Thaiszia - J. Bot., Košice, 15, Suppl. 1: 101-113,
2005 http://www.upjs.sk/bz/thaiszia/index.html

THAISZIA
JOURNAL OF
BOTANY

Distribution and degree of naturalization of *Impatiens parviflora* DC in the southern part of the Silesian-Kraków Upland (Poland)

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CHMURA D. & URBISZ A. (2005): Distribution and degree of naturalization of *Impatiens parviflora* DC in the southern part of the Silesian-Kraków Upland (Poland). – Thaiszia – J. Bot. 15, Suppl. 1: 101-113. – ISSN 1210-0420.

Abstract: Small balsam *Impatiens parviflora* DC. (*Balsaminaceae*), a native therophyte of East Asia, is one of the most invasive species in Poland and in Central Europe. Numerous studies suggest that small balsam is a threat to ecosystem health and can displace indigenous species. Distribution and phytosociological affiliations of *Impatiens parviflora* DC in woodlands of the two adjacent regions: the Silesian Upland and the Kraków-Częstochowa Upland, being the southern part of the Silesian- Kraków Upland (southern Poland) were compared. The geobotanical studies (151 relevés) and floristic survey were carried out in the years 1987-2004. In both regions *I. parviflora* tends to occur more frequently in their southern parts. In the Silesian Upland the species appears in a wider set of forest communities, from coniferous forest, mixed coniferous forest communities to deciduous woodlands compared to the Kraków-Częstochowa Upland, where its occurrence is restricted almost only to deciduous forests. There are differences between habitat preferences, expressed by Ellenberg indicator values. In woodlands of the Kraków-Częstochowa Upland small balsam occurs in more shady forests and on more basic soils, as well as on soils richer in nitrogen compared to the Silesian Upland.

Keywords: *Impatiens parviflora*, distribution, Ellenberg indicators, southern Poland, forest communities, synanthropisation.

Introduction

Small balsam *Impatiens parviflora* DC. (*Balsaminaceae*), alien plant species of Asiatic origin is one of the most invasive species in Poland (TOKARSKA 2003) and in Central Europe (TREPL 1984, PYŠEK et al. 1998). This therophyte was introduced in 1831 into the Botanic Garden in Geneva and within few next decades it was observed as an escape, at the beginning, in botanic gardens, parks in many places in Europe (COOMBE 1956). First records from Poland are dated from the fifties of 19th century from the neighbourhood of Gdańsk (TREPL 1984) and Kraków (BERDAU 1859). Nowadays its range encompasses almost entire country (ZAJĄC A., ZAJĄC M. 2001). During more than recent 100 years this neophyte, (species introduced after 1500) changed its status from that of ergasiophygophyte (casual alien), epekophyte (established in man-made habitats) to holoagriophyte sensu KORNAŚ (1990) i.e. a species established in natural communities. The species colonizes mainly deciduous forests including floodplain forests, oak-hornbeam forests, beechwoods, more rarely oak forests and mixed coniferous forests (KUJAWA-PAWLACZYK 1991, OBIDZIŃSKI, SYMONIDES 2000). Numerous studies suggest that small balsam is a threat to native flora and can compete with indigenous species (DAUMANN 1967, FALIŃSKI 1998, PERRINS et al. 1993). However, there are differences about explanations of mechanism of its invasion and different results are obtained from various scales: phytogeographic, floristic, phytosociological and ecological ones. Many authors believe that success of small balsam in penetration and naturalization in deciduous forest results from local disturbances of the groundlayer structure, loose tree canopy facilitating bigger availability of light (KUJAWA-PAWLACZYK 1991, OBIDZIŃSKI, SYMONIDES 2000, KLIMKO M., PISKORZ 2003). It is congruent with general theories concerning invasiveness of alien species and invasibility of ecosystems (KORNAŚ 1990, DAVIS et al. 2000). It has been long known that appearance of an invasive species can contribute to the further degradation of phytocoenoses (FALIŃSKI 1998, OLACZEK 1974, ŁASKA 2001) leading to its transformation (GORDON 1998, FALIŃSKI 1998, CHMURA, ORCZEWSKA 2004).

On the other hand some data show that *I. parviflora* can survive in very shady forest interiors away from paths in condition of daylight about 5-7% (COOMBE 1956, HUGHES 1965, PERRINS et al. 1993, MACHADO et al. 2003). Generally in Europe small balsam prefers semi-shaded sites on mildly acid or neutral mineral soils (OBIDZIŃSKI, SYMONIDES 2000). The range of this species still increases both in Poland and Europe except its southern part. Habitat preferences and whole spectrum of invaded plant communities of *I. parviflora* are still not fully known.

The aim of this study was to compare a distribution of small balsam in two adjacent regions, but different due to human impact, and analyse its biotopic and phytoecological preferences in invaded natural and semi-natural plant communities.

Material and methods

During the years: 1987-2004 floristic and phytosociological studies were conducted in the Silesian Upland and the Kraków–Częstochowa Upland, both being a southern part of macroregion the Silesian-Kraków Upland situated in South Poland. During floristic studies a cartogramme method was used. The study area was divided into basic research fields - quadrates with a side of 2 km, according to the methodical assumptions of "Atlas of distribution of vascular plants in Poland" (ZAJĄC 1978). Apart from own field studies literature data (KOBIERSKI 1974, URBISZ An. 1996, 2004, Nowak 1999, Tokarska-Guzik 1999, Urbisz Al. 2001 and the others), herbarium materials and swlwcted data from database ATPOL (ZAJĄC A., ZAJĄC M. 2001) were included. Of total own 151 phytosociological relevés taken using the commonly applied Braun-Blanquet method (BRAUN-BLANQUET 1964), 88 come from the Silesian Upland and 63 from the Kraków–Częstochowa Upland. They were taken in woodland communities in large forest complexes; small young woodlands, forest islands or forest crops were excluded from the studies. The geobotanical studies also included nature reserves, 4 in the Silesian Upland and 7 in the Kraków–Częstochowa Upland. The patches with a presence of small balsam with various cover-abundance were studied. The indicator values of *I. parviflora* for light (L), temperature (T), soil moisture (F), nitrogen (N) and soil reaction (R) were used according to ELLENBERG et al. (1992). They were estimated based on mean Ellenberg indicators values of other species in phytosociological records using presence/absence data (DZWONKO, LOSTER 2000). The nomenclature of species was adopted after MIREK et al. (2002) and the phytosociological nomenclature follows MATUSZKIEWICZ (2001).

The relevés were classified using the numerical approach (i.e. Ward method and Manhattan city block distance) with the use of STATISTICA package for Windows (Statsoft 2001). Before the analysis values of Braun-Blanquet were transformed after VAN DER MAAREL (1979). Results of the numerical classification are shown on dendrograms. To assess statistical significance of the differences between Ellenberg indicators values, ANOVA Kruskal-Wallis test was used.

Study area

The Silesian Upland and the Kraków-Częstochowa Upland are macroregions belonging to subprovince the Silesian-Kraków Upland, situated in the southern Poland (KONDRACKI 1988). The first one, covering 3929 km^2 of an area, is characterized by differentiated relief and geological structure. Last half of 18^{th} century changes in economic activity, technical-scientific progress and exploitation of mineral sources (coal, metal ores, sand etc.) caused profound environmental transformation: among others, changes in water relations, pollutions, deforestation. Waste-heaps, ground pits, sedimentation tanks are characteristic features of the Silesian landscape. The mean annual temperature amounts to ca. 8℃ and mean precipitation per year varies from 665 to 859 mm.

The Kraków-Częstochowa Upland covers about 2615 km^2 of an area, is mostly built by Jurassic dolomites. The characteristic elements of the landscape are different in shape limestone rocks (relic mountain) and various caves as well as numerous castles. The mean height of the area amounts to about 350 m a.s.l. The soils of this area are rather poor, 60% of them are podzolic soils, more rarely brown soils occur. Mean annual temperature is a little lower compared to mean country temperature and amounts to ca. 7.5℃. Mean annual precipitation amounts to ca. 700 mm but it increases to the south.

Results

Distribution

Analyzing distribution of *I. parviflora* in the studied macroregions one can observe that majority of its stands is situated in their southern parts (Fig. 1). Percentage of stands is similar in both regions. In the Kraków-Częstochowa Upland small balsam was reported from 293 squares of total number - 660 (44.4 % of the area) and from 487 squares of the total 1060 (45.9 % of the area) in the Silesian Upland. The compact range limit of *I. parviflora* in the Silesian Upland is marked by northern-eastern part of Upper Silesian Industrial District (GOP). However, and in the Kraków-Częstochowa Upland the limit of more compact range is located along the line: Olkusz–Wolbrom. Stands of this species are concentrated in more urbanized part of the region i.e. the surroundings of Kraków, towns situated along major railways and highways. This species occurs the most frequently in man-made habitats and its spread is facilitated owing to density of transport routes and human settlements. From these places the neophyte penetrates forest complexes mainly along forest paths and margins caused due to forest management.

Contribution of small balsam to forest vegetation

The numerical classification of plant communities with a presence of *Impatiens parviflora* demonstrates differences in number and diversity of woodland communities in both regions (Fig. 2, 3). Small balsam in the Silesian Upland was found in various woodland communities (Tab.1). It occurs not only in deciduous forest like in those of order *Fagetalia sylvaticae* PAWŁ. IN PAWŁ., SOKÓŁ. ET WALL. 1928 (oak-hornbeam forest *Tilio-Carpinetum* TRACZ. 1962, floodplain and riverine forests, alliance *Alno-Ulmion* BR.-BL. et R.TX. 1943, beechwoods alliance *Fagion silvaticae* R.TX. et DIEM. 1936), but also penetrates acidophilous oak forest, association *Calamagrostio–Quercetum* (HARTM. 1934) SCAM et PASS.1959. The species occurs quite frequently in mixed coniferous forest (*Querco roboris-Pinetum* W. MAT. (1952) et POL.1955). Sporadically it appears in coniferous forest communities even pinewoods on fresh or dry soils (e.g. *Leucobryo-Pinetum* W. MAT. (1962) 1973). More frequently it grows in wet coniferous forests like *Calamagrostio villosae-Pinetum*, association with characteristic species *Calamagrostis* x *hartmaniana* FRIES (formerly erroneously

identified as *C. villosa* (CHAIX) J.F. GMEL.) and *Molinio-Pinetum* W. MAT et J.MAT 1973. Nevertheless it has smaller medium cover in those communities, besides their examined patches are poorer in number of species compared to *Leucobryo-Pinetum*. There are some phytocoenoses of *Vaccinio-Picetea* BR.-BL. 1939 class or former pine planting in habitats of deciduous forest which are difficult to be classified to lower syntaxa units. These are anthropogenic communities with a presence of *Pinus sylvestris* L. Some degenerated phytocoenoses built by Scots pine *Pinus sylvestris* in tree stand and characterized by a massive occurrence of *I. parviflora* in the groundlayer, was classified as *Pinus sylvestris-Impatiens parviflora* community. The cover-abundance of the neophyte ranges from 60% to 90%.

In the Kraków–Częstochowa Upland the species *Impatiens parviflora* mainly occurs in oak-hornbeam forests (*Tilio-Carpinetum*) and beechwoods (Tab.1). As beech forests are concerned, these are *Dentario glandulosae-Fagetum* W.MAT. 1964 ex GUZIKOWA et KORNAŚ 1969, *Luzulo pilosae-Fagetum* W. MAT. 1964 et A. MAT 1960, and the rarest - patches of *Carici-Fagetum* PANC.-KOTEJ. in.W. MAT. 2001.

Analysis of medium cover and frequency data of patches with small balsam indicate that the most susceptible to its invasion plant community, of those of natural origin, in both studied areas is oak-hornbeam forest (Tab. 1). The cover of Asiatic species ranges between 17.85 and 19.43 respectively in the Silesian Upland and the Kraków-Częstochowa Upland but in the former species richness is much smaller and estimated to almost 17 in contradistinction to the latter where mean number of species estimated to 24.6. Another group of plant communities in which small balsam makes large contribution are those from *Alno-Ulmion* alliance or associations *Fraxino-Anetum, Ficario-Ulmetum* but only in the Silesian Upland. Their patches are much poorer in number of accompanying species and the neophyte has higher cover in them (> 22%) in comparison with the Kraków-Częstochowa Upland. In both regions acidophilous lowland beechwood *Luzulo pilosae-Fagetum* is also abundant in the cover of small balsam. In the Kraków-Częstochowa Upland the patches with the species were more poorer floristically and degenerated, mean number of species < 14%. *I. parviflora* rarely occurs and has small cover in thermophilous orchid beech wood *Carici-Fagetum*. The mean cover does not exceed 10%. Only in the Kraków-Częstochowa Upland the invasive species appears in *Dentario glandulosae-Fagetum*, common plant community of this region, having mean cover 16.5 %.

Of the plant communities from *Vaccinio-Picetea* class, mixed coniferous forest (*Querco roboris-Pinetum*) in both regions is the most frequently invaded by *Impatiens parviflora.* In the Silesian Upland the patches with small balsam are poorer in number of species and mean cover of the neophyte is bigger, almost 18 % (Tab. 1).

Biotopic conditions in woodlands of the examined areas

Analysis of Ellenberg indicators values for both regions shows that small balsam in woodlands occurs in similar conditions (Tab. 2). The biggest

difference concerns light, availability of nitrogen and soil reaction. In the Silesian Upland sites with *I. parviflora* are characterized by a bigger availability of light compared to the Kraków-Częstochowa Upland. In the latter the neophyte grows in more shady places in woodlands. Moreover stands in the Silesian Upland occur on more acid but generally on moderate acid substratum. There is a big statistical difference between two regions in content of nitrogen in soils what is caused by a bigger number of natural patches of floodplain and riparian forests in the Kraków-Częstochowa Upland. These plant communities usually are typified by a larger content of nitrogen in substratum. Moisture of forest habitats of both regions is similar, *I. parviflora* occupies places on fresh soils of moderate dampness. In the Silesian Upland generally places are a little more wet because of numerous patches of anthropogenic, degraded riparian alder forests and wet coniferous forests.

More detailed analysis of biotopic conditions, but in relation to particular plant communities common for both regions, also revealed some differences (Tab. 3). In the patches of *Luzulo pilosae-Fagetum* in the Silesian Upland *I. parviflora* occurs in stands richer in available nitrogen. Amongst patches from *Alno-Ulmion* alliance small balsam appears in more loose tree stands and on poorer in nitrogen, more acid soils in the same region. Apart from those communities, the patches of mixed coniferous forests with the neophyte in this area are characterized by bigher availability of light. As the most invaded phytocoenoses of oak-hornbeam forest by *I. parviflora* are concerned, the studied patches in both regions do not differ significantly likewise the other common plant communities.

Discussion and conclusions

The results of following research confirm literature data about synecological affiliations of small balsam both in Poland and in the studied areas. During wider and long-term phytosociological studies in the Silesian Upland on forest vegetation (CABAŁA 1990) *I. parviflora* was found mainly in plant communities of *Fagetalia sylvaticae* order, more rarely in the patches of *Calamagrostio-Quercetum* and *Querco roboris-Pinetum*. Many patches of above mentioned plant communities represent degraded forms of phytocoenoses due to silviculture management (CABAŁA 1990, SIERKA, CHMURA 2004, CHMURA, ORCZEWSKA 2004). In this region the neophyte was more frequently encountered in mixed coniferous and coniferous plant communities both in their patches and in the neighbourhood. In the Kraków-Częstochowa Upland small balsam occurs only in deciduous forests and sporadically in mixed coniferous communities. Other authors did not find the neophyte in pinewoods, rarely observed it in mixed coniferous woodlands (WIKA 1986; BĄBA 2002; BĄBA, MICHALIK 2002). Sporadical occurrence of the species in termophilous community *Carici-Fagetum* supports the observations that this plant avoids southern slopes (COOMBE 1956, CSONTOS 1984, 1986b). Its habitat preferences in this area are more similar to those described by ELLENBERG et al. (1992) for Central Europe. It

can be explained by smaller disturbance of woodlands, therefore the species is established basically in habitats which better meet its biotopic requirements. Natural, not disturbed, characterized by larger biodiversity, phytocoenoses are efficient barriers for penetration by alien invasive species (FALIŃSKI 1998, KENNEDY et al. 2002). It can be expected that *I. parviflora* will expand its range in both regions due to environmental factors supporting invasion of the alien as forest fragmentation and trampling (ELIÁŠ 1999). The invasion by the species into woodland interiors will probably intensify because, as the results of other studies prove, the species is capable to persist as a understorey species in shade forests even in the presence of competitive native perennials (UHERČÍKOVÁ, ELIÁŠ1987) both in ancient, less disturbed, and new forests of anthropogenic origin (GRAAE et al. 2004). It must be added that management control of this species is very difficult. Experiments with individuals removal before seed dispersal revealed different results: successful attempt of inhibition (ADAMOWSKI, KECZYŃSKI 1998) and high ability to survival owing to permanent seed bank (CSONTOS 1986a). Despite this some efforts should be made to stop the invasion of this species in the future, especially in protected areas.

Acknowledgements

The study is financially supported by State Committee for Scientific Research (KBN), project no. 3PO4G09325 and no. 6P04G05219.

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Tab.1. Mean cover of *Impatiens parviflora* in forest communities in the examined regions.

Plant community (region)	Mean cover	Minimum	Maximum	Mean number of species	Number of relevés
TC (KC)	19.43	5	62.5	24.6	26
TC (SU)	17.85	0.5	62.5	16.9	13
QP (KC)	12.6	0.5	37.5	23.1	7
QP (SU)	17.9	0.5	62.5	17.9	23
AU (KC)	4.4	0.5	17.5	30.4	7
AU (SU)	22.2	0.5	87.5	17.8	6
DF (KC)	16.5	0.5	62.5	23	18
F (SU)	19.6	0.5	37.5	12.2	5
LF (KC)	29.5	0.5	87.5	13.7	3
LF (SU)	19	5	62.5	17.7	10
CF (KC)	9	0.5	17.5	20.5	2
PI (SU)	62.5	37.5	87.5	15.5	10
AP (SU)	9	0.5	17.5	14.5	6
LP (SU)	16.2	5	37.5	18	4
MP (SU)	2.75	0.5	5	16	2
CP (SU)	10.75	0.5	37.5	16.5	4
CQ (SU)	7.5	5	17.5	19	5

Tab. 2. Mean Ellenberg L,T, F, N, R values of *Impatiens parviflora* based on mean values of relevés of woodlands in the Silesian Upland (SU) and the Kraków-Częstochowa (KC) Upland. Significance of differences between two regions were accessed by ANOVA Kruskal-Wallis test (dash – not significant, * - p<0.05, ** - p<0.01, * - p<0.001).**

Ellenberg indicator Ellenberg et al.(1992)	L*** 4	T - 6	F* 5	N*** X	R*** 6
SU	5.17	5.00	5.68	5.03	5.02
min - max	3.5-6.54	2.3-5.75	4.92-6.73	3.25-6.3	3-7
KC	4.46	5.15	5.57	5.80	5.62
min - max	3.3-5.57	2.95-7.47	4.64-10.37	4.36-10.14	4.57-6.84

Tab.3. Comparison of Ellenberg indicator values for particular plant communities in the Silesian Upland (SU) and the Kraków-Częstochowa (KC) Upland. Significance of differences between two regions were accessed by ANOVA Kruskal-Wallis test (N.S. – not significant, * - p<0.05, ** - p<0.01).

Ellenberg indicator		L	T	F	N	R
SU	LF	4.78	5.16	5.56	5.4	5.27
KC		4.34	5.1	5.54	4.67	4.9
Significance		N.S	N.S	N.S	*	N.S
SU	AU	4.96	5.02	6.27	5.95	5.86
KC		4.7	5.04	6.15	6.48	6.38
Significance		*	N.S	N.S	**	**
SU	QP	5.42	5.08	5.51	4.95	5.02
KC		4.67	5.03	5.56	4.74	5.12
Significance		*	N.S	N.S	N.S	N.S
SU	TC	4.66	5.06	5.56	5.57	5.40
KC		4.69	5.33	5.56	5.69	5.55
Significance		N.S	N.S	N.S	N.S	N.S

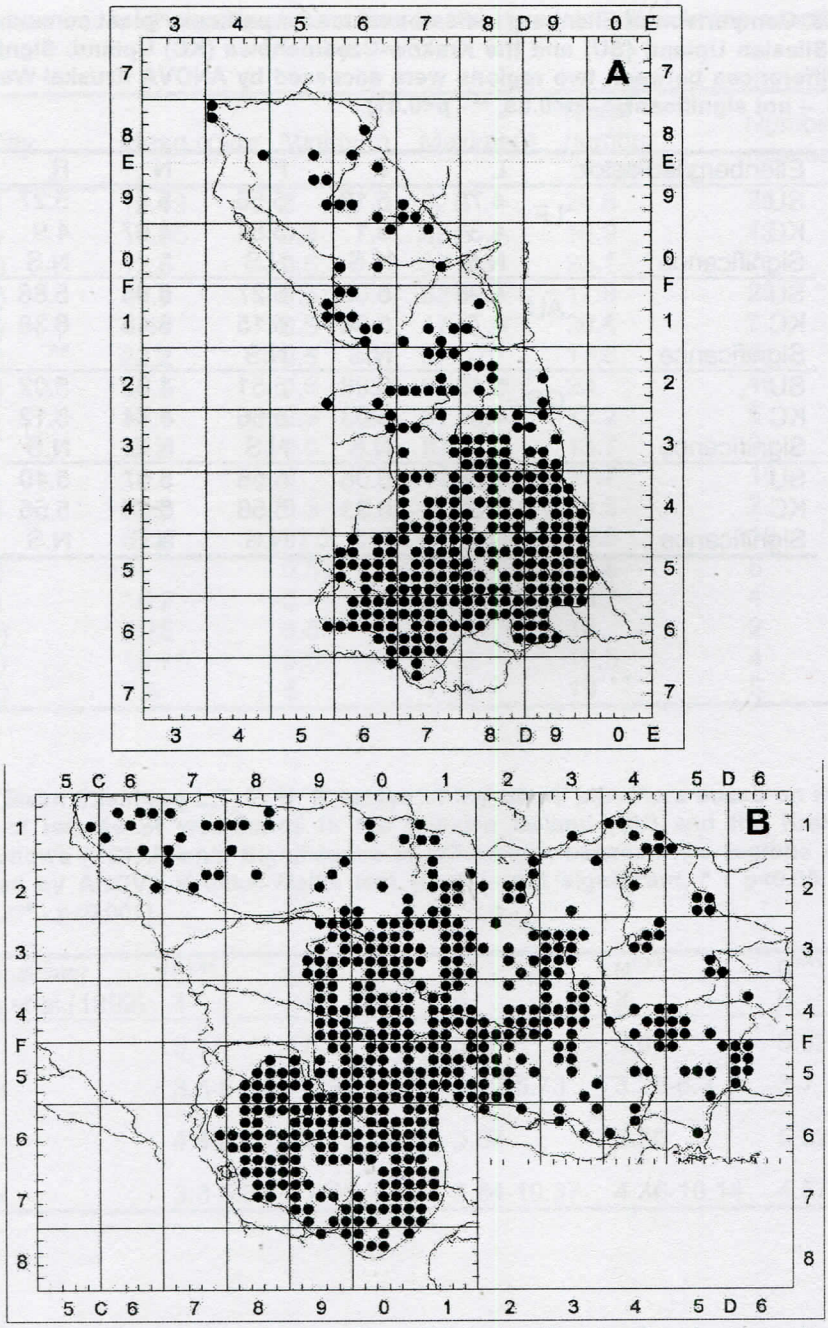

Fig. 1. Distribution of Impatiens parviflora DC in the Kraków-Częstochowa Upland (A) and the Silesian Upland (B).

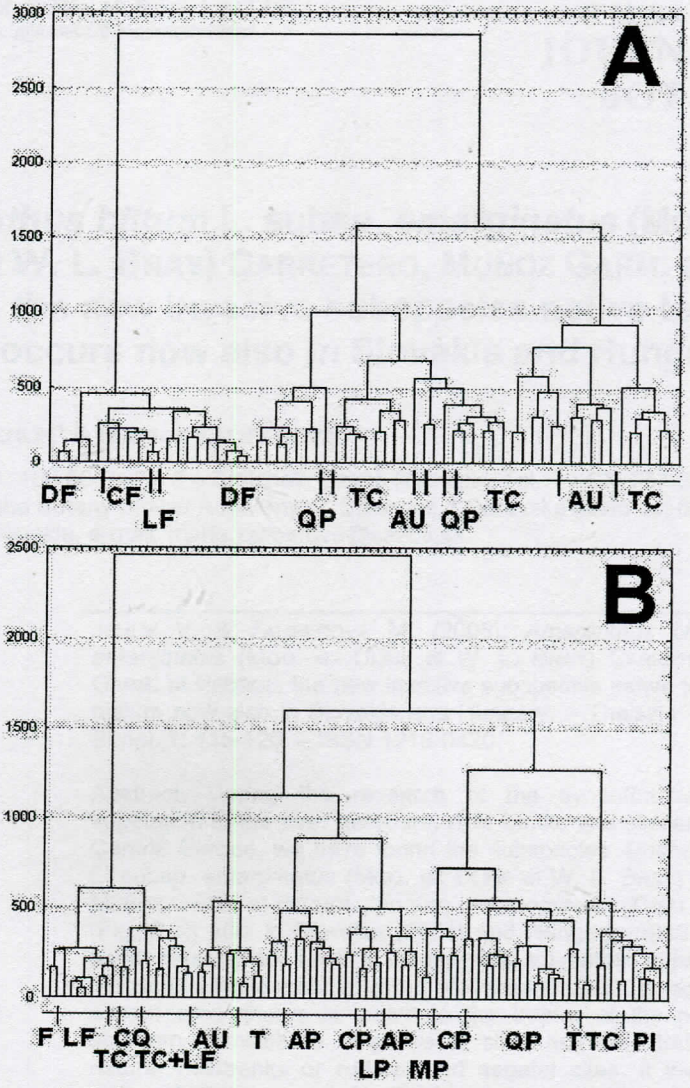

Fig. 2. The numerical classification of plant communities with *Impatiens parviflora* in the Kraków-Częstochowa Upland (A) and the Silesian Upland (B) (southern Poland).

AP-anthropogenic communities with *Pinus sylvestris.*, AU – communities of alliance *Alno-Ulmion*, CF – *Carici-Fagetum*, CP - *Calamagrostio villosae-Pinetum*, CQ-*Calamagrostio-Quercetum*, DF- *Dentario glandulosae Fagetum*, F- communities of *Fagenion alliance*, LF – *Luzulo pilosae-Fagetum*, LP- *Leucobryo-Pinetum*, MP-*Molinio-Pinetum*, PI – community with *Pinus sylvestris* and *Impatiens parviflora*, QP- *Querco robori-Pinetum*, LF – *Luzulo pilosae-Fagetum*, T – transitory communities, TC - *Tilio-Carpinetum*.