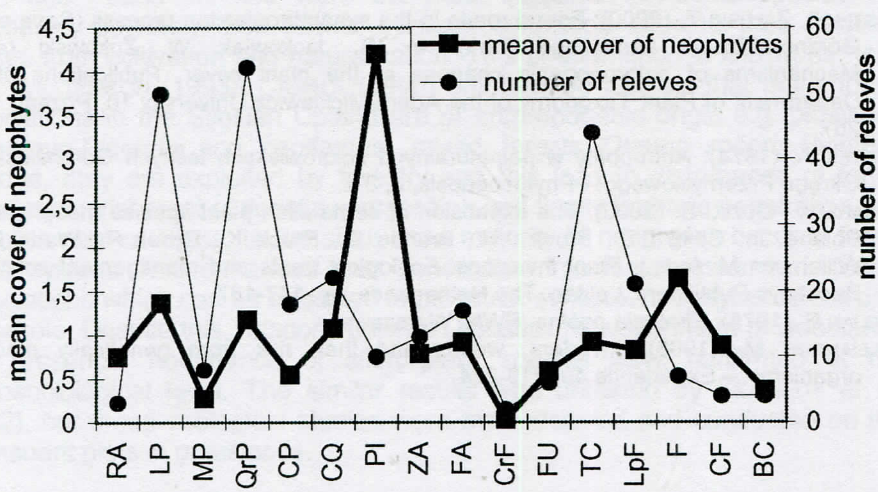

Fig. 2. Susceptibility of forest vegetation to alien plant invasions in the study area. Cover of neophytes are expressed by Braun-Blanquet values. Abbreviations of plant communities follow Table 1.

Tab. 1. Frequency of alien plant species in forest communities of the Silesian Upland and their main characteristics. Numbers represent numbers of relevés.

Species	Total	RA	LP	MP	QP	CP	CQ	PI	AP	FA	CrF	FU	TC	LF	F	CF	BC
A. hippocastanum	3	-	-	-	-	-	-	-	1	-	1	-	-	-	1	-	-
A. negundo	3	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	1
B. frondosa	2	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
C. canadensis	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
E. annuus	2	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-
G. ciliata	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
G. parviflora	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
I. glandulifera	3	-	-	-	-	1	-	-	-	-	-	-	2	-	-	-	-
I. parviflora	124	1	4	2	26	4	10	10	5	11	2	4	27	12	5	-	1
P. serotina	98	1	32	4	25	2	2	1	6	4	-	-	8	8	-	1	4
Q. rubra	110	-	32	1	22	11	10	2	4	2	-	-	14	8	1	1	2
L. polyphyllus	7	-	4	-	1	-	-	-	-	2	-	-	-	-	-	-	-
J. tenuis	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
O. fontana	5	-	-	1	-	-	1	-	-	-	-	-	2	1	-	-	-
R. japonica	3	-	1	-	-	-	1	-	-	-	-	-	-	-	-	1	-
R. pseudacacia	6	-	1	-	2	-	-	-	2	-	-	1	-	-	-	-	-
S. canadensis	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
S. gigantea	11	-	1	-	-	-	4	1	1	-	1	-	1	-	1	1	-
No. of analysed relevés	283	3	50	8	54	18	22	10	13	17	2	6	44	21	7	4	4
Mean tree layer cover		73	65.5	70	66.2	65	63.6	67	60.7	72.3	70	76.6	72.6	74.4	77.8	72.5	72.5

Mean shrub layer cover	11.6	30.3	13.75	21.9	20.8	27.5	21.5	23.07	25	22.5	30	26.2	12.6	13.57	22.5	20
Mean herb layer cover	93	87.3	92.5	88.3	96.1	94.5	94	87.7	84.7	95	96.6	84.7	73.3	70	92.5	100
Mean moss layer cover	16.6	-	-	17.85	1.25	5.8	-	-	5.58	2.5	5.83	1.59	-	-	-	-
Mean species richness	16.7	15.9	14.75	16.6	15.4	18.6	15.3	18.07	18.7	24.5	21.1	18.8	14.95	15.28	19	17.5
Min.	13	10	12	10	11	12	7	10	11	23	19	9	10	8	12	11
Max.	23	23	18	24	36	29	19	30	34	26	22	32	23	21	28	20

Abbreviations: AP- anthropogenic communities with P.silvestris, BC- community Betula pendula-Carex brizoides, CF- Carici-Fagetum, CP- Calamagrostio villosae-Pinetum, CQ- Calamagrostio-Quercetum, CrF- Carici remotae-Fraxinetum F- communities from alliance Fagion, FA- Fraxino-Alnetum, FU- Ficario-Ulmetum minoris, LF- Luzulo pilosae-Fagetum, LP-Leucobryo-Pinetum, MP-Molinio-Pinetum, PI- community Pinus sylvestris-Impatiens parviflora, QP- Querco roboris-Pinetum, RA- Ribeso nigri-Alnetum, TC-Tilio-Carpinetum

Tab. 2. Competitiveness of examined alien species in woodlands of the study area. Numbers represent percentages of stands in particular type of Aleksandrowicz's domination degree.

	Degree of domination					Shannon diversity index		
Species	I	S	W	D	M	X	Min	Max
*Aesculus hippocastanum a**	100	-	-	-	-	0.95	0.78	1.01
Aesculus hippocastanum b	33.3	-	33.3	-	33.3			
Aesculus hippocastanum c	100	-	-	-	-			
*Acer negundo a**	100	-	-	-	-	1	0.95	1.07
Acer negundo b	100	-	-	-	-			
Acer negundo c	100	-	-	-	-			
Bidens frondosa	100	-	-	-	-	0.805	0.694	0.917
Conyza canadensis	100	-	-	-	-	0.893	0.801	0.985
Erigeron annuus	100	-	-	-	-	1.041	0.97	1.113
Galinsoga ciliata	100	-	-	-	-	1.071	-	-
Galinsoga parviflora	100	-	-	-	-	0.792	-	-
Impatiens glandulifera	100	-	-	-	-	0.813	0.645	0.945
Impatiens parviflora	87	11.3	1.7	-	-	0.92	0.267	1.26
Padus serotina a*	56.25	31.25	12.5	-	-	0.95	0.53	1.26
Padus serotina b	24	22.7	25.9	12.9	14.5			
Padus serotina c	95.45	3	1.55	-	-			
Quercus rubra a*	32.5	15	32.5	17.5	2.5	0.93	0.416	1.245
Quercus rubra b	53.2	34	12.8	-	-			
Quercus rubra c	94.6	2.7	2.7	-	-			
Lupinus polyphyllus	85.7	14.3	-	-	-	0.905	0.77	1.123
Juncus tenuis	100	-	-	-	-	1.245	-	-
Oxalis fontana	100	-	-	-	-	0.95	0.824	1.056
Reynoutria japonica	100	-	-	-	-	0.96	0.713	1.12
Robinia pseudacacia a*	50	25	25	-	-	1.079	0.994	1.213
Robinia pseudacacia b	40	40	-	20	-			
Robinia pseudacacia c	100	-	-	-	-			
Solidago canadensis	100	-	-	-	-	1.154	-	-
Solidago gigantea	100	-	-	-	-	1.01	0.792	1.124

I-influent, S-subdominant, W- codominant, D-dominant, M- monopoly species.

*- Values of Shannon diversity index are given for all relevés with presence of a species without reference to specific layer.

Tab. 3. Relations between native and alien plant species number and cover and relations between total frequency of neophytes and their frequency in particular communities. The Pearson correlation coefficients were used (R). (N.S. – not significant, * - p<0.05, ** - p<0.01, * - p<0.001).**

	Number of native species	Cumulative cover of native species
Medium cover of neophytes	R = - 0.122*	R = - 0.26***
Cumulative cover of neophytes	R = - 0.153**	R = - 0.302***
Frequency of neophytes in:		Total frequency of neophytes
Ribeso-Alnetum		N.S.
Leucobryo-Pinetum		R = 0.83***
Molinio-Pinetum		R = 0.66**
Querco roboris-Pinetum		R = 0.69**
Calamagrostio-Pinetum		R = 0.47*
Calamagrostio-Quercetum		R = 0.64**
I. parviflora-P. sylvestris		R = 0.79***
Community with *P.sylvestris*		R = 0.55*
Ficario-Alnetum		R = 0.63**
Carici-Fraxinetum		N.S.
Ficario-Ulmetum		N.S.
Tilio-Carpinetum		R = 0.63**
Luzulo-Fagetum		R = 0.69**
Fagenion		R = 0.57*
Carici-Fagetum		R = 0.51*
B.pendula-C.brizoides		R = 0.59**